USING LOGO TO SUPPLEMENT THE TEACHING OF GEOMETRIC CONCEPTS IN THE ELEMENTARY SCHOOL CLASSROOM

By

JUDITH KAY OLSON

Bachelor of Science
Valley City State College
Valley City, North Dakota
1968

Master of Science
University of Wyoming
Laramie, Wyoming
1981

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of the Oklahoma State University
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Thesis Approved:

Helen Neely Chead

Thesis Adviser

Vernon Troxel

B. Aichele

Thomas D. Johnston

N. Jo Campbell

Norman N. Durham

Dean of the Graduate College

PREFACE

In this study, three groups of students from two sixth-grade classes interacted in distinctly different ways with microcomputers during the study of geometric topics in their regular mathematics class. Geometry achievement, spatial visualization, and locus of control were measured following the supplementary use of Logo.

When a project such as this is undertaken, the assistance and encouragement one receives from many people is vital to its completion. Special gratitude is given to Dr. Helen Cheek, my dissertation adviser, for her understanding, encouragement, and assistance while I was at Oklahoma State University and throughout the writing of this dissertation. I am also grateful to Dr. Vernon Troxel, who served as chairman of my committee and to Dr. Jo Campbell, who offered advice on the statistical analysis. In addition, my appreciation is extended to Dr. Douglas B. Aichele and Dr. Thomas Johnsten for serving on my committee.

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CHAPTER I

INTRODUCTION

The increased availability and affordable prices of microcomputers are making it necessary for educators to evaluate the possible uses of computers in classrooms at all levels. A National Survey conducted by Johns Hopkins University (Becker, 1983-1984) between December, 1982, and February, 1983, reported on the school access and uses of microcomputers. The study was based on data from 1,082 microcomputer-using schools, representing 68% of a nationally representative sample of public and non-public elementary and secondary schools with one or more microcomputers for use by teachers or students prior to January, 1983. By January, 1983, 53% of all schools in the United States had at least one microcomputer obtained for use in instructing students. This included 85% of all high schools, 77% of all junior-senior high school combinations, 68% of all middle-junior high schools and 42% of all elementary schools.

The National Center for Education Statistics (Bell, 1984) reported that in the fall of 1980 there were approximately 31,000 microcomputers in the schools, however, by the spring of 1982 there were nearly 96,000 and it was estimated that there would be 300,000 at the end of 1983. Bell points to the availability of monies to the states through Chapter II of the Education Consolidation and Improvement Act as contributing to this growth.

The use of microcomputers in schools most frequently refers to use in an elementary school to improve achievement in basic skills. Much of the software is targeted at the elementary school level with the premise that microcomputers can be a cost-effective means of increasing the rate of learning. In fact, "drill-and-practice" leads programming as the most employed application of microcomputers in elementary schools. However, as schools have more experience using microcomputers, there is a consistent decline in their use for drill-and-practice while the amount of instruction in programming becomes greater (Becker, 1983-1984).

The real challenge for educators in using microcomputers is not how to interest students in the computer, but how to preserve students' initial interest, while at the same time having the computer serve students as a tool for growth and development (Nelson, 1981b). The questions of what assistance is best for which children under what circumstances are not likely to find any quick or widely agreed upon answers (Higginson, 1981). Furthermore, questions of an optimum educational environment for children have not even been answered for a classroom without microcomputers. Johnson (1983) raises an interesting point, "What if what we are doing is wrong and the computer helps us to do it more efficiently." Bork (1984) in pondering questions regarding education in light of technology provides us with this statement:

> It should be made clear that at this time it is not clear whether the computer will lead to a better or worse educational system than we have today. Like any powerful new technology, computers can be used in either desirable or undesirable ways. The next 5-10 years are the critical period (p. 3).

The students and teachers in two sixth grade classrooms at the elementary school in which the study took place raised funds and purchased two Apple Microcomputer Systems. The school district's policy had been to not provide a separate curriculum for computer literacy in the elementary school, but rather to integrate computers into the traditional curriculum or to provide it as an "extra". But as Bell (1984) points out,

> With the exception of basic arithmetic and reading programs, most of the remainder of the software represents isolated instructional units, which makes it difficult for the teacher to integrate their use into the course sequence in a timely and appropriate way (p. 81).

A purpose of this research is to explore the potential of the programming language Logo and look at the integration of its supplementary use in the traditional curriculum. Logo is an extendable high level computer language developed for educational purposes with a geometry/graphics component that provides children with experiences in geometric concepts. Watt (1983c) has great respect for the power of Logo within the geometry curriculum.

> Logo's ability to create complex geometric shapes from simple procedures makes turtle geometry a powerful tool for creating graphics with the computer and for learning geometry in a way that was never before possible (p. 109).

Since the computer is often seen as a teaching instrument, one could think of the turtle as a device to teach elements of the traditional curriculum such as notions of an angle, shape, the coordinate system, symmetry, congruence, transformational geometry, and similarity. By integrating Logo with a geometry unit one can be more closely in tune with students' developmental levels and their experiences will be similar within the classroom setting. At the same time Logo introduces students to powerful computing ideas via the construction of new sets of primitive commands. Programming a computer in Logo is seen as teaching the computer a set of new commands based on what it already knows how to do, therefore creating a personal computer language to suit the user's purpose. Watt's enthusiasm for the potential of Logo in our schools is reflected in the following:

> With its ease of use, exciting applications, and educational benefits, Logo may someday replace BASIC as a universal first programming language. Logo's suitability for structured programming and modular problem solving may also lead to its use in introductory computer science courses (Watt, 1983c, p. 106).

Statement of the Problem

Microcomputers are being used in many schools throughout the United States in the belief that they are important for children. However, little research indicates what children learn from working with microcomputers, how they learn to work with the technology and in what ways such skills relate to measurements in the affective domain (Jewson and Pea, 1981).

> A lot has been said about microcomputers affecting students, teachers and the whole process of schooling, but there has been relatively little scientific investigation of their impact. We need well-designed studies using random assignment to treatments, reasonable alternative treatments provided to control groups and enough cases to allow for generalized findings to a range of schools (Becker, 1983-1984, p. 6).

The questions for educators are how to manage the educational environment and how best to structure a child's experiences to provide for optimal learning. Reports from Johns Hopkins (Becker 1983-1984) indicate that the way microcomputers are presently used has more of an impact on the social organization of learning than on increased student achievement. Increased student enthusiasm for schooling, students working more independently, students helping one another and answering each other's questions, and students being assigned to do work more appropriate to their achievement levels are some of the social effects observed by a substantial number of teachers.

Three major camps have developed concerning the use of microcomputers in the schools: 1) Those who believe the computer should be used as a machine to teach the traditional curriculum and promote school learning. This means using computer assisted instruction (CAI) to teach basic skills. The three most common categories for CAI software are drill-and-practice, tutorial systems and simulations and educational gaming. Drill and practice is designed to exercise previously-learned skills, while tutorial systems teach new information as well as exercise previously available knowledge. Simulations and educational gaming emphasize instruction by illustration and are interactive. 2) Those who feel that computers should be seen as a new social and technological phenomenon and that children should learn about them. Computer topics would be inserted into the curriculum throughout the grades to provide an understanding of what is happening in the world and to achieve some degree of computer literacy. The definition of computer literacy ranges from students having the skills to work the machines for solving problems to understanding the social and technological aspects of computers, including how the computer functions and its potential applications.
3) Those who believe that the power of the computer can be best exploited by teaching all children how to program. By learning to program, students learn how computers operate and develop the knowledge and skills necessary

for getting computers to do what one wants (Carter, 1981). The National Center of Education Statistics report shows that these three camps are all represented in the schools. One third of the 27,500 schools it surveyed listed computer literacy as their principle objective, a quarter of the schools mentioned computer science as a topic in itself, one in five listed learning enrichment and instruction in basic skills as their goal, while one in seven reported using microcomputers for compensatory and remedial instruction (Fiske, 1983).

Although computers must be employed in a manner consistent with the philosophy of the teacher and curriculum of the school, Logo may be a unifying factor of the three camps when educators make decisions on how to use the microcomputer in their classrooms. Consideration must be made of the individual skills and interests of the teacher and the classroom atmosphere. However, the extendability of Logo allows children the possibility of using programs for learning basic skills while being introduced to ideas of programming at their own level of development. Logo provides a well-designed learning experinece which leads to the development of higher-level skills. It may not be a substitute for learning basic skills such as mathematics, but while supplementing this learning, students would become comfortable with computers and learn about their potential.

This study examined the effects of supplementing traditional textbook instruction of selected geometric concepts with Logo. It was designed to explore the possible differentiating effects on geometry achievement, locus of control, and spatial visualization among three different groups using microcomputers; a CAI group, a Logo group, and a control group.

Specifically, the objectives of this investigation are to answer the following questions:

A. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students in the three groups be significantly different?

B. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the male sixth grade students significantly differ from the female sixth grade students?

C. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students significantly differ when both treatment and sex are considered?

D. Will time of measurement significantly affect the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students?

E. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students be significantly different when both treatment and time of measurement are considered?

F. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students be significantly different when both sex and time of measurement are considered?

G. Will the means on geometry achievement, spatial visualization, and locus of control for success and failure in achievement situations for the sixth grade students be significantly different when treatment, sex and time of measurement are considered?

Hypotheses

Stated in null form, the hypotheses to be tested using an alpha level of .05 are:

H_1: There is no significant main effect for treatment.

H_{1a}: The type of treatment group does not significantly affect spatial visualization as measured by the Monash Spatial Visualization Test.

H_{1b}: The type of treatment group does not significantly affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{1c}: The type of treatment group does not significantly affect internal locus of control for success in achievement situations as measured by the Crandall Intellectual Responsibility Questionnaire.

H_{1d}: The type of treatment group does not significantly affect internal locus of control for failure in achievement situations as measured by the Crandall Intellectual Responsibility Questionnaire.

H_2: There is no significant main effect for sex of the subjects.

H_{2a}: The sex of the subjects does not significantly affect spatial visualization ability as measured by the Monash Spatial Visualization Test.

H_{2b}: The sex of the subjects does not significantly affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{2c}: The sex of the subjects does not significantly affect locus of control for success in achievement situations as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_{2d}: The sex of the subjects does not significantly affect locus of control for failure in achievement situations as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_3: There is no significant interaction effect between treatment and sex of the subjects.

H_{3a}: Type of treatment and sex do not significantly interact to affect spatial visualization as measured by the Monash Spatial Visualization Test.

H_{3b}: Type of treatment and sex do not significantly interact to affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{3c}: Type of treatment and sex do not significantly interact to affect locus of control for success as measured by the Crandall Intellectual Responsibility Questionnaire.

H_{3d}: Type of treatment and sex do not significantly interact to affect locus of control for failure as measured by the Crandall Intellectual Responsibility Questionnaire.

H_4: There is no significant main effect for time of measurement.

H_{4a}: Time of measurement does not significantly affect spatial visualization ability as measured by the Monash Spatial Visualization Test.

H_{4b}: Time of measurement does not significantly affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{4c}: Time of measurement does not significantly affect locus of control for success in achievement situations as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_{4d}: Time of measurement does not significantly affect locus of control for failure in achievement situations as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_5: There is no significant interaction effect between time of measurement and treatment.

H_{5a}: Time of measurement and type of treatment group do not significantly interact to affect spatial visualization ability as measured by the Monash Spatial Visualization Test.

H_{5b}: Time of measurement and type of treatment group do not significantly interact to affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{5c}: Time of measurement and type of treatment group do not significantly interact to affect locus of control for success as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_{5d}: Time of measurement and type of treatment group do not significantly interact to affect locus of control for failure as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_6: There is no significant interaction effect between time of measurement and sex of the subjects.

H_{6a}: Time of measurement and sex do not significantly interact to affect spatial visualization as measured by the Monash Spatial Visualization Test.

H_{6b}: Time of measurement and sex do not significantly interact to affect achievement on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{6c}: Time of measurement and sex do not significantly interact to affect locus of control for success as measured by the Crandall Intellectual Responsibility Questionnaire.

H_{6d}: Time of measurement and sex do not significantly interact to affect locus of control for failure as measured by the Crandall Intellectual Responsibility Questionnaire.

H_7: There is no significant three-way interaction effect of time of measurement, treatment and sex.

H_{7a}: There is no significant three-way interaction effect of time of measurement, treatment and sex on spatial visualization ability as measured by the Monash Spatial Visualization Test.

H_{7b}: There is no significant three-way interaction effect of time of measurement, treatment and sex on geometric concepts as measured by the Julian Elementary Test of Geometric Concepts.

H_{7c}: There is no significant three-way interaction effect of time of measurement, treatment and sex on locus of control for success as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

H_{7d}: There is no significant three-way interaction effect of time of measurement, treatment and sex on locus of control for failure as measured by the Crandall Intellectual Achievement Responsibility Questionnaire.

Importance of the Study

Logo was designed at Bolt, Beranek and Newman, Inc., a high-technology consulting firm in Cambridge, Massachusetts, as early as 1968. The original version of Logo was designed by Wallace Feurzig, Daniel Bobrow and Seymour Papert with the idea that programming might be a useful educational discipline to teach children. Logo is most widely recognized for its turtle graphics, but there were no provisions for computer graphics in Logo at first due to the expense of the necessary hardware. The turtle graphics mode has contributed most to the success of Logo because it provides an accessible means for picture construction. The user is not required to have a great store of mathematical or computer knowledge, but rather to make use of familiar body movements such as forward, backward, left, and right (Ross, 1983).

Work has been done at two different locations to refine Logo: the Artificial Intelligence Laboratory of Massachusetts Institute of Technology and the Department of Artificial Intelligence of the University of Edinburgh, Scotland. Logo is now available in many versions, although most American versions have resulted from the M.I.T. research project. As Ross (1983) points out the M.I.T. research work makes the assumption that Logo would never easily fit into the conventional mathematics curriculum. At the Department of Artificial Intelligence of the University of Edinburgh research work on the development of Logo from 1972 onwards has a slightly different underlying assumption. Rather than revolutionize the curriculum, their belief is that Logo can best gain acceptance by using it within the conventional curriculum in some way. The Edinburgh version of Logo was developed by Research Machines Ltd. of Oxford and is less demanding on the user's understanding and prior knowledge than the M.I.T. versions.

Until 1979, Logo was not available on microcomputers because it is a complex system that requires a powerful microcomputer. Most of the memory is filled up when Logo is loaded, which leaves relatively little space for writing procedures. Today, educators have their pick of microcomputer systems that have Logo software available: Apple, Atari, Radio Shack Color Computer, Commodore, Texas Instruments, and IBM. In addition, new versions are being developed to enhance those on the market and others are being developed to run on new machines. DR Logo, which takes advantage of the 16-bit computers and erases many of Logo's limitations, is one such version (Watt, 1983c). For this study, Logo Computer Systems Inc. (LCSI) Apple Logo was chosen because of its availability, its high-resolution turtle graphics, and the presence of Apple II microcomputers in the classrooms used for this study.

As has been noted, there have been many influences in Logo's development, but Seymour Papert is most prominently recognized as its primary conceptualizer, developer, researcher and public advocate. Papert's research efforts as director of M.I.T.'s Logo group were aimed at developing Logo into an educational vehicle and have been influential in computer users' acceptance of Logo (Watt, 1983c). Logo's prominence among educators interested in microcomputers is primarily due to Papert's book, Mindstorms, in which he develops his ideas on how computers can revolutionize education. Papert says:

> It is not true to say that the image of a child's relationship with a computer I shall develop here goes far beyond what is common in today's school. My image does not go beyond: It goes in the opposite direction (p. 5).

Papert describes Logo as much more than a programming language; he also describes it as a philosophy of education. The educational philosophy to which Papert refers was derived primarily from two sources: The developmental theories of Jean Piaget with whom Papert worked for five years in Geneva and the ideas from the scientific field of Artificial Intelligence. From Piaget comes the idea of creating learning environments in which most of what children learn occurs naturally in the process of interacting with their environment. From Artificial Intelligence comes ideas about ways to use programming languages to aid thinking and problem solving. Recursion and list processing programming techniques in Logo were derived from the Artificial Intelligence language LISP.

Logo was coined from the Greek word for "word" or "thought". It has been summarized as a language for learning how to think by building mental models of the world, of oneself, and of the learning process through intellectual exploration (Harvey, 1982). As Harvey describes it, this exploration:

> . . . may begin in a weak, haphazard way, but a good learner develops strategies for purposeful exploration. The more one learns, the better the model of learning and the more able one becomes as a learner (p. 191).

Some questions are emerging regarding the theories Papert established in Mindstorms. Rousseau and Smith (1981) suggest that Papert's ideas should be thoroughly examined in light of various learning theories and not only the work of Jean Piaget on which so many of his ideas are built. Ross (1983) likewise expressed concern about the effects of the use of Logo, "All the educational research carried out so far suggests that Logo has a great deal to offer as a means of teaching conceptual thinking, but no survey yet has been on a big enough scale to be conclusive" (p. 8). The Lamplighter School Logo project found that research studies which were expected to be a part of the project have not materialized. Scandura (1983) made an analogy between Logo and the new math of the 1960's when he stated, "perhaps the greatest limitation of the Logo movement is that its effects remain undocumented, despite millions of dollars used to support its development" (p. 16).

For this study, Logo was chosen to supplement the teaching of geometric concepts because not only is it easy enough for anyone to use, but it is also powerful enough for any project. The phrase "no threshold, no ceiling" has been the guiding rule of Logo's developers as they tried to make it possible for young children to control the computer in self-directed ways while at the same time making Logo a "general purpose programming system of considerable power and wealth of expression" (Abelson, 1982). It was designed to allow each child to manipulate the system according to her developmental skills and needs at a given time. A new Logo learner can enter directly into the world of turtle geometry without memorizing formulas. Procedures are created using a child's own body knowledge of how to move forward or back and how to turn left or right for drawing squares, triangles, and circles.

Teachers seem to be receptive to Logo although we must remember that what is exciting to one teacher is threatening to another. It is not enough to learn the language of Logo, but methods for implementing it in the classroom are also important. A classroom teacher brings his own experience and understanding of how children learn and how to provide for individual learning in a classroom setting to the Logo environment. It is important for a teacher to understand the variety of learning paths that students can take according to their own learning styles and developmental levels while organizing individual learning in Logo. Training teachers does not appear to present a problem. In the Brookline Project (Watt, 1982), it had been assumed at the start that teacher knowledge would be a major limiting factor in what students could achieve, but it turned out that this was not the case. Today's teachers are teaching in and sharing a world with children for whom technology is a way of life. Those students who spend more time with the computer than any teacher can afford to spend are potential teachers and helpers. In general, Logo tends to create a partnership between students and teachers in place of the traditional relationship of teacher and learner.

The Lamplighter School Logo Project found that teachers just do not have enough time for curriculum development in addition to all their other duties. Although Piagetian learning, upon which Logo was developed, refers to learning without a curriculum and without deliberate teaching, children need to be supported as they build their own intellectual structures. Simple interaction with Logo does not seem to be enough. Children also need an expert to guide and stimulate investigations while being encouraged to use their Logo thinking skills in other settings. The activities in Logo that promote thinking processes should be tested in other non-computing contexts as well. Experiences on a computer should never replace experiences with real events and objects, expecially for children in the concrete operational stage, who reason logically as long as they have concrete referents. Therefore, in designing curricular programs for children in the stage of concrete operations, it is important to coordinate computer opportunities with noncomputer activities based on the developmental needs of children as well as their own unique experiences. Logo is an excellent environment for helping students see the connections between different situations as they develop learning and thinking strategies.

Geometry is an excellent topic in the elementary school with which to integrate Logo and put children's knowledge of programming to use. Here, students can do some experimenting with the subject while at the same time applying thinking skills in a different context. Although the amount of geometry contained in the elementary school mathematics textbook series has steadily increased between 1960 and 1975, teachers tend to move geometry aside for the arithmetic they perceive as being the "basics". Having instructional materials readily available for use in the classroom may help bring an awareness that the world is a "maze of geometry". The National Council of Teachers of Mathematics (NCTM) includes geometry as one of its "Ten Basic Skills" and suggests: Students should learn the geometric concepts they will need to function effectively in the three-dimensional world. They should have knowledge of concepts such as point, line, plane, parallel and perpendicular. They should know basic properties which relate to measurement and problem solving skills. They also must be able to recognize similarities and differences among objects (NCTM, 1977).

Kantowski (1981) feels the graphics capability and capacity of the microcomputer to allow a student to interact by posing or responding to questions during an instructional sequence are two properties of the microcomputer that have great potential for improving instruction in geometry. Yakimanskaya (1971) suggests that the use of visual aids are not merely auxiliary but are essential in the development of ability in geometry and advocates the use of drill and practice with spatial concepts similar to that used in forming the concepts of number and operation. Writing a computer program about a mathematical concept forces the student to confront the concept and her understanding of it while the use of turtle graphics provides a visual illustration of a geometric concept that the student might otherwise not visualize (Boulay and Howe, 1981). Children need a variety of informal experiences with shapes to begin to recognize attributes of figures and to form their own definitions. Logo provides a unique environment for creating these geometric experiences. Although Logo is not geometry and geometry is not Logo (Moore, 1984), students need geometric concepts to develop Logo constructions while further geometric understanding is enhanced by developing Logo procedures.

During stages of cognitive development, learners go from concrete, to pictorial, to symbolic (Bruner, 1973). Children learn best through first manipulating concrete objects; by making the action of the computer more concrete. Logo builds a bridge between abstract reasoning and actual experience. Concrete and pictorial learning represent simple mathematical ideas and those representations depend heavily on spatial attributes. Therefore, spatial visualization ability appears to be of utmost importance at early stages of development and it has been shown that performance on spatial tasks improves after exposure to training programs (Bendzel, 1978).

The three variables of the study were chosen to provide data on cognitive and affective measures. Barnes and Hill (1983) list questions that should be researched regarding the use of Logo. This study addresses some of these and others raised by educators: 1. Do children gain a sense of control or personal ownership by designing a Logo procedure? 2. Does using Logo enhance children's cognitive abilities, such as spatial ability, problem solving, and thinking processes? 3. What degree of mastery of the mathematical subject matter involved in turtle geometry is possible? This study should provide some needed direction for educators being faced daily with decisions on how microcomputers will be used in the classroom. When considering the impact of microcomputers on education, these decisions would be based on a wide spectrum of information.

Assumptions

It is assumed that the effect of using microcomputers in the elementary classroom to teach geometric concepts will be measurable on the Julian Elementary Test of Geometric Achievement. An assumption is also made that experience in the pictorial mode of the microcomputer will be directly or indirectly related to a student's performance on a spatial visualization test. Therefore, it is assumed that the Monash Spatial Visualization test is a reliable index of a student's spatial ability. Furthermore, using the Monash Spatial Visualization Test assumes that thinking about a spatial question can be summarized by attending to four independent characteristics: the dimensionality of thinking required, the amount of internalization required, the manner in which the answer is to be presented, and the type of thinking required.

The results of the Crandall Intellectual Achievement Responsibility Questionnaire (IARS) are assumed to be reliable indices of a student's internal or external locus of control of reinforcement for success or failure in achievement situations. The locus of control construct is assumed to be an indicator of a student's feeling of personal control over her environment.

Limitations

This study is limited to sixth grade students who were enrolled at the elementary school in which the study took place during the 1983-84 academic year and completed the pretesting with the Julian Elementary Test of Geometric Achievement, the Monash Spatial Visualization Test and the Crandall IAR. Furthermore, this study is limited to the extent to which these instruments measure the constructs so indicated for each of the students involved.

Definition of Terms

The following definitions apply to this study:

Subjects. Participating sixth grade students enrolled in an elementary school located in a western university town during the 1983-84 academic year.

Experimental Group 1, E_1. A random selection of one third of the students of two self-contained sixth grade classrooms with seven students from Classroom R and seven students from Classroom F. The gender make-up of this group included seven males and seven females. This group was taught a six-week unit on geometry using traditional curricular materials along with manipulatives and supplemented by eight weeks of geometry-related computer assisted instruction (CAI) on the Apple Microcomputer System. Each subject was scheduled for nineteen$^+$ hours of computer time.

Experimental Group 2, E_2. A random selection of one third of the students in two self-contained sixth-grade classrooms with six students from Classroom R and eight students from Classroom F. The gender make-up of this group included seven males and seven femlaes. This group was taught a six-week unit on geometry using traditional materials with manipulatives and supplemented by eight weeks of Logo on the Apple Microcomputer System. Each subject was scheduled for nineteen$^+$ hours of computer time.

Control Group, C. A random selection of one third of two self-contained sixth-grade classrooms with seven students from Classroom R and seven students from Classroom F. The gender make-up of this group was seven males and seven females. This group was taught a six-week unit on geometry using traditional curriculum materials with manipulatives but had no geometry-related experiences on the computer. Each subject was scheduled for nineteen$^+$ hours of computer time during which time the student was involved in mathematics computation in the form of drill and practice, tutorial or educational gaming.

Classroom R. A self-contained sixth-grade classroom consisting of twenty students of whom nine were males and eleven were females from whom the three groups in the study were randomly sampled. The classroom teacher was an experienced female with significant experience in using computers in the classroom.

Classroom F. A self-contained sixth-grade classroom consisting of twenty-two students of whom twelve were males and ten were females from whom the three groups in the study were randomly sampled. The classroom teacher was a first-year male with minimal experience in using computers in the classroom.

Traditional Curriculum. This refers to instructional materials and methods employed by most elementary school teachers where textbooks are the main source of information and direction. In this study the textbook materials were supplemented by manipulatives.

Geometry Unit. A six-week unit on geometric concepts with forty to sixty minute daily class periods using textbooks and manipulatives. Topics included angles, perpendicular and parallel lines, identification of polygons, perimeter, triangles, similarity, circles, slides, flips, turns, symmetry, congruence, three-dimensional figures, area, and volume.

Computer Assisted Instruction (CAI). Instruction that is delivered via the technology of the microcomputer. The three categories of CAI in this study are drill and practice, tutorial systems, and simulations and educational gaming.

Logo. An interactive high-level procedural language developed for educational purposes at the Artificial Intelligence Laboratory at M.I.T. The use of Logo for this research was the Turtle Graphics facet of the language. This study employed the Apple II version of Logo designed by Logo Computer Systems, Inc.

Geometric Achievement. Each student's achievement in geometry was measured by the Julian Elementary Test of Geometry Achievements. Subjects were administered Form A as the pretest and Form B as the posttest. Achievement was determined by using a repeated measures design with each subject serving as her own control.

Julian Elementary Test of Geometry Achievement (JETGA). A sixty-four item multiple choice test measuring knowledge, understanding, and application of geometry topics in the elementary school. The JETGA measures the following topics in geometry: angles, area, circles, congruence, cubes, curves, cylinders, identification, lines, perimeter, planes, points, Pythagorean theorem, symmetry, and triangular pyramid.

Spatial Visualization Ability. An ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli. Each student's spatial visualization ability was measured by the Monash Spatial Visualization Test by repeated measures of the pretest and posttest using each subject as her own control.

Monash Spatial Visualization Test. A paper and pencil spatial test consisting of thirty questions divided into sections A and B. Section A contains fifteen multiple choice questions while section B has fifteen short answer questions requiring various forms of presentation. The test is suitable for grades 5-10 and requires the use of different kinds of spatial thinking; dimensionality, internalization, presentation, and thought processes (DIPT).

Locus of Control Construct. The allocation of responsibility for an outcome ranging from internal to external locus of control of reinforcement. Locus of control was determined by using a repeated measures design on the pretest and posttest of the Crandall IAR Questionnaire.

Internal Locus of Control of Reinforcement. The perception of positive and/or negative events as being a consequence of one's own actions or relatively permanent characteristics and thereby under personal control.

External Locus of Control of Reinforcement. The perception of positive and/or negative events as being unrelated to one's own behaviors in certain situations or relatively permanent characteristics and therefore beyond personal control.

Crandall Intellectual Achievement Responsibility Questionnaire (IAR). A scale for assessing children's beliefs for internal versus external locus of control of reinforcement responsibility in intellectual academic achievement situations. The scale is composed of thirty-four forced-choice items with an equal number of positive and negative events. Each subject has a total internal responsibility score and separate subscores for internal responsibility for success (IARS) and internal responsibility for failure (IARF).

Overview

This study is divided into five chapters. The first chapter is a statement of the problem under consideration and definitions of terms used in the study. In Chapter II, relevant studies concerned with the use of microcomputers in the classroom, Logo, CAI, locus of control and spatial visualization are discussed. The experiment is discussed in Chapter III and includes the design and sample, the measuring instruments, the collection of data, and the methods of analyses used in the treatment of the data. The results are reported in Chapter IV as the data are analyzed, while Chapter V presents the summary, conclusion, and implementation as well as suggestions for further study.

CHAPTER II

REVIEW OF RELATED LITERATURE

Within the statement of the problem and the importance of the study presented in Chapter I, a broad overview of Logo and computer usage in the public schools was given. The purpose of this chapter is to present a review of pertinent literature related to the issue of microcomputers in education, access and use of microcomputers in the schools, computer assisted instruction, Logo, geometry, spatial visualization, and locus of control. Because technology and its impact in education is changing so rapidly, the literature reviewed in this chapter was chosen because of its relation to the purpose of the study and to give background information to the reader.

Microcomputers in Education

The number of microcomputers in our elementary and secondary schools is tripling every eighteen months with estimations that there will be one school computer for every 23 students in America by the end of 1987. However, many questions are left to be answered and developments to be made before computers can realize their full potential within the educational system (Grayson, 1984).

The potential of educational computing is repeatedly discussed in the literature (Becker, 1982; Bork, 1984; Camarda, 1984; Fiske, 1983; Grayson, 1984; Komoski, 1984; Pea, 1983, and Watt, 1983d), but it is not clear who will bear the burden of fulfilling that potential. Even though parents expect schools to provide computer learning, more computers were purchased by parents of school-age children in 1984 than were purchased by schools (Komoski, 1984). In fact, one out of every six school-age children has access to a computer at home and computers in homes outnumber computers in schools by a ratio of almost 10 to 1. A market research firm, Future Computing Inc., predicts that by 1987, 70% of the one billion dollars per year spent on educational hardware and software will be products for the home rather than for schools (Watt, 1983a). Because expectations for educational computing are high, schools are being placed in a precarious situation. For the most part, schools are understaffed, underfunded, and lacking trained personnel in computing, but if schools do not assume the challenge to realize the potential for educational computing, they will be criticized for not preparing students for the future.

Education in the United States has been receiving enthusiastic support along with criticisms (Gallup, 1984, Reagan, 1984; Boyer, 1985; Saphier and King, 1985). To infuse a cooperative effort involving parents in computing, Camarda (1984) describes a home-school computer experiment where parents get directly involved by being able to call up their children's academic records on the computer to see which skills they have mastered. Houston Independent School District has made similar moves toward providing ways in which parents and schools can work together by instituting a computer loan program to assist parents with tutoring their children at home (Fiske, 1983).

We can see that educational computing is still in its infancy as we observe educators focusing on starting new programs, acquiring computers, training teachers, developing software and curriculum materials, and learning what computers can do (Watt, 1984b). Schools are known to be conservative and slow to change, but technology is promoting new educational methods more rapidly than educators can learn to use them. As Watt (1983a) points out, there is a confusion that has schools scrambling for the latest technology before examining their goals and deciding what they will do with computers when they get them.

Miller (1984) describes five evolutionary stages of educational computing in the schools: 1) Experimentation--which begins with locally produced software. 2) Instant computer literacy--which involves the purchasing of equipment, developing a computer literacy curriculum, and trying to integrate it all at once. 3) The search for appropriate software to use in all subject areas. 4) Integration of computers to fit the structure of the classroom and the development of computer labs, resource centers and networks. 5) Computers are everywhere--tool-type software is used for regular classroom instruction to individualize instruction; learning sites are in libraries, learning centers, community centers, and the home; and parents attend training programs and borrow computers and software from the libraries.

Although we must evaluate the effect of computers in the classroom so we can be confident about what the computer is doing to the teaching and learning process, premature attempts to measure the success of educational computing programs could be detrimental (Watt, 1984b). The need for American educators to evaluate and report on computer usage may interfere with the time necessary for planning and experimentation to develop quality programs. No doubt, accountability will soon be upon schools to determine exactly what about computers and learning should be measured. After defining objectives, testing methods must be produced.

During 1986, "computer competence" will be tested by Educational Testing Services for inclusion in the National Assessment for Educational Progress study (NAEP). Information about access to computers, the way computers are used, time spent outside of school using computers, playing video games and watching television will also be gathered. The NAEP study should be helpful in telling us the direction educational computing is taking within our schools. However, testing computer competence could determine what schools decide to teach and how they teach it rather than reflect what schools are already teaching. The danger exists that the testing criteria could become the curriculum (Watt, 1984b).

Although many uncertainties exist about the future of computing in education, we can be sure microcomputers will assume increasing importance in the instructional process. Other states may follow Florida's statute declaring that "it is the policy of the state to use computers and related technology to make instruction and learning more effective and efficient and to make educational programs more relevant to contemporary society" (Watt, 1984b, p. 86). Bork (1983) lists several predictable trends in computer education: 1) The number of computers in schools will continue to increase. 2) Commercial companies will step up efforts to sell computers and produce and distribute computer-based learning materials. 3) Computers will continue to evolve and improve while prices continue to come down. However, Bork goes on to say, if we continue business as usual rather than face the challenge to integrate the interactive capabilities and full potential of computers, our schools will continue to decline and the educational problems that plague us now will remain unsolved.

Several futuristic computer educators give us visions of computing in the future (Becker, 1982; Bork, 1984; Camarda, 1984) that contain goals concerning the potential of computers in the classroom about which many of us dream: The use of intelligent and communicative machines in intellectually stimulating and humanistic environments, highly complex information storage and retrieval, and the development of logical thought processes and problem solving skills by students as a result of interactions with computers. It is possible now to develop materials so that computers could function to provide education with these outcomes (Becker, 1982).

Access and Uses of Microcomputers in the Schools

Based on survey information, Ingersoll and Smith (1984) predicted the number of microcomputers in schools should have exceeded one million by the end of the 1985-86 school year. By the end of 1983-84, 83% of schools had microcomputers and by 1986 it is predicted that the rate will reach 96%. In 1982, approximately 140,000 microcomputers were sold to schools, but by 1987 the annual sales are predicted to be approximately two million. The microcomputer purchases made now are apt to be additions to an existing base or replacements. Schools appear to choose computer models that have been available for some time and for which a variety of educational applications have been developed. Also, because schools will not buy new equipment that is incompatible with previous equipment, the problem of having too few microcomputers for the number of students will continue for awhile. The number of microcomputers is still small in comparison to the number of students or number of classrooms (Becker, 1982). In spite of seemingly large number of microcomputers being placed in schools, Ingersoll and Smith (1984) state that

> . . . it will take at least ten years at today's purchase rate to have enough microcomputers in schools to enable the average child to have enough time on a computer to make a significant impact on learning (p. 87).

The most extensive information on computer access and use comes from a national survey under the direction of Henry Jay Becker conducted at Johns Hopkins University (Becker, 1983-1984). The study was based on a probability sample of 2,209 public, private, and parochial elementary and secondary schools in the United States. The reported results are based on 68% of that sample which is 1,082 microcomputer-using schools. By January 1983, 53% of all schools in the United States had at least one microcomputer--83% of all high schools, 77% of all junior-senior high school combinations, 68% of all middle-junior high schools and 42% of all elementary schools. It was noted that even the smallest secondary schools are more likely to have at least one microcomputer than are the largest elementary schools. Elementary schools tend to have microcomputing equipment in smaller numbers and with less capacity.

Before 1982, a single teacher in the school provided the initial impetus for obtaining microcomputers, but now administrators are initiating purchases and involving parents and groups of teachers. In the Western region of the United States, teachers are the more influential in how schools obtain and use microcomputers, while administrators make those decisions in the South. The West also leads the country in the ratio of computers to students (Becker, 1983-1984).

Peterson (1984) points out that the lack of major support at the federal level for a national policy of educational computing is creating a new disadvantaged class of people. The Johns Hopkins survey (Becker, 1983-1984) reports this differentiation by noting 12,00 of the wealthiest schools are four times as likely to have microcomputers as are 12,000 of the poorest schools. In January, 1983, 70% of the schools in the more affluent areas had at least one microcomputer while the poorer areas reported 40% of their schools having microcomputers. In addition, schools with predominantly white student enrollments have twice as many computers as do minority schools.

Becker (1982) raises two basic questions concerning microcomputer usage: 1) What uses, if any, should we make of today's microcomputer products in today's classrooms? 2) What can we do to make microcomputers more useful to schools during the next five years?

Fiske (1983) reports that the uses of computers range from simple drill and practice to simulations on the theory of relativity. Schools are using computers in a variety of subject areas: in music for composition, foreign languages, reading, in home economics to analyze diets, in art for graphics, banking and applying for a job in vocational courses, in study courses for ACT and SATs, and in special education to accommodate students with impairments. In addition, programming is taught using beginning and advanced BASIC, FORTRAN, Logo, and advanced placement in Pascal.

Secondary schools are the largest pre-college users of microcomputers and spend the majority of their usage time teaching students about computers and how to program them in BASIC. Teaching programming nearly always means BASIC as 98% of the schools in the Johns Hopkins survey (Becker, 1983-1984) teach BASIC while 5% teach FORTRAN, Logo, or Pascal.

The greatest use of microcomputers in the elementary school is for "drill-and-practice". However, as teachers become more experienced with computers, there is a consistent decline in the use of microcomputers for drill-and-practice. As this happens, the use of microcomputers for instruction in programming increases in both the elementary and secondary schools (Becker, 1982). Becker points out that one of the main issues of using computers in the classroom is the organizational problem. Microcomputers are basically designed for individual use and teachers are trying to adapt them to group-based instruction. Decisions need to be made as to which students should have access and where they should be placed.

About 16% of students in the elementary schools and 13% of students in the secondary schools use microcomputers during any given week in a typical school that has microcomputers. Elementary schools are more likely than secondary schools to have microcomputers, but have not yet begun to use them with students. Microcomputers are in use by students for approximately 2-3 hours per day in the elementary school. A student user typically has twenty minutes per week at the computer because most elementary schools have only one or two microcomputers and the opportunity to use microcomputers is extended to as many students as possible. Elementary schools typically only use their equipment for one-half of the school day (Becker, 1983-1984). Euchner (1983) also reports that about 75% of schools with computers actually utilize them less than half of the day.

The instructional time in the elementary school is divided up into 40% for using programs for mathematics and language facts; one third for copying, writing, and testing computer programs; and 20% for playing learning games. In the secondary schools, users had 45 minutes per week, which was divided up into two thirds for programming and computer literacy, 18% for drill and practice, and 16% for learning games and word processing. When considering total student time on microcomputers in pre-college educational institutions, three fourths of the time occurs in the secondary school while only one fourth occurs in the elementary school. Although intensive use of microcomputers for drill and practice is reported by 22% of the elementary schools, computers do not actually function as major ingredients in skill building through drill and practice because most students do not get a sufficient amount of time to learn significant subject matter. The effect of using drill and practice may be to demonstrate the nature and capacity of the computers and their usefulness in practicing skills.

Elementary schools try to give access to as many students as possible while secondary schools give each student a greater amount of time, thereby, making the computer accessible to fewer students. Peterson (1984) discusses the dilemma of dispersing computers equally among classrooms or concentrating them in a central location. If all students are given a little to be fair, schools take the chance of spreading usage so thinly that it is probably wasted rather than concentrating in a few classrooms to maximize effectiveness.

Peterson (1984) also raises the issue of some students needing computers more than others, such as handicapped, gifted, and socially or educationally disadvantaged students. The Johns Hopkins survey (Becker, 1983-1984) reports that two very different approaches are used. One is to use microcomputers for lower achieving students for increased motivation in hopes of bringing up achievement levels. The other is to use them to provide faster-learning students with a challenge.

While secondary schools report little usage of microcomputers for drill and practice (10%), they report intensive use of microcomputers for programming in 64% of the high schools. In the junior high schools, 32% report intensive use for programming and only 18% of elementary schools use microcomputers intensively for programming. BASIC is the language used most frequently; however, Logo is used in the elementary schools in the Northeast region where 11% of the elementary schools in the survey provided 30 hours of instruction in Logo (Becker, 1983-1984). Becker (1982) believes the choice of language in which programming instruction should be given is a function of grade levels and abilities of students, training of teachers, and available equipment. Since programming is most successful when introduced into the curriculum in the first year of middle school or junior high school, Logo may be easier for younger children to learn even though BASIC is more widely available. Students in grades 6-8 seem to be sufficiently mature to understand the abstractions involved in programming.

The study conducted at Johns Hopkins (Becker, 1983-1984) also reported regional differences in microcomputer usage. In the Northeast, the elementary schools do not use their microcomputers as intensively as other parts of the country and provide access to fewer students each week. Fewer students used microcomputers for longer periods of time with more time for programming than subject matter instruction. More students use the equipment in the Midwest, but for less time each week. In the Midwest, a general computer literacy for all students is emphasized more than intensive use by a select number of students. The student-to-microcomputer ratio is less adequate in the South and microcomputers are used for drill-and-practice more there than in other regions.

In the Western cities microcomputers are used predominantly to teach programming skills to above-average students. Drill and practice is the preferred activity in rural elementary schools where the only cluster of schools using microcomputers equally for above-average, average, or below-average students is found. The use of microcomputers is spread over a broad range of students in suburban and rural western elementary schools where the best ratios of student-to-microcomputers of any of the elementary schools in the survey is located.

Differences among secondary schools were not as pronounced as among elementary schools, although it was reported that schools in the West and Midwest tended to have more active programs with microcomputers than other regions. The Johns Hopkins survey only reported geographic averages, therefore, care must be taken not to over-generalize.

Computer literacy versus computer assisted instruction initially was the big issue because computers were first used in the classroom to duplicate what teachers had done in drill and practice. Teachers are now realizing that the real potential of the computer lies in students using computers to discover things for themselves (Fiske, 1983).

The meaning of "computer literacy" is the issue schools now have to face. The main areas of computer literacy are usually defined as how computers work, computers in our lives, programming, and ethics. It is intended that through these areas, students will develop skills to think and solve problems on their own, know how a computer functions and its potential applications, and have the knowledge to make intelligent choices later in their lives (Fiske, 1983). The question of whether computer literacy courses give children the conceptual basis for solving complex problems and handling large systems of information is largely unexamined

(Watt, 1983d). A variety of factors contribute to the level of computer literacy achieved: the diversity of the computer software, the variety of educational programs, numerous terms used in describing projects and languages, the different methodologies, and the fear teachers have of computers (Lawton and Gerschner, 1982).

Barbour (1984) notes the shifting of computer education away from programming toward computer applications like word processing, spreadsheets, and data base management. Schneiderman (1983) suggests that emphasis should be on what students can do with computers rather than what they should know about them. Rather than one computer awareness or programming course, Barbour suggests emphasis should be placed on the integration of computers into the curriculum. Thus, programming should be a course offering rather than a requirement to operate a computer effectively.

Too few computers in the schools may have some positive aspects by forcing social interaction around the machines (Camarda, 1984). Fiske (1984) also points out that the presence of computers actually enhances social contact because students become interested in activities of their peers. They tend to work together to debug programs and develop their own procedures for sharing of programs. The Johns Hopkins survey (Becker, 1983-1984) reports that social interactions do occur as 67% of the work at computers is in a social situation either through working in pairs or getting help while doing individual work.

"A lot has been said about microcomputers affecting students, teachers and the whole process of schooling, but there has been relatively little scientific investigation of their impact" (Becker, 1983-1984, p. 6). The social impact of microcomputers on learning appears to be greater than the impact on increased student achievement. Several observations on the social organization of learning are reported by teachers: increased student enthusiasm for schooling; students working more independently, without assistance from teachers; students helping one another and answering each other's questions; and students being assigned to do work more appropriate to the achievement level (Becker, 1983-1984). In this type of computer environment, educators can be facilitators of the education process rather than be the source of knowledge (Fiske, 1983).

No doubt, teachers are at the focal point of the social transformation computers are producing and individual teachers must make decisions on how best to incorporate computers into the schools.

> The key to efficient use of computers in education is to place the machines in the hands of individual teachers with the clear understanding that these teachers can use their computers for whatever purposes they perceive as most appropriate (Wagschal, 1984, p. 242).

Teachers play a large role in planning how microcomputers will be used with students by selecting software and by training other teachers. Programs are most successful and productive when a group of teachers rather than a single teacher is involved (Becker, 1983-1984).

Along with decisions on curriculum and software, schools must decide where microcomputers should be placed. The best outcomes among elementary schools were reported when decisions involved both the principal and teachers (Becker, 1983-1984). It may be best to leave computers in the hands of teachers who enjoy the computing experience and will make them an integral part of the classroom experience; however, a centralized laboratory will make more efficient use of the equipment. Centralization of computers exphasizes computer assisted instruction and computer managed instruction record keeping while computers under the control of the classroom teacher will be used more for curriculum enhancement (Becker, 1982).

Microcomputers were placed in regular classrooms in over 50% of the schools in the Johns Hopkins survey while libraries housed 35% in the elementary schools and 20% in the secondary schools. In addition, computer labs were used in one-third of the elementary schools and one-half of the secondary schools (Becker, 1983-1984).

Much of the literature on microcomputers in the schools is still at the opinion and theory level which is why Becker (1982) issues this challenge: "We need well-executed evaluations of different ways of using microcomputers and evaluations of specific computer-related teaching products used in instructional programs with comparable students and control groups" (p. 57). Sloan (1985) expresses this concern:

> American educators have made no concerted effort to ask what level, for what purposes and in what ways the computer is educationally appropriate and inappropriate, in what ways and to whom we can count on its being beneficial or harmful (p. 51).

Computer Equity

Computer equity refers to equal access to computer learning regardless of a student's social or economic status (Anderson, et al., 1984). If children were introduced to computers early in school and all students maintained equal access, the use of microcomputers could be seen as the great equalizer (Watt, 1984a). The computer could be a vehicle for reducing educational discrimination and inequity by providing a means for overcoming obstacles for disadvantaged students. The computer is non-discriminating and does not select who to instruct or who can learn. It is not culturally or sex biased, but rather it gives the same feedback to everyone (Schubert and Bakke, 1984). Computer usage could provide positive reinforcement and motivation for those students with unfavorable dispositions toward learning. Microcomputers could also provide communication beyond the disadvantaged students' own subculture, while increasing their level of information processing skills (Lipkin, 1983).

Statistics from the 1982 NAEP indicate that the opportunities for learning that microcomputers offer are not reaching all students. Less than 17% of junior high school students from rural and ghetto areas reported use of computer equipment, while 32% of "urban/rich" students had access to equipment. In addition, 18% of the students in small towns versus 26% in large cities have access to microcomputers. Regionally, there is also a difference with 12% of 13 year-olds in the South having computer experiences compared to 24% of students in the West having similar experiences (Anderson, Welch, and Harris, 1984). In addition, Becker (1983-1984) reported that 48% of the elementary schools outside of the South had a microcomputer, while only 29% of those in the South did.

Not only are there differences in the number of computers in schools, but difference exists in how they are used. The wealthy schools teach programming while the inner city and rural schools use microcomputers for drill and practice. Therefore, two distinctly different philosophical approaches to the use of computers exist. Students exposed to programming see the computer demonstrated as an intellectual tool where they tell the computer what to do, while students exposed to drill and practice see the computer demonstrated as an instructional delivery system where the computer tells them what to do (Alvarado, 1984).

The New York City School District has developed several programs to bridge the gap between students with home computers and those without them. Some of the programs they have established are (a) free summer and vacation time "computer camps," (b) after school computer clubs, (c) scholarships for private computer camps, and (d) after school computer classes for parents and children (Alvarado, 1984).

Estimates from the United States Department of Labor indicate that 50-75% of the jobs in the near future will involve computers ranging from simple button-pushing to sophisticated programming. Salary inequities exist as a result of occupational discrepancies. Females only earn 59% of what men earn which results from the fact that females comprise 80% of all clerical workers, 63% of computer operators earning approximately $12,000 a year, and only 25% of system analysts earning approximately $27,000 per year (Sanders, 1984).

Since so many careers in our society depend on the ability to use computers, girls need to be encouraged to continue in computer education. There is ample evidence of a gender gap in computer education, but the reasons for its existence are only speculative at this point. Hawkins (1984) concluded that the sex difference that existed in computer usage at the Bank Street School was related to the particular use of the computer and the way it was organized and supported in the classroom. Some of the factors contributing to the sex difference in learning and achievement are (a) the impact of societal images on girls, (b) the expectation of different life goals for boys and girls, (c) the structure of the learning tasks, (d) the nature of the feedback in performance situations, and (e) the organization of the classroom setting.

Several researchers have suggested that the gender orientation of educational software is contributing to computer inequity (Fisher, 1984; Kolata, 1984; Lockheed and Frakt, 1984; Watt, 1984a). Much of the educational software is written to appeal to males as evidenced by traditionally gender-related rewards such as touchdowns, home runs, or shoot-em-ups and has built-in competitiveness, action, and loud noises (Watt, 1984a). Fisher (1984) reports that there is a preference of males for action and aggressive formats in software while females prefer fantasy, word-oriented rewards, and completion tasks in software. This is supported by the fact that Pac-man is equally popular with females because it involves a completion task. When junior high school students evaluated the titles of 75 randomly selected pieces of software for gender orientation, 40% were listed as being written primarily for males and 5% for females (Lockheed and Frakt, 1984). Many times there is no inherent bias in the software, but the images used to attract students are male-oriented racing cars and spaceships. Even Texas Instrument's Logo sprites such as the car, truck, and rocket appeal more to males (Fisher, 1984). However, some educational publishers are beginning to write software that appeals to girls. Rhiannon Software/Adventure stories have intelligent spirited heroines working cooperatively to solve problems (Watt, 1984a).

Gilliland (1984) suggests that the "actions of parents and society combine to demonstrate to girls that computers are not for them" (p. 42). Sanders (1984) goes further and points out some of the subtleties that often go unnoticed. Female stereotypes are so commonplace that they may go unnoticed (a) when the Logo turtle is referred to as he, (b) when illustrations on computer magazines predominantly depict male computer users, (c) when computer games are male-oriented, and (d) when boys outnubmer girls in programming classes and interactions with computers after school.

Lockheed and Frakt (1984) report that no sex difference in awareness, interest, and attitudes toward computers exists, but males do have greater access to computers than females. Watt (1984a) has found no systematic efforts to exclude girls from computer access. In fact, at the elementary level it was more or less equal; however, starting in the seventh grade, there is an overwhelming male representation with high school boys outnumbering girls in programming courses by almost two to one. Despite the fact that the world's first programmer, Augusta Ada Lovelace, was a female and the first major computer developed in 1940 had 100 females operating it, fewer females than males are involved in computing in the schools.

In a study at the American Institutes for Research in Palo Alto, it was found that only 37% of the high school students in programming classes were females. Similarly, the Lawrence Hall of Science reported only 27% of their students in computer courses were females. The level of the course offerings show even greater discrepancies. Muira and Hess (1984) report 28% females in beginning and intermediate programming classes, 14% in advanced programming classes and only 5% in advanced assembly language courses.

When girls do sign up for computer classes, it is important that they, as well as all students, have positive experiences and become involved in extracurricular computing. Fewer females than males will take the time to become really involved with computers. To become fully proficient at programming, students must invest a great deal of time. A girl who chooses to spend time in the computer center isolates herself from interactions with friends and social relationships, which are very important to adolescents (Lockheed and Frakt, 1984). In addition, to avoid conflict, females tend to defer to males when both want to use the computer (Boss, 1982). Fisher (1984) notes that in early adolescence, boys tend to run in packs and intimidate the girls who are interested in computer clubs.

Since Sheingold and Endreweit (1983) report that sex was the greatest factor affecting differential use of machines at all grade levels, teachers are urged to ensure that girls have an equal share of computer usage. Kolata (1984) feels that elementary school teachers are the key for getting girls involved with computers.

The problem of equal access in the schools is compounded by unequal usage outside the classroom. Boys are usually the ones who are enthusiastic enough about computers to use them before and after school (Sanders, 1984). More boys have access to computers at home or at a friend's house. In a 1982 survey conducted in California, 21% of the boys and 15% of the girls had access to a computer at home (Fisher, 1984). Lockheed and Frakt (1984) reported even more of a discrepancy with 15% boys and 7.5% girls having a computer at home.

As evidenced through enrollments at summer computer camps, parents seemed more willing to invest in computer training for sons than for daughters. Summer camp enrollments reported by Muira and Hess (1984) indicated there were 74% boys to 26% girls. These data came from 5,533 students in 132 instructional groups. Also, it should be noted that the proportion of girls was highest in day classes sponsored by public schools and lowest in private residential camps. This proportion of girls in summer computing activities and camps decreased as the cost and grade level increased. Therefore, even though interest toward or understanding of the relevance of computers was similar for boys and girls, boys received more experiences with computers and spent more time interacting with computers (Lockheed and Frakt, 1984).

Interventions by schools and other public agencies may be necessary to prevent the inequities that have been identified from becoming the norm in society (Muira and Hess, 1984). EQUALS in Computer Technology trains classroom teachers to promote computer equity. Teachers must first become comfortable with the technical aspects of computing and then learn teaching strategies to tailor computer use to the individual learning styles of all students. Teachers taking EQUALS workshops reported a 12% gain, from 35% to 47%, between 1982-83 in the number of girls enrolled in their computer classes (Gilliland, 1984; Watt, 1984a).

Alvarado (1984) discusses the aggressive affirmative action strategies in the New York City public schools. Books, periodicals, and software are regularly evaluated for sexism. Female teachers are encouraged to teach computer classes to provide positive role models while programming instruction emphasizes Logo or other graphic approaches to programming to appeal to females.

Lockheed and Frakt (1984) stated that girls would rather learn application programs for word processing, database use, or graphics than learn programming skills for which they see little practical use. Hawkins (1984) investigated the gender issue and found that girls showed less interest in programming than boys and developed less facility with Logo. Boys scored better on measures of programming expertise, showed more enthusiasm, and spent more time programming than girls did. As reported through teacher interviews, there was a noticeable sex difference in interest and accomplishment in programming. However, the use of word processing software did not show a sex difference as both boys and girls were equally involved.

Because computers were initially incorporated into the mathematics or science curricula which have been dominated by males, computers entered the classroom with sex-related inequities (Hawkins, 1984). Both Lipkin (1983) and Luehrmann (1985) state the need to use computers as a bridge to the study of mathematics rather than remove the link only for the purpose of attracting more females. By teaching only application courses rather than including some programming in introductory computer classes, students will lack the prerequisite skills for continuing on in computer classes. Luehrmann suggests defining a computer literacy curriculum requiring a programming language paralleling the mathematics curriculum requiring algebra as a prerequisite for further study. Inequity will only be reinforced if differential course taking is used as a remedy to the imbalance in computer classes.

Obviously, the issue of computer equity has surfaced and some possible solutions have been discussed, but computers are not yet accessible and attractive to all students, therefore, equal educational outcomes have not been realized.

CAI and Educational Software

When examining computer based instruction through CAI or other types of educational software, it is evident that how a computer is used is much more important than the fact that it is used. As Bracey (1982) stated, good software has better potential for producing good effects than does bad software.

Research using CAI is compounded by the difficulty of controlling the number of variables that can affect learning and test scoring. Such variables include (a) teacher competency, (b) quality of the materials, and (c) the social and economic background of the students. Computer assisted instruction discussed in the literature typically consists of drill and practice or tutorial programs. Because both test students' understanding and provide immediate reinforcement, the distinction between drill and practice and tutorials is often unclear. Tutorial programs provide more initial presentations of information and concepts on the subject matter as well as more detailed instructional feedback and problem presentation than drill and practice does. Tutorials can either be learner controlled or resemble a system called intelligent CAI which attempts to model students' understanding and to provide dialogue. Tutorials are appealing but time consuming to program; therefore, they have limited use.

Supply and demand make drill and practice the most commonly produced software. It is easier to program than other kinds of instructional software and many standard areas of the school curriculum incorporate repetitive practice which drill and practice can enhance (Becker, 1982). However, because the emphasis is now on the integration of computers into all areas of the curriculum, teachers want software to be more closely tied to the curriculum and to contain a variety of print materials to accompany the software (Ingersoll and Smith, 1984).

Bork (1984) states that although the amount of software available for use at all grade levels and in all content areas has increased greatly, the quality has remained consistently low. The knowledge of how to produce good computer based learning materials has not been utilized. A large-scale development of curricular materials that makes the computer an integral part of learning is needed. Most educational software is not clearly tied to other instructional activities but rather is produced as short disconnected modules. Although Bork claims that not more than 1% of the total instructional time in the classroom involves computers, attention must be paid to educational software productions. As Komoski (1984) points out:

> The quality of educational computing in a school is going to depend on the quality of the software selected for use in the school and on the way in which the use of that software is integrated into the overall curriculum (p. 245).

The capabilities of the computer will never be realized if schools are satisfied with existing software.

Prior to 1984, over 700 educational software companies had produced between 7,000 and 10,000 software packages. The success and profitability of these companies depends more on marketing than on the quality of their products (Komoski, 1984). However, some of the well-established companies are putting resources and expertise into developing and marketing high-quality educational software. Several efforts are being made to assist educators in obtaining quality materials. The Northwest Regional Education Laboratory has established a clearinghouse called MicroSift where software is collected and evaluated. Information is disseminated through a database operated by Bibliographic Reference Service (Grayson, 1984). Of the hundreds of programs evaluated by a national network of software evaluation teams of the Educational Products Information Exchange Institute (EPIE), only 5% were judged to be of high quality while more than half were deemed not worthy of recommendation. Komoski (1984) estimates that scarcely one out of every five software programs has been learner-tested by its publisher during development. Other evaluation efforts are being conducted by CONDUIT, Minnesota Educational Computing

Consortium (MECC), and the Oklahoma State University Clearinghouse of Information on Microcomputers in Education (CHIME) newsletter. A national software reference library has also been established where patrons can interact with a database to locate materials and try them on computers in the library (Grayson, 1984).

As educational software incorporates the techniques of artificial intelligence, another dimension of educational software will be available (Bork, 1984). However, creating such software costs the developer more than schools will pay (Luehrmann, 1984).

Most of the research on computers in education involves computer assisted instruction. Using a broad, comprehensive view of computer literacy, Battista and Steele (1984) report that both computer assisted and computer programming instruction were effective in improving high ability fifth graders' computer literacy. Evidence of improvement in the affective domain was measured by the Minnesota Computer Literacy and Awareness Assessment (MCLAA). Only the CAI group improved in the cognitive domain on the MCLAA. Students in the programming group were concerned only with learning how to control computers and not how they were used, while those in the CAI group became interested in learning more about computers and computing in general.

Steele and Battista (1984) found that computation scores of CAI groups improved significantly more than those of the control group, but there were no significant differences between groups or gains in concept or problem solving scores. Interacting with microcomputers for drill and practice in mathematics increased students' knowledge about computers even though no explicit discussion of computer topics was given. This was evidenced by the CAI group's significant gain over the control group on both the affective and cognitive domains of computer literacy. The difference between the CAI and control groups on gains in computer literacy scores was evident for low, middle and high levels of intellectual ability.

Smith (1973) looked at changes in student attitudes when using computers. After eleven weeks, there was no significant difference between pretest and posttest mean scores of the CAI group on any of the self-concept measures or locus of control scales. CAI seemed to promote realistic attitudes toward mathematics as a result of continuous feedback and individually prescribed problems for each student. By individualizing the content and pace of instruction, CAI appears to help students avoid fear of failure. The seemingly impersonal nature of the computer interaction did not have a dehumanizing influence on students as reported on three separate measures. The results on the three measures indicated students (a) did not have less confidence after using CAI, (b) their aspiration levels were about the same, and (c) their feelings of control over the environment did not change.

Several researchers have summarized studies on CAI (Burns and Bozeman, 1981; Edwards et al., 1975; Lawton and Gerschner, 1982; Thomas, 1979; Vissonhaler and Bass, 1972). Overall, the results appear mixed and the data reporting on the effectiveness of CAI in comparison to traditional instruction is inconclusive. The content areas generally examined are language arts and mathematics. In language arts, CAI groups improved from one tenth to four tenths of a school year over traditional instruction. Most comparisons in mathematics favor a combination of CAI and traditional instruction over traditional instruction only. Researchers generally concluded the following:

(1) Instruction supplemented by CAI is more effective than normal instruction alone.

(2) Any given CAI mode is not more effective relative to student achievement.

(3) Students obtained mastery status in short periods of time.

(4) CAI generates favorable attitudes.

(5) There are equal retention rates between CAI and traditional instruction.

Although the studies on CAI are vast, each is reported separately with few replications. Therefore, the total picture is difficult to analyze. When the number of studies is large and findings are diverse, reviewers see what they wish in the results (Kulik, Kulik, and Cohen, 1980). By using the quantitative method of meta-analysis, researchers have a statistical tool to draw more reliable, reproducible and general conclusions. Meta-analysis is the analysis of analyses to measure treatment effectiveness (effect size) to obtain a quantitative synthesis of research outcomes. The effect size given is the number of standard deviations that separate the averages in the comparison groups (Slavin, 1984). However, meta-analysis only provides a picture of the past and does not give a view of the future.

Burns and Bozeman (1981) employed meta-analysis to look at the effectiveness of CAI used in conjunction with mathematics in elementary and secondary schools with student achievement as the outcome criterion. CAI was used as a supplement, not as a replacement, in the forty studies Burns and Bozeman examined. They concluded that the instructional environments supplemented by CAI in mathematics significantly enhance learning at both the elementary and secondary levels among highly achieving and disadvantaged students. However, achievement of average level students was not significantly more effective in producing achievement gains among boys at the intermediate grade level. There was no relationship between experimental design and study outcome.

The meta-analysis performed by Hartley (1977) revealed that effects from CAI were not as large as the effects of programs using peer and cross-age tutoring, but larger than programmed instruction or individual learning packets. Hartly concluded that CAI is an effective way of teaching mathematics at the elementary and secondary levels.

Kulik (1983) used meta-analysis to examine the most recent applications of CAI, in addition to the early applications of CAI, within a wider variety of instructional outcomes. Kulik used 51 comparative studies on CAI in grades 6-12; these included five different types of applications of computer teaching, specifically, drill and practice, tutorial, computer-managed teaching, simulation, and programming the computer to solve problems. Educational outcomes were described in four areas: (a) learning, (b) academic attitudes, (c) attitudes toward the computer and (d) instructional time. The average effect of CAI on achievement was to raise student test scores by .32 standard deviations or from the 50th to 63rd percentile. Only small effects were obtained on academic attitudes while attitudes toward computers were more positive in groups using CAI.

In a meta-analysis of CAI used in college teaching Kulik et al. (1980) found a small, but significant, improvement in achievement, as well as positive attitudes of students toward instruction and the subject matter. Although CAI at the college level was not as effective as CAI at the elementary level, the computer can function satisfactorily in college courses and reduce time spent in instruction.

Stronger results were produced in more recent studies indicating that more appropriate use of instructional technology is now made. Shorter studies also showed stronger effects reflecting better controlled studies.

When CAI teaches specific skills or a body of knowledge, it is easier to test outcomes, but problem solving or higher cognitive skills, are more difficult to test (Bonner, 1985). CAI has the potential to free teachers from being dispensers of information and allow them time for advising and being an intellectual mentor. However, if the CAI is not responsive to the students' control, they may lose interest (Johnston, Markle, and Holt, 1983).

Logo

Logo has been called the "educational language of the future" (Watt, 1984c). It may someday replace BASIC as a universal first programming language in the public schools because of its ease of use, exciting applications, and educational benefits. In addition, because of its suitability for structured programming and modular problem solving, it may also be used in introductory computer science courses to ease the transition to more complex languages such as Pascal and LISP.

Logo is a programming language that was designed by a group of people whose major interest was the process of human learning. It was developed in the late 1960's under Seymour Papert's direction at Bolt, Beranek, and Newman, a social science consulting firm in Cambridge, Massachusetts. Logo was derived from a high-level language used in the field of Artificial Intelligence, called LISP. The Logo project was implemented on a large research computer at Massachusetts Institute of

Technology (MIT) in 1970. When microcomputers became powerful enough to support Logo, versions were developed for the Texas Instruments 99/4A and Apple microcomputers. Some discussion of the development and philosophical basis of Logo is given in Chapter I.

Logo may be a little ahead of its time because of its need for a large amount of computing power and memory. Used on present microcomputers, it works more slowly than some languages and uses up considerable memory. As microcomputers with more memory and higher speed become available, Logo qualities will become more eminent (Carter, 1983).

Beginning programmers initially learn Logo quickly, but often become confused and frustrated when the full power of the language is presented. Therefore, Logo is best suited for an initial graphics-based introduction to programming (Tinker, 1983). Going beyond a graphics environment, Logo can create and manipulate groups of words and numbers much better than many other computer languages. Logo's origins at MIT's Artificial Intelligence Laboratory are reflected in its "list processing" capabilities that can simulate human thought processes (Markuson, Tobias, and Lough, 1983).

Educators disagree about which language to teach. Although BASIC is probably the most common, it is not accessible to the youngest students and does not necessarily foster good problem-solving techniques (Tinker, 1983). Unlike BASIC which was made for a totally different purpose, Logo was designed for learning. Logo allows elementary school children opportunities to begin programming quickly and painlessly. Papert points out that "Logo is not necessarily easy, but it's easy to get into" ("Talking Turtle," 1983, p. 2). With Logo, students need not learn a complicated set of language elements to begin writing programs, yet they can develop powerful programs using original words as building blocks. It is possible for every student to develop an individual Logo language. Tinker (1983) believes the best computer literacy curriculum right now is to teach Logo to beginning students, change to an intermediate language and then teach Pascal for an applications language.

> Logo is designed to place the child in a setting where she or he controls both the learning environment and the technology. The child assumes the authority role, instructing the computer to follow directions (Markuson et al., p. 75).

The structure of Logo provides an environment where this freedom can be successful (Dale, 1984). The graphics feedback makes the process more than simply trial and error; it is one of trial and revision if a series of turtle moves does not produce what is expected (Carter, 1983). Children need to be supported as they explore and build their own intellectual structures. Papert (1981) clarifies that "teaching without a curriculum does not mean spontaneous, free from classrooms or simply leaving the child alone" (p. 88).

Unlike CAI where the answer is either rewarded when correct or the user is instructed to "try again", with Logo there is no right or wrong. Traditional CAI has attended to learning differences in terms of pace and interest, but ignored individual learning styles. Logo can accommodate an individual's style by allowing him or her the freedom of expression (Martin, 1981). Solomon (1982) identified three different learning styles that can be seen in Logo programming: (a) the planner who builds structured programs either from the top level down or bottom level up, (b) the macro-explorer who uses subprocedures as building blocks to arrive at a product, and (c) the micro-explorer who gradually explores in a conservative manner. Papert summarizes how learning styles are recognized in the process of using Logo, "The spirit of Logo is to produce a language that encourages an attitude of taking it and changing it, shaping it to yourself. This is true of individuals, it's also true of cultures" ("Talking Turtle," 1983, p. 16).

The greatest amount of Logo research in the United States has been carried out at MIT by the Logo group under the leadership of Seymour Papert. Other Logo leaders in this research include Harold Abelson, Andrea di Sessa, Marvin Minsky and Wallace Feurzeig from Bolt, Beranek and Newman, Inc. In the early 1970's Logo research was carried out in the Lexington Public Schools. A special laboratory was also set up at MIT where students from Cambridge public schools and the Boston area were involved in the research. Beginning in 1977, the Brookline School system, where Dan Watt taught elementary school, worked closely with MIT on a research project with sixteen sixth grade students. As an extension of this collaboration, curriculum materials have been developed and tested for Logo.

As a result of extensive recording of students' experiences in the Brookline Project, it was found that the essential parts of geometry were captured more concretely, more deeply, and more intuitively than in traditional conceptual frameworks (Papert, Watt, di Sessa, and Weir, 1979). Regarding the learning of programming, the authors wrote

> . . . all students irrespective of performance level were engaged by computer activities in the Logo environment, all underwent significant observed learning and we made significant progress towards developing a methodology of channelling this learning toward mastery of programming (p. 1.15).

Two of the sixteen students did not "learn to program" according to the skills set in the project. The students were introduced to a pre-planned

Logo/turtle learning unit, but deviations were allowed when it would lead to a more meaningful learning experience.

The students using Logo in the Brookline Project did better on angle and line estimation than other students with a different computer experience and those students with no computer experience. Their knowledge was measured within the context of applications rather than knowledge of discrete facts. Estimates involving linear numbers were easier for the students than estimates involving angular numbers. The authors conjectured that this may be due to students being able to visualize linear magnitude better than discontinuous angular numbers. After closely observing the sixth grade students at Brookline, the authors concluded that the students using Logo have the opportunity to function like a mathematician and formulate propositions to discover predictable regularities and then to test, extend, revise or discard items.

Three conclusions can be reached from the Brookline Project:

1. CAI has its place in the regular curriculum, but it is inadequate as a major part of computer education and the computer literacy program.

2. BASIC is too difficult for the average fourth, fifth and sixth graders.

3. Logo has the elements for a comprehensive computer program since it teaches programming, uses graphics and provides new approaches to problem solving (Markuson et al., 1983).

The first microcomputer to support Logo was Texas Instruments 99/4A. This was initiated in 1978 at the Lamplighter School in Dallas as a joint effort with the MIT Logo group and Texas Instruments. At the beginning of the four-year project, the school had fifty computers available for about 400 children between the ages of 3 and 9. It now has the highest concentration anywhere in America with at least one computer for every five children ("Talking Turtle," 1983). Computers became a permanent and ongoing part of the school environment and afforded an opportunity to explore what happens in an environment when the number of computers is not a limiting factor. Regular school life goes on while some children are occupied with the computers; when computing is accepted as an integral part of the school, but not allowed to dominate it. However, Logo has not been integrated into as much of the school's curriculum as had been planned (Watt, 1982).

Since research was not the main emphasis among teachers at Lamplighter, very few studies have been reported. However, results from one project suggest that Logo instruction may be effective in teaching thinking. Students in a third grade classroom who had received twice as much instruction in Logo were significantly better on a rule-learning task after nine months (Gorman, 1981).

The main concern at Lamplighter is teaching a way to think and, at the same time, teaching the child to believe in himself. The philosophy of Lamplighter is one of individualization, improvement of self concept and communication skills. With Logo, skill levels seem to lack significance as teachers at Lamplighter provide opportunities for success and a real sense of accomplishment. Even the young children experience this success by controlling the computer with single-key commands through a simplified version of Logo. The Lamplighter School is not a competitive atmosphere; instead children help each other learn how the computer works with different "experts" emerging as children continue their explorations.

Several Logo research and development projects began early in the New York City area. The Microcomputer Resource Center at Columbia

University has been conducting summer classes and teacher training workshops in Logo for some time, stressing a good understanding of the developmental education concepts behind Logo as well as a strong working knowledge of Logo. Likewise, the New York Academy of Science has trained teachers in the New York City School System and used the first TI Logo computers in different schools at different age levels. The major focus of the Computers in the Schools Project has been the implementation in the school, training and supporting teachers to ensure successful use of Logo in the classroom. Classrooms of students in grades two through nine each had an assigned computer with teachers who had extensive training. The staff reported that interaction among students was a major positive consequence of having Logo in the classroom. Two conditions were important in this project: (a) each classroom had at least one computer for an entire year, (b) all the teachers volunteered for the project and took summer training without additional pay. Plans were made for a "magnet" school where students would have access to computers from the earliest grades.

Some of the most extensive and on-going research out of New York City has come from the Bank Street College model school which is part of the Bank Street College of Education. The focus has been on the kinds of interactions that occur among children using Logo. Researchers have been trying to determine if, and how, Logo enhances problem solving and planning skills (Papert et al., 1979) and how the use of microcomputers in the classroom may relate to other cognitive and social skills (Jewson and Pea, 1982). The Bank Street School for Children is committed to a child-centered approach to education and teachers are experts in creating "functional learning environments". Functional means the learning activities have a function or purpose from the point of view of the child with the teacher's assistance to make the tasks meaningful by demonstrating their significance in skill usage and in the adult world (Newman, 1984). After two years of observing and interviewing children and teachers in third and sixth grade classes, researchers found children showed very little planning in their Logo programming. Pea (1983) observed children designing programs while writing lines and watching the results on the screen in an interactive manner rather than pre-planning an activity through a well-defined goal. Their discovery learning did not include more conceptually challenging aspects of Logo. "Children were engaged in the Logo activity, but were not learning to program" (Newman, 1983, p. 6).

As a result of the work at Bank Street, the philosophy of the discovery-oriented, child-centered approach was questioned by the teachers. Without losing the intrinsic motivation of Logo, the teachers at Bank Street felt that goals had to be set and activities had to be formulated to effectively get ideas across to children. By guiding activities, but not imposing them, Logo programming can become functional for both teachers and children and can be included as part of childrens' schoolwork.

Research conducted by Hawkins (1983) indicates that the computer "subject" must have the same status as other curricular areas in terms of required knowledge so it will not be viewed as a supplementary activity. Childrens' perceptions of working together was to have fun or when something was particularly difficult and they needed information. The children at Bank Street knew the characteristics of good collaboration and disliked being assigned to collaborative work by the teacher.

However, children may desire solitary work when speed and efficiency are of primary importance and there is an over-emphasis on accountability (Newman, 1983; Hawkins, 1983). Computers have the potential for providing a context for productive collaboration among children, but the learning opportunities depend on the classroom environment.

From these early Logo projects used experimentally in mathematics classrooms in the United States, several generalizations emerge. Students enjoyed using Logo. They felt successful in doing relatively formal work in this context and were motivated by this success. The formalism of Logo was fairly natural. Logo allowed them to express ideas in their personal style, and they showed individuality and originality of expression (Feurzeig and Lukas, 1972).

The largest ongoing Logo research project, other than MIT, has been at the University of Edinburgh, Department of Artificial Intelligence (Papert et al., 1979). Researchers at Edinburgh have studied students' learning of mathematics and its relationship to Logo programming. Specifically, they looked at students' ability to do mathematics and to talk about their mathematics. The research was structured through instructional materials and standardized testing. The Edinburgh Logo researchers took the approach of reforming education rather than revolutionizing it (Howe, 1980). Their hope was to move Logo into normal classrooms and teach mathematics through programming (Ross, 1981). Edinburgh's approach was more teacher-directed, more structured than the MIT Logo research and focused on programs as models of mathematical processes. New materials and methods were reconciled with existing methods and materials because there was concern expressed that teachers and parents need a guarantee that students will acquire the same exit qualifications as they would have through more traditional teaching methods.

The Edinburgh project was designed to discover whether the ability of 11-13 year-old boys to do school mathematics, defined as creative use of analytic skills, and to talk about their mathematics was changed by exploring mathematical problems through programming. The study was undertaken for two years. During the first year, students were taught Logo programming through self-paced worksheets while the second year involved the use of programming to explore troublesome topics in mathematics. The mathematical understanding of less able children was improved, students had more positive attitudes about mathematics and were more willing to talk about mathematics (Howe, 1980).

Ross (1981) points out that programming problems get in the way of mathematical exploration. Therefore, the Edinburgh Logo project provided concept demonstrations of pre-written Logo procedures designed to give students some feeling of the mathematical topics. Ross's concern is whether an overcrowded curriculum can accommodate the time necessary to teach programming to a level of understanding and then go on to also teach mathematics.

Programming in Logo can distort a course towards what is programmable and away from what is mathematically important, but it is possible to increase student's understanding of particular topics in mathematics. However, Boulay (1980) found that anxieties about mathematics were difficult to change among student teachers. Boulay concluded that programming based mathematics projects should have short programs written by students and should deal with properties of mathematical processes under consideration. Reworking algorithms in programming notation is not of itself a useful activity for student teachers to undertake. Because student teachers were worried about spending too much time learning Logo, a second study focused on running pre-defined procedures and discussing the mathematics involved. The work on geometry included exploring angles, symmetry, and properties of regular polygons. The activities were highly structured and involved only a small amount of program construction by students. However, student teachers had to explain how and why an algorithm used by a computer program worked (Boulay and Howe, 1981). This shift of emphasis did not develop the understanding that comes from defining programs nor did it provide students with a sense of program ownership. Students who were about to graduate, however, improved in attitudes and made gains in mathematical performance.

The research discussed so far was chosen because the projects were begun in the late 1970's and have been sustained. As "Logo fever" moved through the country and world, many other projects were begun in public and private schools, but only a limited number of research studies have addressed some of the questions posed as a result of early observations and data collections.

Austin (1976) was concerned with the teachers of Logo and how well those teachers with little training in either mathematics or computer science would adapt to an environment in which the principle tool is the computer and the primary subject is mathematics. The teachers not only learned the specific materials presented, but were able to apply their knowledge to new problems. The teachers were less willing to try new ideas and approaches than children but proceeded more rapidly. They also tended to write long "linear" programs instead of using subprocedures. The mechanics of editing and using files was found to be difficult for teachers.

Reimer (1984) and Clements and Gullo (1984) addressed using Logo with younger children. Reimer's pilot study with sixteen kindergarten children found that the Logo programming experience had a statistically significant effect on readiness. The results of the study suggest that five-year-old kindergarten children in a Logo programming experience can show greater gains in several commonly taught curricular and developmental areas than children of the same age and grade level who do not have this experience. Clements investigated the effects of computer programming on the cognitive style, metacognitive abilties, cognitive development, and ability to describe directions of six-year-old children. In a comparison of CAI to Logo, the Logo group had significant pre- to posttest differences on Torrance tests of Creative Thinking on fluency, originality, and overall divergent thinking, while no significant differences were found for the CAI group. The Logo group decreased on the number of errors on the Matching Familiar Figures test, while the CAI group had no significant differences. A possible explanation is that CAI requires quick answers while Logo encourages thoughtful planning, reflection of the thinking processes and explicit analysis of errors in debugging.

The Logo programming group significantly outperformed the CAI group in ability to monitor and evaluate their own cognitive processes (metacognition). This may reflect the consistent feedback and awareness of problem and solution processes which allows for modification of Logo projects. The Logo group also scored significantly higher on describing directions, but no significant differences were found between Logo and CAI on cognitive development (classification and seriation).

Logo has potential for affecting mathematical learning because students have an opportunity to talk about mathematics. In "Talking Turtle" (1983), Papert considers the problem and then provides a solution:

> Half of our problem with mathematics teaching is because children don't communicate mathematically, talk about math and actually experience math problems...When you have used mathematical principles as a key to enjoyable physical activities your feeling for mathematics is likely to be warmer, more personal and more engaged (pp. 5,18).

People in the classroom teaching Logo are not computer programmers. Most teachers need not only learn the language of Logo, but also to learn how to implement Logo and create a Logo environment in the classroom (Riordan, 1982). "Knowing when and when not to intervene seems to be the secret of artful Logo teaching" (Moore, 1983, p. 14) Logo teachers are an integral part of the learning process and must help students see the connections between different situations (Dale, 1984).

Peterson (1984) issues a challenge to educators concerning the use of Logo:

> Is Logo really the "chess" of computer language, simple yet complex, the open door to geometry and mathematics, or is it an indulgence of its mathematical and computer-scientist founders, an elegant way to fill up a computer screen with pretty pictures and fool children and their teachers into thinking they've really accomplished something? (p.18)

Logo is not intended to be a labor saving device for the teacher. It requires careful management and time for planning meaningful activities for groups as well as individual students. Both knowledge of the subject and organized flexibility in scheduling are also required of teachers to produce a successful Logo experience in the classroom. Logo is demanding of the classroom teacher, but when small questions lead to big discoveries, the satisfaction for both students and teachers can be great.

Geometry

More time is spent teaching arithmetic than geometry in the elementary school because the need for learning arithmetic is more evident and there is a greater concern with basic arithmetic skills (Fielker, 1979). However, Lesh (1976) suggests, "what could be more relevant and interesting than activities dealing with the everyday visual experiences of children" (p. 212). Results from the National Assessment of Educational Progress (Carpenter, Coburn, Reys, and Wilson, 1975) indicate that children had difficulty applying geometric concepts, especially concepts of perimeter and area.

One of the difficulties faced when considering the mathematical basis for elementary school geometry is the lack of a theoretical or practical consensus as to what geometric concepts should be taught in the elementary school (Robinson, 1976). Spatial concepts and properties of geometric figures are the main topics taught today in an intuitive, informal, and experimental approach (Julian, 1972). However, Lesh (1976) points out that elementary textbook series appear to be changing from a "traditional" to a "transformational" approach to the teaching of geometry.

Whatever topics are included in the elementary school curriculum, a goal in teaching geometry should be to develop geometry as part of ongoing mathematical activity rather than a set of static and isolated facts. Geometric topics are often used as a break from usual classroom activities. As a result, they are taught apart from other mathematical concepts and often no connection is made between geometry and other ideas in the book.

A variety of experiences and strategies to operate on children's knowledge of geometry is essential to facilitate the understanding of geometric concepts and how to apply them in the world. As the basic concepts of geometry are found in a child's world, we need to point out geometric shapes in our surroundings and apply geometry in practical situations. However, when children study geometry from textbooks they are only using abstract models of the real world.

The world of geometry should be presented to children with concrete representations through manipulatives. Copeland (1979) states that just looking at geometric shapes and being told what they are is not enough; children need to physically explore shapes as a basis for the necessary space relation abstractions. Yakimanskaya's belief is that "the study of geometric material should be active, concrete and visual from beginning to end" (1978, p. 152). Chertverukhin (1978) also supports the need for a concrete approach to geometry, "A study of geometric material is useful only when it is accompanied by a concrete conception of the properties of geometric figures in space" (p. 8). Thus, instruction in geometry should be approached concretely and intuitively through activities designed to investigate mathematical ideas in geometry. With informal, concrete and intuitive activities in geometry, students can begin to recognize and state their own definitions for geometric shapes rather than use pre-defined definitions (Lesh, 1976).

The use of visual explanations in textbooks is the usual geometric exposure given to children. Therefore, if the visual approach dominates geometry instruction, methods should be used that will also increase spatial visualization skills. When introducing a geometric concept Yakimanskaya (1978) suggests analyzing the spatial relationships inherent in the figure, rather than isolating fundamental essential properties of a figure.

Besides the fact that spatial visualization is necessary in our daily life, research has shown correlations between success in geometry and spatial skills (Slaby, 1984; Sherman, 1979). Since this correlation exists between geometry and spatial skills, we must wonder whether teaching geometric concepts to children increase their spatial skills or must we use other methods to increase spatial visualization skills so performance in geometry can be successful? As Martin (1976) asks, "Should instruction be aimed at developing the child's concept of space or the child's concept of geometry?" (p. 3).

Martin (1976) believes that:

> Instruction should be aimed at assisting the child develop a well-organized concept of space. This does not mean that there would not be many geometrical concepts in the curriculum. But the concepts would be those necessary for achieving the primary objective (p. 3).

More information is needed about how children think about geometric ideas. By examining the evolution of spatial concepts we may understand the methods children use in making mathematical judgments involving geometry as well as arithmetic concepts. Lesh (1976) suggests looking at the sequencing of geometric concepts in the light of Piagetian theory and to relate observations and findings to other mathematical learning. Since children usually have not received much explicit instruction on geometric concepts, it may be relatively easy to study the "natural" development of spatial concepts while controlling the effects of specific prior training.

Many geometric concepts are closely related to the arithmetic concepts of the elementary school curriculum. Lesh (1976) has looked at instructional models used to introduce number concepts and the geometric concepts that are assumed children understand. Models used to illustrate and teach arithmetic and number concepts such as the number line, fraction bars, Cuisenaire rods, arrays of counters and diagrams all have an understanding of certain spatial concepts inherent in them. Misunderstanding the models may indicate lack of understanding of the spatial concepts. Since spatial experiences seem to be the dominant manner in which children interact with concrete materials, the extent to which geometric experiences could facilitate or hinder the acquisition of arithmetic concepts should be investigated. For instance, Lesh (1976) suggests that a better understanding of area concepts could contribute to understanding of rational numbers.

Geometry is often not considered important in its own right by most elementary teachers. The two most common reasons elementary teachers gave for teaching geometry were that many topics were fun and they were preparing children for high school geometry. Lesh (1976) suggests that what elementary teachers consider to be fun in geometry can become important topics in goemetry, therefore important topics can also be fun.

Lesh (1976) suggests a developmental transformational approach to the teaching of geometry in both the elementary and secondary schools. Piaget has stated that children develop from topological to projective to Euclidean spatial concepts (Piaget and Inhelder, 1967). Piaget's "topological" concepts are those involving properties that are within a particular point of view independent of connections with other states. "Projective" concepts are those involving properties which become important when various points of view are connected by a system of transformations. "Euclidean" concepts are those in which the observer becomes one of the transformed objects, that is, all objects are located with respect to fixed points of reference. Therefore, space becomes Euclidean when topological space is structured by reference elements. Euclidean geometry is a more restrictive system than projective geometry, which is more restrictive than topology. However, not all topological and projective concepts are mastered before any Euclidean concepts, since some topological concepts develop relatively late (Lesh, 1976).

Lesh suggests using the transformational approach to teaching geometry as a model to explore the sequential development of children's mathematical concepts in geometry. Teaching transformations in geometry has typically focused on the basic rigid motions of slides, flips, and turns in the elementary school. Children tend to focus on the end product rather than the process since they do not think of transformations as continuous "motions" connecting two fixed states. In the same manner that children are often able to solve problems while not being able to explain the steps that were taken to reach the solution, they are not explicitly aware of the system of operations used in transformations. Transformation tasks are not mastered until formal operational thinking begins to evolve, therefore activities to intuitively investigate transformations are necessary (Lesh, 1976).

Turtle Geometry

Using the Turtle graphics mode of Logo makes it possible for children to engage in abstract thinking by relating new ideas to familiar concrete experiences. Rather than teaching geometric ideas through abstractions such as points, lines and coordinate; Logo encourages relating geometric concepts to body movements (Carter, 1983).

To develop Logo constructions, students need some geometric concepts, and likewise, geometry understanding is enhanced by developing Logo procedures. Although Moore (1983) has written extensively on geometry through Logo, she recognizes the need for developing geometric concepts with the use of manipulatives and related experiences in other environments besides Logo.

Work with Turtle geometry provides a conceptual framework for such aspects of mathematics as the relation between shapes and angles, coordinate systems, positive and negative numbers, use of variables, symmetry, congruence, transformational geometry, and similarity. Papert, Watt, di Sessa, and Weir (1979) define the "subject matter" of Turtle geometry in the Brookline Project to be the following:

1. Use of numbers to measure lengths and angles. Formal and intuitive understanding of special angles such as 90°, 360° and 180°.

2. Group properties of numbers such as FORWARD 10, FORWARD 10 is equivalent to FORWARD 20 and FORWARD -10 is the inverse of FORWARD 10.

3. Relationships involving the use of angles to define polygons and other regular figures.

4. Similarity and symmetry.

5. Cartesian coordinate system.

6. Non-cartesian coordinate systems such as ad hoc coordinate systems and polar coordinates.

7. Concept of state and state transparent procedures.

8. Curves as made up of "infinitesimal" line segments developed through the algorithm for a circle.

9. Combining movements.

10. Total Turtle Trip Theorem.

Euclidean geometry uses the static concept of a point while Turtle geometry uses the dynamic concept of a Turtle. The authors of the Brookline Project view this as a more direct and intuitive access to formal geometry. In Turtle geometry, the idea of an angle is an action, an amount of turning, something that can be done with the body or a mental image of the body. The results of the Brookline Project indicate that it is easier to learn Logo and Turtle geometry together than to learn either separately. Students did not distinguish between learning to program in Logo and learning Turtle geometry (Papert et al., 1979).

The properties of numbers within different roles is discovered as a result of the use of numbers as input to Turtle commands. The input to FORWARD (FD) determines the size of a figure, while the input to RIGHT (RT) determines the shape. The inputs to FD are mainly quantitative and a continuous function while the inputs to RT are largely qualitative and a discontinuous function.

Students' use of mathematical operations as the additive property of numbers is demonstrated through combining Turtle commands such as combining FD 20, FD 20 into FD 40 or RT 30, RT 10 into RT 40. The use of inverses or negative operations is demonstrated by using BACK (BK) as an inverse to FD or LEFT (LT) as an inverse to RT. Linear operations are combined more easily by students than are angular numbers.

Students soon learn that RT 180 reverses the direction of the Turtle and RT 360 completes a rotation so the Turtle still faces the same direction. Rotational numbers have a modularity with respect to a "complete rotation" of 360°. As rotations are combined, the total rotation increases until it is 360° and then after 360° the orientation of the Turtle is the same as if it had been turned 360° less. This modularity demonstrates that the inverse of RT 90 is LT 90, but it is also RT 270 or LT 450; thus, particular angular rotations can have more than one inverse. In the Brookline Project (Papert et al., 1979) some students never made use of these while others used equivalence with ease.

Students quickly discovered the "Total Trip Theorem", which states "any time the Turtle has completed a series of steps and returned to its exact starting position and heading, it has rotated through 360° or an integer multiple of 360°" (Papert et al., 1979, p. 5.55). Focusing on the "special angles" such as 60° and 90° can be an important step leading to the understanding of the significance of 360° and the Total Trip Theorem. Billstein (1982) described how students generalized from the "special" 60° angles needed to draw an equilateral triangle to proving the sum of the interior angles of any triangle is 180° by using the Total Trip Theorem.

In addition to the Total Trip Theorem, two other theorems are important in Turtle geometry: (a) the Logo Symmetry Theorem and (b) the Logo Similarity Theorem. The idea of symmetry is one which most students encounter as part of the Logo experience. The Logo Symmetry Theorem states "if all the right and left commands in a sequence of Turtle commands are reversed, without changing any of the commands in the sequence, the resulting design will be a mirror image of the original design" (Papert et al., 1979, p. 5.70). Most students used reversing LT and RT for symmetrical designs while others used an "implied axis of symmetry" and worked across from one side rather than starting from the middle. In addition, many students used rotational symmetry.

The Logo Similarity Theorem states that "a proportional change in all the FD and BK steps in a sequence of Turtle commands, while holding the angles constant, will change the size, but maintain the shape of the figure drawn by the commands" (Papert et al., 1979, p. 5.66). Few students understood this principle in its full generality, but their desire to create similar designs allowed them to use it in a simpler form in their Logo projects and often provided the first use of variables.

Students can develop an intuitive feeling for differential geometry as they discover that specific consequences of one particular Turtle action, dependent on a specific position and heading, can be used to predict a more distant effect, achieved by a sequence of such actions. While students work in Turtle geometry, they become aware of the local geometry of the Turtle and take into account the Turtle's position and heading. Several structures are used to organize two dimensional space in Turtle geometry: (a) Turtle coordinates, (b) domain specific coordinate systems, (c) standard cartesian coordinates, and (d) various types of polar or angular coordinates (Papert et al., 1979).

Logo is designed to simplify the use of cartesian coordinates for specific applications. Students can output the x and y coordinates of wherever the turtle happens to be or move the Turtle directly to a point on the screen by giving the x and y coordinates. Many students find it easier to move the Turtle around the display screen in horizontal and vertical steps than to accurately estimate the distance and direction to which the Turtle is moved. A student who uses this approach is not using "coordinates", but in a sense "drawing a mental grid" and creating a structure in the mind. Polar coordinates can be useful in Logo projects in which the Turtle always returns to a fixed point, but changes its orientation, to carry out a sequence of actions. Students who make use of this particular approach develop an intuitive understanding that may later help them understand a more formal use of polar coordinates (Papert et al., 1979).

Greenleaf (1984) describes a graphics language and system called Euclid which subscribes to the Logo philosophy of the computer's role in the classroom for learning to program rather than programmed learning. The subject matter of Euclid is traditional Euclidean and is intended for use in the plane geometry classroom. Euclid builds on Logo's success in primitive commands that have visual output and has a framework for creating higher-order commands or procedures similar to Logo.

Many approaches and topics are applicable to the teaching of geometry in the elementary school. The research and ideas presented here were limited in scope to develop the relationship among geometry, Logo, and spatial visualization.

Spatial Visualization

There are at least two distinct spatial abilities: (a) spatial visualization and (b) spatial orientation. McGee (1979) defines spatial visualization as the ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli. This process involves recognition, retention, and recall of a configuration in which three-dimensional objects are rotated, reflected, or translated. Spatial orientation involves (a) the comprehension of the arrangement of elements within a visual stimulus pattern, (b) the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented, and (c) the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem. Spatial visualization ability requires that a figure be mentally restructured into components for manipulation while the whole figure is manipulated in spatial orientation.

The relationship of spatial visualization ability to mathematics achievement has frequently been implied in research studies. However, Fennema (1975) claims that there is too little information about the relationship between spatial ability and mathematics to draw a final conclusion. Early work by Very (1967) claimed that research on spatial ability had failed to produce any significant correlations of this factor with any facet of mathematics performance. However, several studies since then have indicated that a correlation does exist between spatial visualization and mathematics achievement, especially for performance in geometry.

Battista's (1979) study supports the relationship between mathematics achievement and spatial ability with the assumption that problem solving is important to mathematics achievement and that right hemisphere processing is spatial. These findings suggest that right hemisphere processing is an important factor in activity-oriented geometry courses. Moses (1980), using three age groups--elementary, junior high, and university pre-service elementary teachers--studied the relationship between visual thinking tasks and problem-solving performance. The results showed a significant correlation between problem-solving performance and degree of visuality. One additional finding of this study was that instruction in visual thinking tasks affected spatial ability and reasoning ability, but did not affect problem solving performance or degree of visuality.

Sherman (1979) shows a correlation between spatial visualization and mathematics achievement. Mathematical problem solving was predicted by 9th grade variables of mathematics achievement and spatial visualization. Fennema (1975) deducts that if spatial visualization items are geometrical in character and if mathematical thought involves geometrical ideas, then spatial visualization and mathematics are intertwined. The relationship between mathematics and spatial visualization is further supported when the developmental trend of spatial ability is considered, as well as the fact that tests of spatial visualization contain many of the same elements contained in mathematics tests.

The issue of sex-related differences in spatial visualization ability and whether experiences will affect this difference is being reported more frequently in the literature. Benbow and Stanley (1980) claim that it is the greater male ability in spatial tasks that explains their research findings of sex differences in mathematics achievement. Badger (1981) discusses some of the pros and cons proposed for a possible genetic sex linkage for spatial ability. Most of the discussion has evolved around the difference in mean levels of performance on spatial tasks for the two sexes. Some of the proposals explaining the sex difference are (a) that spatial ability is carried by a recessive gene on the X chromosome and when it is present it manifests itself in greater proportions in male behavior, (b) the different levels of androgen and estrogen between the sexes may cause some of the observed differences in spatial ability, and (c) the differential rate of brain lateralization between the sexes is responsible for spatial differences.

There is a tendency in the literature to refer to any spatial test as a measure of spatial ability, therefore the inconsistent results that are reported on sex differences are often a result of the definition of spatial ability. As Clements (1978) points out, "No definition of spatial ability is universally accepted by educators and psychologists, although many attempts have been made to define it" (p. 58). McGee (1979) reports that male superiority on tasks requiring spatial visualization and orientation is among the most persistent of individual differences; however those differences do not reliably appear until puberty. Vanderberg and Kuse (1979) suggests a parallel between the sex difference in perceptual-cognitive tasks and sexual hormone development because the difference does not reliably appear until age 9 or 10, peaks at about 18 years of age, and then slowly declines again, paralleling hormone development. It does appear that the developmental course of spatial ability is affected more by maturation and possible age-related hormone levels than are other cognitive abilities.

Sex differences have been most consistently found on tasks involving spatial visualization, although discovery of sex differences in visual-spatial skills is highly dependent on the type of visual-spatial measurement used and personal experience brought to the testing situation. The problem of defining spatial ability has been approached through the development and use of criteria for classifying spatial tasks. This is demonstrated in work by Wattanawaha and Clements (1982) who report similar findings when a variety of spatial tasks were given to groups of adolescent boys and girls. The results indicated that (a) not all spatial tests or items on spatial tests show significant differences between the sexes, but differences that do occur are in favor of males and (b) the tests or items that most consistently differentiate between the sexes are three-dimensional tasks.

Fennema and Sherman (1977) feel that the sex-related differences are strongly influenced by learning and environmental factors. Fennema (1975) reported no significant sex difference in either mathematics achievement or spatial visualization task performance in subjects 4-8 years of age, but claims a sex-realted difference in both mathematics achievement and spatial visualization tasks between upper elementary and high school. Fennema and Sherman (1978) found no sex-related differences in spatial visualization among subjects in grades 6-8. Their correlational study indicated a relationship between spatial visualization and mathematics achievement that is similar for males and females.

Guay and McDaniel (1977) found that among elementary school children, high mathematics achievers have greater spatial ability than low achievers. This supports the notion that the relationship between mathematical and spatial thinking among elementary school children appeared to exist for low level as well as high level spatial abilities. Low-level abilities require the visualization of two-dimensional configurations, but no mental transformations of those visual images, while high-level abilities require the visualization of three-dimensional configurations and the mental manipulations of these visual images. Considering high and low level spatial tasks; males had greater high level spatial ability than females, while males and females had similar low level spatial ability. The observations in this study are consistent with reviews indicating sex differences favoring males, but inconsistent with reviews suggesting sex differences are evident only during early adolescence. McDaniel and Guay (1977) administered four spatial tasks and found high achievers to have greater spatial ability than low achievers.

Moses (1980) found that on each spatial test at every grade level males performed better than females. The gap between males and females gets noticeably wider from fifth to ninth grade to university students on spatial visualization tasks. The author concludes that the notion the typical female cannot perform as well as the typical male appears to be incorrect because, given the opportunity to develop certain spatial skills, females can succeed.

Sherman (1980) found that in predicting problem solving, spatial visualization was the second highest predictor and a stronger predictor for females than for males. Confidence in learning mathematics also correlated with spatial visualization. In another study, Sherman (1979) found that spatial visualization was a significantly better predictor of geometry for girls than for boys. This indicates that spatial visualization contributed more uniquely to the prediction of mathematics performance for females than for males.

Moses (1982) suggests that spatial visualization is an important element in problem solving. Wheatley (1977) supports the importance of spatial activities to problem solving through greater use of the right hemisphere of the brain. Superior thinking requires the efficient use of two fully developed hemispheres and fully developed interhemispheric communication systems (Brooks, 1978). An optimum learning environment contains components that utilize both hemispheres. This can be accomplished by using concrete materials and hands-on experiences that contain both spatial components and analytical reasoning opportunities. This leaves the learner free to use whichever mode is desired and is the more efficient.

Richardson and Krutestski (Lean and Clements, 1981) both have partitioned students into three categories with respect to the visual-verbal dimension. In the first group are the visualizers, or geometric types, who prefer visual imagery or a pictorial mode in solving problems. The second group consists of verbalizers, or analytic types, who prefer the verbal-logical mode to visual or pictorial representations. In the third group, we find the mixers, or the harmonic types, who use both verbal-logical and visual-pictorial modes freely without preference. For this third group, it is theorized that the left hemisphere utilizes its ability to tap the right hemisphere's visual-spatial knowledge about a stimulus. However, this does not mean that all students need visualization skills to be good problem solvers. Clements (1982) found that low performers benefited by visualization of a problem, but high performers tended to experience interference and preferred an analytic, verbal method. But by supplying students with spatial skills, we can increase the probability of success for the student who has found no success in an analytic mode of instruction and needs a viable alternative.

Webb (1979) reported that pictorial representation accounted for a sizable proportion of the variance in scores on a problem-solving inventory and students who drew and used pictures tended to obtain higher scores. Moses (1979) reported significant correlations between problem-solving performance and degree of spatial visuality while noting that instruction in visual thinking tasks affected spatial ability and reasoning ability. Refined spatial abilities can improve children's problem solving abilities in a variety of situations, while the process of solving everyday problems can, in turn, help children overcome spatial ability difficulties (Yakimanskaya, 1978).

Yakimanskaya's work (1978) and other Soviet literature on spatial abilities demonstrates the concern they have for developing spatial concepts and imagery under the influence of school instruction rather than waiting for a natural course of spatial development. Chetverukhin (1978) stated that the development of spatial imagery is one of the important tasks of general education. It is suggested to Soviet teachers that they provide special exercises for developing spatial imagery which are carefully planned and organized while teaching geometric concepts.

Although Badger (1981) states that performance on spatial tasks appears to be resistant to environmental influences, the work of Moses (1979, 1980) clearly indicates that spatial ability is not innate and can be improved. This improvement is most noticeable with female students who have had very few spatial experiences and can profit considerably from exposure to spatial activities. There is some uncertainty among researchers (Smith and Schroeder, 1979; Smith and Litman, 1979) as to when this instruction should occur to be optimally beneficial to the enhancement of spatial abilities.

It is claimed

> . . . that even though the existence of many sex-related differences is currently being challenged, the evidence is still persuasive that in many cultures male superiority on tasks that require spatial visualization is evident beginning during adolescence (Fennema, 1982, p. 3).

Wattanawaha and Clements (1982) voice agreement after a review of research of spatial ability. They feel there can be no dispute that in most cultures sex-related differences, favoring males, appear during adolescence on many tasks that require so-called spatial skills. Methods for developing spatial skills need to be devised and implemented into the elementary school curriculum before differences appear.

Bishop (1980), upon reviewing research on the learner's environment, concluded that "it is likely that teaching approaches are an important determinant of spatial abilities" (p. 263). Cross-cultural studies (Mitchelmore, 1976) showed differences in teaching-produced differences in three-dimensional drawing ability, with informal approaches to geometry and the use of manipulative materials making a difference. Manipulative materials in primary schools helped children perform better on spatial ability tests (Bishop, 1973) and the choosing of more space-related courses points to higher spatial scores (Sherman, 1977). While working with students in the middle grades, Lappan and Winter (1982) had success in increasing students' ability to visualize three-dimensional objects and to record two-dimensional views of these objects. At the same time, the students expressed enjoyment with participating in the activities. Lappan and Winter describe in detail the sequence of activities they have developed and used with middle school students. Spatial thinking is one of the areas of cognitive deficiency that Feuerstein (1980) believes can be enhanced with mediated experiences. The educator's role is to provide intervention between the student and the environment to transform, reorder and organize stimuli. Mitchelmore (1976) states there is still a need for "the development of practical geometrical and spatial teaching programs and for their experimental testing" (p. 172).

How much responsibility should mathematics teachers take for the training and teaching of spatial abilities? Bishop (1980) feels that it should be every teacher's responsibility to use spatial activities which will generalize easily into the mathematics classroom context.

Locus of Control

The concept of internal and external locus of control has received a great deal of attention during the last two decades and is a popular topic in current personality research. However, there are problems with the definition and focus of the internal/external construct ranging from beliefs about contingencies of reinforcement to the "control" aspects of the construct. Even though several clear statements of locus of control have been made by Rotter (1966) and others, it is still a cloudy subject that depends upon interpretation of the individual investigator or theorist (Strickland, 1977). Lefcourt (1976) offers the following general definition:

> As a general principle, internal control refers to the perception of positive and/or negative events as being a consequence of one's own actions and thereby under personal control; external control refers to the perception of positive and/or negative events as being unrelated to one's own behaviors in certain situations and therefore beyond personal control (p. 207).

Individuals have been found to differ in the degree to which they believe that they influence outcomes of situations. The same reinforcement in a given situation may be perceived by one individual as within her/his control and by another as outside her/his influence (Crandall, Katkovsky, and Crandall, 1965; Rotter, 1966; Lefcourt, 1976).

One of the major conceptions that bears a relationship to the belief in internal versus external control of reinforcements is that of the need for achievement (Rotter, 1966). Crandall et al. (1965) suggest that people who are high on the need for achievement have some belief in their own ability or skill to determine the outcome of their efforts. Weiner and Kukla (1970) found that individuals high in resultant achievement motivation ascribe success to high ability (internal) and failure to bad luck (external), while individuals low in achievement needs attribute success to good luck (external) and failure to lack of ability (internal).

Although little relationship has been found between intelligence and locus of control measures, relationships have been found between internal perceptions and measures of achievement performance (Rotter, 1966; Lefcourt, 1976; Crandall et al., 1965; McGhee and Crandall, 1968; Messer, 1972; Nowicki and Strickland, 1973). Children with an internal locus of control achieved higher school grades and a positive relationship was found between locus of control and achievement test scores. Gozali, Cleary, Walster, and Gozali (1973) explained this relationship in a study where they found that internals use time in a manner more appropriate to the test-taking situations than do externals.

In most of the studies there were sex differences. Messer (1972) explained the fact that the internal score for failure (I-) was a better predictor for grades for girls while the internal score for success (I+) predicted better for boys by relating to culturally determined origins. The independence of the success and failure subscales implies that assuming responsibility for successful intellectual academic experiences may be different from assuming responsibility for failure experiences. Therefore, girls take the blame for their failures and tie them closely to academic performance, while boys take credit for successes and relate them to school success. A girl is considered too assertive when she brags about successes and blames others for failures, while it is permissible for a boy to assume the masculine role and claim credit for success. The total internal score (I) on the Crandall Intellectual

Achievement Responsibility Questionnaire (IAR) was found to be slightly higher for girls than for boys, especially from grade 6 upward. There was no significant change in internality in general (total I) from third grade to fifth grade or from sixth grade to twelfth grade for either of the sexes nor for boys and girls together. However, between the tenth and twelfth grade, boys showed a significant decrease in the I+ subscale scores. Crandall et al. (1965) suggest two possible reasons for this decrease in I+: (a) it may be that the immenence of graduation and thinking about employment provoked uncertainties in boys about future success or (b) it may be that older boys have developed an increased sense of modesty that caused them to respond to the questionnaire as though they were not responsible for their intellectual academic good fortune. Girls, however, did not show a significant increase in their I+ score, but did significantly increase their internality for negative events. The first change took place between third and fourth grade and by the sixth grade the girls assumed a level of responsibility for negative events that was slightly greater than what the boys finally achieved in twelfth grade. In addition, girls I-scores continued to increase during junior and senior high school.

Different teaching strategies will result in varying effects on students as a result of their locus of control according to research results found by Parent, Forward, Canter, and Mohling (1975). Their results showed that students high on internal locus of control performed better under low discipline conditions, while high external control students performed better under high teacher discipline conditions. Smith (1973) investigated the locus of control variable in connection with CAI and found that the impact of CAI did not produce feelings of less control over the environment.

Locus of control appears to be a developmental construct with students' responses becoming more internal with age. However, this may not be true if children have arrived at an external view as a defense against failure. This is where appropriate instruction in school classrooms plays a crucial role. Nowicki and Strickland (1973) found that internal/external beliefs can be modified and appear to be flexible in response to specific events in one's life. Buriel (1981) suggested that teachers are instrumental in the development of children's beliefs about the cause of behavioral outcomes and, therefore, teachers' socialization practices are important. Stipek and Weisz (1981) found that children with internal control involve teachers more in their learning situations and seek more information than do children with external control. In addition, many of the learning paradigms utilized in teaching are under the teacher's control for reinforcement for success or failure. Stallings (1975) found that children in learning situations with a high rate of drill and practice had higher reading and mathematics scores, but tended to accept responsibility for failure while not for success. It is at this point in the instructional design that a teacher must make major decisions concerning initial achievement results versus long term education and personal benefits for the students. All of these studies put the classroom teacher in a crucial role for affecting the locus of control of children since the effect of the reinforcement depends on whether or not a person perceives a causal relationship between his own behavior and the reward.

Is superior achievement the cause or the result of a child's perceived locus of control? Messer (1972) concludes it is quite possible that both are true because:

> A feeling of internal control with regard to school work probably leads to greater achievement. At the same time, a child who achieves well, or who has higher intelligence, is likely to develop more readily a feeling of being in control of his own academic destiny (p. 1461).

Because internal locus of control is directly related to achievement behavior, students' performance in achievement situations can be improved by moving them toward more internal perceptions. An internal score on the Nowicki-Strickland Locus of Control Scale for Children (1973) was significantly related to academic competence and social maturity and appeared to be a correlate of independent, striving, self-motivated behavior.

Both Rotter (1966) and Strickland (1977) reviewed studies that provide us with generalized findings for descriptions of internal/external behaviors:

1. Locus of control appears to be related to conforming and compliant behavior with internals maintaining individual judgment and resisting influence and externals succumbing to pressure from others. However, if the internally oriented person perceives it is to his advantage to conform, he may do so without yielding any of his control.

2. Internals depend on their own abilities and interpretation of task demands while externals respond to social influence.

3. Internals work harder at intellectual performance tasks and can delay immediate gratification.

4. Internals prefer to rely on their own efforts while externals may need more initial structure and support from others.

5. Internals seem less threatened by persons who are different from them and are more tolerant of others.

6. Internals attempt to take responsibility for their lives and change uncomfortable and aversive situations taking steps to improve environmental conditions. Externals may be more concerned with control on individuals exerted by institutional pressures.

7. Internals are more willing to take risks to test their abilities. Externals put themselves in low risk situations so they can easily attain goals or in extremely high risk situations so failure is not under their control.

8. Internals are more alert to those aspects of the environment that provide useful information for future behavior.

9. Internals place greater value on skill or achievement reinforcements and are generally more concerned with their ability.

Does this mean internal is all good and external all bad? Strickland (1977) points out that while internals are achieving and independent, they may also be arrogant and manipulative. At the same time externals are described as defensive and low risk takers, they might be realistic and able to adjust to conflicting demands. However, internals seem to be able to take advantage of situations to improve task performance and are better at engaging in goal-directed behavior.

The locus of control construct as measured by the Crandall Intellectual Achievement Responsibility Questionnaire has been used in studies of learned helplessness (Dweck, 1975). It was found that "helpless" children, characterized by expectation of failure took less responsibility for outcomes of their behavior and tended to place less emphasis on the role of effort in determining success and failure than did children who persisted in the face of failure. The total internal score for helpless subjects was significantly lower than persistent subjects. Following a training period, children who were taught to attribute failure during training to insufficient effort were able to persist after failure in the test situation. Chapin and Dyck (1976) found that the impact of attribution retraining on persistence depends on the way success and failure experiences are presented. As a result of their study, they concluded that errorless procedures were detrimental and that occasional failure teaches the individual how to cope while attributing failure to lack of effort rather than to lack of ability.

Dweck and Repucci (1973) saw children attributing lack of ability to the outcome of their actions, taking little responsibility while giving up easily following exposure to an insoluble task. Following failure, those children most likely to give up in the face of failure when compared to the more perservering subjects (a) took less personal responsibility for the successes and failures with which they met and (b) to the extent that they did take responsibility tended to attribute the outcomes of their behavior to ability rather than to effort. In addition, Dweck and Bush (1976) report girls' greater tendency to avoid situations in which failure in likely and to show decreased achievement strivings under failure or evaluative pressure.

Another interesting finding from Dweck and Bush (1976) is that children of each sex responded to feedback from different agents in different ways, both in the way they interpreted that feedback and how it affected their performance. Girls showed rapid improvement in performance with a peer evaluator, but little improvement following failure feedback from an adult. Boys, on the other hand, showed no improvement over the failure trials when the agent of evaluation was a peer, but showed immediate improvement in performance when the feedback was delivered by an adult evaluator.

Locus of control clearly fits within an attributional framework and is one of the dimensions of attribution theory. "The internal/external construct relates to whether or not the individual perceives that he possesses power over what happens to him" (Lefcourt, 1976, p. 207). Attribution Theory refers to why an event occurs or to the allocation of responsibility for an action. It is the process by which an individual interprets events as being caused by a particular part of the environment. There are four major perceived causes of success and failure at achievement tasks: ability, effort, task difficulty, and luck (Weiner, 1974). These four perceived causes can be comprised within two causal dimensions: (a) locus of control (internal/external) and (b) stability (stable/unstable). Locus of control influences the affective response to success and failure while causal stability influences expectancy of success. Ability and task difficulty are stable and relatively unchanging over time while effort and luck may increase or decrease from situation to situation. On the locus of control construct, ability and effort are internal while task difficulty and luck are not within personal control and are, therefore, external. Looking at both dimensions, ability is both internal and stable, effort is internal but stable, task difficulty is external and stable, while luck is external but unstable.

Like locus of control, causal attribution has a major role in the nature of the learning process and studies have shown positive results for changing causal attributions. These changes came about by providing tasks that were suitable to the person's own ability which provided opportunities for success.

As a result of the research reported here, it can be concluded that locus of control is not a "trait" variable, but rather there are shifts in locus of control as a result of the situations encountered.

Summary

As microcomputers have become more accessible to schools in the 1980's, there has been a proliferation of ideas and suggestions as to how they should be used in the classroom. Some of the existing literature on the issues of computers in education and the access and use of microcomputers in the schools have been reviewed, along with the related topics of computer equity, computer assisted instruction and Logo. Most of the articles reviewed indicated a need for more research in these areas.

In addition, the review of literature included geometry and spatial visualization and the correlation that exists between the two. Supportive literature was also found for the importance of locus of control in the learning environment.

CHAPTER III

DESIGN OF THE STUDY

This study compared the effects of the supplementary use of microcomputers in the instruction of geometric concepts using two different modes (Logo and Computer Assisted Instruction). Traditional textbook materials supplemented with manipulatives were used as the primary instructional materials for the teaching of geometric concepts.

Subjects

The subjects were forty-two sixth grade students from two self-contained classrooms (Classroom R and Classroom F) enrolled at an elementary school in a western university city of approximately 26,000 residents during the 1983-84 academic year. The city is along the front range of the Rocky Mountains and the university is a major employer. The elementary school in the study is located in a stable area with a primarily middle to upper middle class population.

There were a total of twenty-one females and twenty-one males in the study with twenty students (eleven females and nine males) from Classroom R and twenty-two students (ten females and twelve males) from Classroom F. The students in Classroom R had some significant instruction in BASIC programming previous to the study during the fall semester while the students in Classroom F had little exposure to or use of microcomputers in the school curriculum. Two Apple microcomputer systems were located in Classroom R during the fall semester for the students' use. The teacher in Classroom R was an experienced female and had previously used microcomputers in the classroom while the teacher in Classroom F was a first-year male teacher using microcomputers for the first time.

Procedures

Three groups were involved in the study. All groups used the same traditional textbook materials, manipulatives, and learning centers for instruction on geometric concepts. The daily mathematics instruction was conducted primarily by the regular classroom teachers for six weeks. The investigator of the study served as a consultant and worked with the teachers in planning the curriculum and providing materials.

All students in the study used the 1983 Holt Mathematics series textbook materials during their daily mathematics class period, which averaged forty-five minutes. Because of scheduling concerns the mathematics class periods ranged from thirty to sixty minutes depending on the particular day's schedule for each of the classrooms' special activities, such as art, music, and physical education. All mathematics class time was before lunchtime and both classrooms had approximately equal amounts of instructional class time. A weekly list of the topics covered and the materials used appears in Appendix A.

Three groups were involved in the investigation consisting of two treatment groups and a control group. Experimental Group 1, E_1, had supplementary work using computer assisted instruction covering the geometric concepts being studied in their mathematics classes. Students in Experimental Group 2, E_2, were introduced to programming in the Logo computer language while the Control Group, C, had access to the microcomputer, but the software used did not consist of any geometric topics. The geometry unit continued for six weeks at the beginning of spring semester while the computer time extended for approximately eight weeks in order to provide each student with at least nineteen scheduled computer hours. Students were scheduled to work on the computer at various times throughout the day. If absences did occur, students were encouraged to use the make-up time provided each day for their group. However, it was impossible to maintain stringent control to absolutely ensure that all students spent the same number of contact hours with the microcomputer or that the time spent was with equal task attentiveness. Since each student had her/his own booklet and met with her/his group on a weekly basis, there was a sense of ownership that minimized the amount of interaction and sharing between groups.

The two classroom teachers and the investigator jointly planned the topics for the geometry unit. All the learning centers and manipulatives chosen were a result of planning sessions held weekly. Before the study commenced, the investigator and teachers reviewed and chose the software to be used in the computer assisted and control groups. All three of the educators involved were available to all the students for assistance, although the students tended to rely on the person meeting with their group.

During the first week, students worked individually at the computers for twenty minute periods. It was determined at that time that some students would benefit by interacting with a partner. At the same time all students would be getting more time on the computer. Therefore, for the next five weeks students worked in pairs for twenty-minute periods. During the final two weeks, the time period was extended to thirty minutes as students seemed to need more uninterrupted time as they became more comfortable with their work. This was especially true for E_1 and E_2. Adjustments were made for conflicting pairs as they arose, so some students worked together with the same partner for the duration of the study while others changed partners. Partner changes were more necessary with E_2, the Logo Group, where more cooperation and interaction were needed to accomplish the assignments.

Each of the three groups met as a group for one-half hour each Wednesday morning to receive information and instruction on the computer assignment for the next week. E_1 met with the teacher of Classroom R, E_2 met with the investigator of the study, and C met with the teacher of Classroom F. During the course of instruction on the geometric concepts in the regular mathematics class, the CAI (E_1) group used tutorial, drill and practice, educational gaming, and simulation software that was closely alligned with the topics covered in their mathematics class period (see Appendix A). Students in the E_1 group were each given a booklet containing information sheets with directions for using each piece of software and questions to be answered while using the software. The booklets were constructed by the investigator. Appendix A contains samples of these auxiliary materials.

During the one-half hour session on Wednesday mornings, the Logo Group, E_2, was given instruction on a programming technique or topic, which was to be incorporated during their computer times for the week. While learning programming commands and experimenting with Logo, each student had her/his own booklet with worksheets to be completed at the computer. Included in Appendix A is a list of Logo resources used in assembling these booklets.

After the initial introduction to Logo, the students worked at their own pace and developmental level. Some of the students completed all the activities while others did not. A list of the activities and topics on which the students worked in their booklets can be found in Appendix A. Weeks six and seven were devoted to directly applying Logo programming to the geometric topics students were studying in their textbook and learning centers. Students were given specific assignments to complete during this time (see Appendix A). Most of the students only completed a portion of these. Week eight was devoted to allowing students freedom to develop a creative project. They were asked to use whatever they had learned and any materials and books available to design a final project using procedures and subprocedures.

The Control Group, C, was scheduled for similar computer experiences to prevent a treatment bias due to the novelty of the computer. However, the software used was chosen to eliminate as much graphic representation as possible so that no geometric concepts would be reinforced. Since the computer experience was reinforcing mathematics, the software was tutorial, drill and practice, and educational gaming involving mathematics computation. The software contained no geometric topics. Each student had her/his own booklet with assigned worksheets to be completed while at the computer or immediately following the session. Samples of these worksheets can be found in Appendix A.

Assignment to Groups

The subjects were randomly assigned to the three groups; Experimental Group 1 (E_1), Experimental Group 2 (E_2) and Control Group (C). Subjects were randomly assigned to the three groups so that each group consisted of approximately one-third of each class to prevent a confounding by teacher effect. Eight students from Classroom R who had been receiving enrichment instruction in mathematics were randomly assigned to the three groups before the remaining students in Classroom R were assigned. The study was designed to have an equal number of females and males in each group; therefore, within each classroom the females and males were randomized into groups separately. Finally, the groups were randomly assigned to treatments.

Figure 1 illustrates the assignment of subjects across treatments, sex, and classroom.

		Classroom R	Classroom F	Total
E_1 - CAI	Females	4	3	7
	Males	3	4	7
E_2 - Logo	Females	3	4	7
	Males	3	4	7
C - Control	Females	4	3	7
	Males	3	4	7
Total		20	22	42

Figure 1. Assignment of Subjects

Instruments

Three evaluation instruments were used in this investigation. All of the instruments were objective, paper-pencil instruments containing either forced choice, Likert scale, multiple choice or short answer responses. The three instruments used were the Julian Elementary Test of Geometry Achievement (Form A and B) (Julian, 1972), the Monash Spatial Visualization Test (Wattanawaha, 1976) and the Crandall Intellectual Achievement Responsibility Questionnaire (Crandall et al., 1965). Each instrument was administered twice, once prior to the study and then at the completion of the study. The pretest was administered in December with the testing completed at least one week before Christmas break. The exception to this was the one female in the Control Group who joined Classroom R in January. The posttests were given the last week before spring break began in March when the treatment was terminated. The Julian Elementary Test of Geometry Achievement had alternate forms for the pre and posttest while the other two instruments had only one form, which was repeated for the posttest.

The Julian Elementary Test of Geometry Achievement (JETGA) is a multiple choice test designed to assess certain goals of the cognitive domain attained by students in an elementary school geometry program. Knowledge, understanding, and application of geometry topics are the objectives measused by the JETGA. The questions and topics for each objective are given in Appendix B. An investigation was undertaken to study the relationship of students' test scores on the JETGA with their test scores on mental abilities, reading level, arithmetic computation ability, and arithmetic reasoning ability. Pearson r coefficients calculated between scores on Form A and scores on mental abilities and arithmetic computation were significant, and accounted for 46% of the shared variance between the scores on the three cognitive measurements. The mental abilities and arithmetic computation scores were also significantly related to the scores on Form B and accounted for 38.6% of the variance of scores. The overall Kuder-Richardson formula 20 coefficient of internal consistency for each form of the JETGA was .96. The coefficients of stability for Form A was .85 and the Form B coefficient was .82. The mean biserial correlation for Form A was .83 and for Form B, .83. The total group equivalence of forms coefficients obtained by reversing the order of test administration were .83 when Form A was administered first (A_1,B_2) and .80 when Form B was administered first (A_2,B_1). The mean item difficulty index for Form A was .36, while the Form B test had a mean item difficulty of .35.

Spatial visualization ability was measured by the Monash Spatial Visualization Test. The Monash Spatial Visualization Test (MST) is a pencil-and-paper spatial test that is largely based on Wattanawaha's Monash Spatial Test I (Wattanawaha, 1976). Wattanawaha determined that a group-administered paper and pencil test could measure the same thing as an individually administered equipment test. Wattanawaha's Dimensionality, Internalization, Presentation, Thought Process (DIPT) classification system for spatial questions was used as an aid for developing spatial questions requiring different kinds of thinking. The DIPT classification system is intended to apply to non-speeded tasks (Clements and Wattanawaha, 1978). The DIPT system is based on the assumption that the most important general characteristics of spatial tasks are: The Dimensionality of thinking required by the task, the degree of Internalization required, the manner in which the task requires an answer to be Presented, and the Thought process required by the task, and in particular, whether the mental operation which has to be used for the task is given, or whether it has to be determined. Associated with each of the four independent characteristics is a number of values, three each for dimensionality, internalization, and presentation, and two for type of thinking. A question with a classification of (2,1,2,1) would be one that required two-dimensional thinking, a visual image to be formed but not mentally manipulated, the answer to be a drawing or some other accurate description of a visual image, and the application of one or more mental operations that were implicitly, but not explicitly, defined in the question. Details on the DIPT classification system appear in Appendix B.

The Monash Test has reliability coefficients of .77 and .83 (Clements, 1983), and a large factor analytic study (Clements, 1978) indicated that the items from the MST 1 had a higher spatial visualization loading than any of the other tests in a battery of tests that included the Space Relations test of the Differential Aptitude test and the two spatial visualization tests in the Educational Testing service's Kit of Factor-Referenced Cognitive Tests. The items from which the Monash Spatial Visualization Test was constructed were analyzed by means of the Rasch model (Wattanawaha and Clements, 1982) and no question with a Rasch probability of less than .10 was included.

To assess locus of control (LOC), the Crandall Intellectual Achievement Responsibility Questionnaire (IAR) was used for a measure of the internal level of control the students perceived to have before the study and then at the completion of the study. The IAR was developed within the context of a larger research program dealing with children's achievement development and it is aimed at assessing children's beliefs in reinforcement responsibility exclusively in intellectual-achievement situations. Investigations have demonstrated direct relations between perceptions of internal control on the IAR and academic performance measures as well as performance on persistence in experimental learning tasks and situations (Crandall and Lacey, 1972).

The IAR scale is composed of thirty-four forced-choice items. Since half of these items are negative experiences and half are positive experiences, each item stem describes either a positive or a negative achievement experience which routinely occurs in children's lives. This stem is followed by one alternative stating that the event was caused by the child and another stating that the event occurred because of the behavior of someone else in the child's immediate environment. Rather than including a variety of external environmental forces, the IAR limits the source of external control to those persons who most often come in face-to-face contact with a child (parents, teachers, and peers). A child's internal for success score (I+) is obtained by summing all positive events for which she/he assumes credit, and her/his internal for failure score (I-) is the total of all negative events for which she/he assumes blame. The total internal score (I) is the sum of a child's I+ and I- subscores. Crandall, Kotkovsky, and Crandall (1965) found high mean scores, relatively short ranges, and a small amount of variance around means suggesting that there are a number of non-discriminating items which elicit an internal response from most children. However, there were sufficient individual differences in children's responses to allow prediction to achievement performances.

Crandall, Kotkovsky, and Crandall (1965) found that the consistency of children's IAR responses over time is moderately high. The test-retest correlations in a study with children in grades 3, 4 and 5 were .69 for total I, .66 for I+ and .74 for I-. These correlations were all significant at the .001 level. Because the IAR contains two kinds of items, positive and negative events, split-half reliabilities were computed separately for the two subscales. For a random sample of 130 of the younger children, the correlation is .54 for I+ and .57 for I- after correction with the Spearman-Brown Prophesy Formula. The brevity of the subscales influences the lack of high split-half reliabilities. Low correlations between the two subscales raises some doubt about the use of the total I score alone. The use of the two subscales is warranted because of the possibility that self-responsibility for successes and failures may develop at different rates and be learned separately (Crandall and Lacey, 1972). Since this score combines self-responsibility for success and failure, it may mask important differences between the two in the individual child. Internality was not found to be related positively, consistently or highly to intelligence-test scores; therefore, it is not assumed to be simply another measure of intelligent behavior.

Collection of the Data

The pretest scores on the four instruments were gathered prior to instruction on geometric concepts for all groups. All testing was administered in written form in group sessions. This occurred in December, 1983, with all testing being completed previous to the last week before Christmas break. It was necessary to complete the testing before classes resumed in January in order to allow eight weeks of class-time prior to spring break in March. Only students who completed all of the pretesting were included in the study. Since one female joined the class on the first day of classes in January, she was administered the pretest and included in the study. Three other students joined the class during the study but were not pretested or included in the study.

The treatment for the study began on January 3, 1984, and continued for eight weeks to the beginning of spring break on March 3, 1984. Posttests for the dependent variables were administered during the last week of the study before students left for spring break. Exceptions to this were two students who were ill during that week. The female student from E_2 was administered tests during the week of spring break while the male student from the Control Group was tested the week students returned to school.

Hypotheses

The purpose of this study was to determine the effect of using the microcomputer to supplement the teaching of geometric concepts in the elementary school. Further, geometry achievement, spatial visualization and locus of control were measured to investigate the effects of Logo and CAI. In addition, these effects were measured specific to the sex of the students involved. Hypotheses were developed to provide a focus for the study. They are stated in the statistical null form on pages 8-11 and tested at the .05 significance level. The .05 level of significance was chosen in an attempt to achieve a desirable balance in the probabilities of Type I and Type II errors occurring.

Treatment of the Data

The design of the study is a four-factor experiment with repeated measures on the two factors. It is a mixed design with two between-groups measures and two within-groups measures. The between-groups measures are treatment (Factor G) and sex (Factor S) and the within-groups measures are the repeated measures of the pretest and posttest (Factor P) and measures of the four distinct variables across groups (Factor M).

The multiple dependent variables here constitute a special kind of within-subjects factor since within factors are factors that describe the organization of variables either into repeated measures factors or into distinct dependent variables (Dixon, 1983). Figure 2 presents a schematic diagram to illustrate the nesting of Factor S within Factor G and Factor P within Factor M.

The treatment Factor G was under the direct control of the experimenter while the classification Factor S was not. The effects of the treatment factors are of primary interest to the experimenter, whereas classification factors are included in an experiment to reduce experimental error and to clarify interpretation of the effects of the treatment factors (Winer, 1971). A factorial design was selected because information from factorial experiments is more complete than that obtained from a series of single-factor experiments. In factorial designs the evaluation of interaction effects are permitted to show effects attributable to the combination of variables above and beyond that which can be predicted from variables considered singly.

A repeated measures design was chosen to control for individual differences and because of the number of subjects in the study. The repeated measures design also has the ability to reveal small but reliable effects. Further advantages of repeated measures designs are discussed by Pedhazur (1982) who writes:

> Probably the most important advantage of repeated-measures designs is that they afford the researcher control for individual differences among the subjects. Individual differences are probably the largest source of variation in most research studies. When left uncontrolled, as in a completely randomized design, they comprise part of the error term. In repeated-measures designs each subject serves as his own control. Consequently, it is possible to identify

		m_1		m_2		m_3		m_4	
		p_1	p_2	p_1	p_2	p_1	p_2	p_1	p_2
g_1	s_1	Y_{11}	Y_{11}	Y_{11}	Y_{11}	Y_{11}	Y_{11}	Y_{11}	Y_{11}
	s_2	Y_{12}	Y_{12}	Y_{12}	Y_{12}	Y_{12}	Y_{12}	Y_{12}	Y_{12}
g_2	s_1	Y_{21}	Y_{21}	Y_{21}	Y_{21}	Y_{21}	Y_{21}	Y_{21}	Y_{21}
	s_2	Y_{22}	Y_{22}	Y_{22}	Y_{22}	Y_{22}	Y_{22}	Y_{22}	Y_{22}
g_3	s_1	Y_{31}	Y_{31}	Y_{31}	Y_{31}	Y_{31}	Y_{31}	Y_{31}	Y_{31}
	s_2	Y_{32}	Y_{32}	Y_{32}	Y_{32}	Y_{32}	Y_{32}	Y_{32}	Y_{32}

1. The subject effect is nested under both factors G (treatment) and S (sex).

2. Y_{ij} denotes the group of subjects assigned to treatment combination GS_{ij}.

3. Each of the groups is observed under all levels of factors P (time of measurement) and M (type of measure) but each group is assigned to only one combination of factors G and S.

Figure 2. Schematic Representation of Data Matrix

> the variance due to individual differences and separate it from the error term. This, therefore, leads to a more precise analysis. Repeated-measures designs are also more economical than completely randomized designs in that they afford considerable savings in the number of subjects required for a given study. Finally, repeated-measures designs enable one to study phenoma across time. This is particularly useful in experiments dealing with learning or developmental studies (p. 553).

There are four qualitatively distinct variables measured with two qualitatively similar measurements on two separate occasions for each of the four variables. By generating multiple scores for each subject in a repeated measures design, a class of multivariate data was produced. In addition, each of the four qualitatively distinct responses was measured on each of the two occasions producing doubly multivariate data (Bock, 1975). This presented a mixed model multivariate design with groups X subjects within groups X occasions X variables.

Multivariate analysis of variance with repeated measures was used to test the respective hypothesis. The Biomedical Computer Program BMDP4V (Dixon, 1983) was the statistical program chosen for the analyses. This decision was based on the nature of the data and discussions in the literature on the use of conventional analysis of variance versus multivariate analysis of variance (Winer, 1971; McCall and Applebaum, 1973; Davidson, 1972; Morrison, 1967).

The univariate analysis of variance tests may wrongly reject the null hypothesis with a probability larger than that corresponding to the critical value of F in the tables if the variances and covariances of the variables are not uniform. When the same subjects contribute data to each occasion of a repeated factor, it must be further assumed that the population covariances are all equal (McCall and Applebaum, 1973). However, if the repeated factor has only two levels, as is for sex in this study, there is only one covariance and thus there is no possibility of heterogeneity of covariance. Given reasonably homogeneous variances within each of the two occasions, the conventional analysis of variance with repeated measurements can be used. Since the second of the repeated measurements consists of four dependent variables, it is a possibility that the uniformity assumption is violated.

Box'x test is recommended to test for uniformity of the variance-covariance matrix, but it is computationally as difficult as the multivariate test and when n is small one cannot depend on Box's test to detect serious departures from uniformity (Davidson, 1972). The usual method of adjusting α to compensate for its increase when the uniformity assumption is violated is to alter the degrees of freedom for the univariate test statistic. Greenhouse and Geiser and Huynh-Feldt both have adjusted the degrees of freedom for a more conservative univariate test (Dixon, 1983). However, provided the degree of heterogeneity of the covariances is relatively moderate, the usual univariate test tends to give results closer to the nominal significance levels than do results under Greenhouse-Geisser. The conservative test may not reject the hypothesis being tested as often as it should be rejected. The Greenhouse-Geisser is an extremely conservative test and .05 level of significance tends to be closer to .01, particularly when subjects, factors, and levels of factors are small (Winer, 1971).

When uniformity is questionable, only the modified univariate and the multivariate tests give an investigator the necessary control over the probability of a Type I error (Davidson, 1972).

> If the tenability of homogeneity of covariance is ambiguous, the multivariate test is probably the single most exact,

> powerful, and versatile analysis of repeated-measurement data. Greenhouse-Geisser approach is easiest and versatile, but probably too conservative (McCall and Applebaum, 1973, p. 414).

In addition, the univariate test is relatively powerless to detect any reliable difference between highly correlated experimental conditions when other less well correlated conditions are present. Since the multivariate test is designed to search among the data for the within-subject contrast, it can detect those differences (Morrison, 1967). Without a multivariate test, we cannot know whether the significance of the second component is merely repeating the significance of the first component due to the intercorrelation, or whether it is providing additional evidence. The correlation matrix for the dependent variables in the study is presented in Figure 3.

Therefore, the recommendations are to use either the modified univariate test or the multivariate test if the uniformity assumption may not be met or if there is a high correlation between experimental conditions. In considering the power of the multivariate test, it is usually somewhat more powerful provided that subjects exceed groups by a few, as in this study. With the above consideration in mind, the investigator made the choice to use the multivariate analysis of variance to detect overall significant differences. In making this decision, there was a loss of power in detecting differences because the statistical technique makes relatively few assumptions. If the multivariate test is significant, however, it is permissible to examine specific contrasts and look at univariate analysis of variance for interpretation of the overall significance. One must be aware that it is not uncommon in multivariate analysis of variance to have significant differences for

	Pre MST	Post MST	Pre JETGA	Post JETGA	Pre IARS	Post IARS	Pre IARF	Post IARF
Pre MST	1.0000							
Post MST	.6824	1.0000						
Pre JETGA	.5892	.6289	1.0000					
Post JETGA	.6181	.7263	.7602	1.0000				
Pre IARS	.0862	.0563	.1691	.2422	1.0000			
Post IARS	-.1099	-.3924	-.0333	-.0712	.5417	1.0000		
Pre IARF	.1406	.0521	.1365	.1219	.5120	.1802	1.0000	
Post IARF	.0289	-.2225	.1781	.0897	.4190	.5427	.6157	1.0000

Figure 3. Correlation Matrix of Dependent Variables for all Students

one or more dependent variables but no significant overall multivariate effects or the reverse situation (McCall and Applebaum, 1973). To further explain and interpret the meaning of the interactions, the means were also graphed and visually interpreted.

Summary

In this chapter, the design of the study and the treatments for each of the three groups were described. Students from two sixth-grade classrooms were randomly assigned to three groups, each of which interacted in a prescribed manner with the computer to supplement a unit on geometry. Since the students were tested on four qualitatively distinct variables, a pretest-posttest design with repeated measures was chosen to control for individual differences.

Initially, a multivariate analysis of variance was performed on the four dependent variables: spatial visualization, geometry achievement, locus of control for success, and locus of control for failure. This analysis was followed by specific comparisons and univariate analysis of variance.

CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

Chapter IV presents the results of the analyses of the data and is organized according to the statistical techniques used in the analyses. The .05 level of significance was designated for the rejection of the null hypotheses presented in Chapter I. All null hypotheses were tested using non-directional alternative hypotheses. Since F tests are robust with respect to minor violations of the assumptions of homogeneity of variance and multivariate normal distribution, no tests for these assumptions were performed.

Multivariate Analysis of Variance

Multivariate analysis of variance using BMDP4V with repeated measures was applied initially to determine whether there were overall significant differences. Since the multivariate analysis of variance is simply an extension of the univariate analysis of variance model to a set of response variables or a vector, the multivariate analysis of variance tested the equality of group means of several variables simultaneously and served as an overall test of the null hypothesis of the equality of mean vectors of groups.

Cell sizes, means and standard deviations of the scores on the pretests and posttests of the four measures (MST, JETGA, IARS, and IARF) for all students are presented in Table I, and by group and sex in Tables II and III.

TABLE I

SUMMARY OF PRETEST AND POSTTEST MEANS AND STANDARD DEVIATIONS OF ALL SUBJECTS' SCORES

Cell classification			MST[a] Pretest	MST[a] Posttest	JETGA[b] Pretest	JETGA[b] Posttest	IARS[c] Pretest	IARS[c] Posttest	IARF[d] Pretest	IARF[d] Posttest
Total ratings		$\bar{x}$	12.07	15.53	27.86	36.62	13.10	12.86	11.48	11.28
n = 42		s	4.14	4.94	8.09	8.71	2.33	2.52	2.45	3.20
CAI	Female	$\bar{x}$	11.43	15.00	28.29	39.57	13.43	14.14	12.14	12.00
	n = 7	s	1.72	2.31	6.50	7.41	2.23	1.68	3.13	4.24
E_1	Male	$\bar{x}$	12.00	18.57	29.00	35.29	13.14	11.14	11.14	9.14
n = 14	n = 7	s	4.83	5.47	10.83	8.90	1.57	2.12	2.80	4.49
Logo	Female	$\bar{x}$	9.86	13.14	26.00	32.00	13.43	14.86	11.43	13.57
	n = 7	s	3.02	6.47	6.14	8.33	2.23	1.68	2.57	2.23
E_2	Male	$\bar{x}$	12.00	15.71	27.29	36.86	12.71	11.57	10.71	9.29
n = 14	n = 7	s	3.46	4.46	9.59	7.38	1.60	3.69	2.14	2.73
Control	Female	$\bar{x}$	11.00	13.86	26.29	35.86	14.14	13.43	12.57	13.14
	n = 7	s	3.27	4.67	6.63	9.82	2.41	2.99	1.51	1.86
C	Male	$\bar{x}$	16.14	16.86	30.29	40.14	10.57	12.00	10.57	10.43
n = 14	n = 7	s	7.40	6.12	10.86	10.21	1.90	2.94	2.94	3.74

[a]Monash Spatial Visualization Test
[b]Julian Elementary Test of Geometry Achievement
[c]Crandall Intellectual Achievement Responsibility Questionnaire for Success
[d]Crandall Intellectual Achievement Responsibility Questionnaire for Failure

TABLE II

SUMMARY OF PRETEST AND POSTTEST MEANS AND STANDARD DEVIATIONS BY TREATMENT GROUPS

Cell classification		MST[a] Pretest	MST[a] Posttest	JETGA[b] Pretest	JETGA[b] Posttest	IARS[c] Pretest	IARS[c] Posttest	IARF[d] Pretest	IARF[d] Posttest
CAI E_1 n = 14	$\bar{x}$	11.71	16.79	28.64	37.43	13.29	12.64	11.64	10.57
	s	3.50	4.44	8.59	8.18	1.86	2.41	2.90	4.45
Logo E_2 n = 14	$\bar{x}$	10.93	14.43	26.64	34.43	13.07	13.21	11.07	11.43
	s	3.32	5.50	7.76	7.97	1.90	3.24	2.30	3.16
Control C n = 14	$\bar{x}$	13.57	15.36	28.29	38.00	12.36	12.71	11.71	11.86
	s	6.11	5.46	8.89	9.88	3.27	2.95	2.37	3.09

[a]Monash Spatial Visualization Test
[b]Julian Elementary Test of Geometry Achievement
[c]Crandall Intellectual Achievement Responsibility Questionnaire for Success
[d]Crandall Intellectual Achievement Responsibility Questionnaire for Failure

TABLE III

SUMMARY OF PRETEST AND POSTTEST MEANS AND STANDARD DEVIATIONS BY SEX

Cell classification		MST[a]		JETGA[b]		IARS[c]		IARF[d]	
		Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Female	$\bar{x}$	10.76	14.00	26.86	35.81	13.67	14.14	12.05	12.90
n = 21	s	2.70	4.62	6.18	8.73	2.20	2.18	2.42	2.90
Male	$\bar{x}$	13.38	17.05	28.86	37.43	12.14	11.57	10.90	9.67
n = 21	s	5.57	5.26	9.99	8.70	2.46	2.86	2.49	3.50

[a]Monash Spatial Visualization Test
[b]Julian Elementary Test of Geometry Achievement
[c]Crandall Intellectual Achievement Responsibility Questionnaire for Success
[d]Crandall Intellectual Achievement Responsibility Questionnaire for Failure

The results of the multivariate analysis of variance are presented in Table IV. When the grouping variable has only two groups, BMDP4V reports Hotelling's T-squared statistic (TSQ) as the multivariate analysis of variance test of the equality of means. Harold Hotelling proposed the T^2 test as a multivariate generalization of the Student's t test (Chatfield and Collins, 1980). If the grouping variable has more than two groups, several multivariate statistics are reported. The author chose to use Wilk's lambda likelihood ratio (LRATIO) which serves as an overall test of the null hypothesis of the equality of mean vectors of two or more groups (Pedhazur, 1982). Since BMDP4V reports multivariate and univariate results, both are reported where appropriate. Whenever univariates are reported as significant, the F tests have large enough critical values using both the traditional univariate and the adjusted degrees of freedom of Huynh-Feldt to reject the null hypotheses. The author elected to use Huynh-Feldt because it makes an adjustment in the degrees of freedom to allow for a more conservative test while it is not as conservative as Greenhouse-Geisser. This less conservative test was chosen to reduce the chance of making a Type II error by failing to reject a false null hypothesis. The multivariate analysis of variance used all four variables in the analyses, therefore the hypotheses for overall significance are considered first. Univariate ANOVA's for each of the four variables were performed using BMDP2V to identify specific variables on which differences were meaningful.

Hypothesis 1 failed to be rejected at the .05 level of significance since there was no overall significance for the main effect of treatment groups for the four dependent variables. Both the between groups and within groups main effect had F ratios lower than the critical value.

TABLE IV

RESULTS OF THE MULTIVARIATE ANALYSIS OF VARIANCE
WITH REPEATED MEASURES

Source	Statistic	df	multi-variate	df	uni-variate
Between Ss					
Group (G)	LRATIO	16,58	1.04		
Sex (S)	TSQ	8,29	2.50*		
G X S	LRATIO	16,58	2.44*		
Within Ss					
MVAR[a] X G	LRATIO	6,68	.48		
				6,108	.52
MVAR X S	TSQ	3,34	4.28*		
				3,108	4.02*
MVAR X GS	LRATIO	6,68	.30		
				6,108	.56
MVAR X P[b]	TSQ	3,34	23.74*		
MP[c] X G	LRATIO	6,68	1.24		
				6,108	1.33
MP X S	TSQ	3,34	.96		
				3,34	.73
MP X GS	LRATIO	6,68	2.41*		
				6,68	2.38*

*p < .05

[a]Multiple variables--indicates all four variables taken together as a single conceptual variable.

[b]Time of measurement

[c]Interaction between multiple variables and time of measurement

Hypothesis 2 was rejected at the .05 level of significance because there was an overall significant main effect for sex using all the dependent variables. Both the between groups and the within groups F ratios for sex were significant ($p < .05$).

There was a significant ($p < .05$) two-way interaction between treatment groups and sex when using all the dependent variables, therefore hypothesis 3 was also rejected. The between groups analysis, which takes all variables using the pretest and the posttest of each of the four variables as separate dependent variables (G X S), yielded a significant ($p < .05$) F ratio while the within groups analysis did not (MVAR X GS). Since the within groups MVAR represents a single conceptual variable rather than an analysis of single dependent variables, the results may differ.

Hypothesis 4 is rejected because when all four variables are considered as a single conceptual variable (MVAR), there is a significant ($p < .05$) main effect for time of measurement (MVAR X Time of Measurement (P)). However, hypothesis 5 failed to be rejected since there is no significant ($p < .05$) two-way interaction between time of measurement and treatment groups (MP X G).

No significant ($p < .05$) interaction was detected between time of measurement and sex (MP X S); therefore, hypothesis 6 failed to be rejected. However, there was a significant ($p < .05$) three-way interaction between time of measurement, treatment groups and sex (MP X GS), and hypothesis 7 was rejected. Since significance ($p < .05$) was detected in the MANOVA, univariate tests of each dependent variable were performed to determine which differences contributed to the significance of the MANOVA.

Monash Spatial Visualization ANOVA

The results of the ANOVA on the MST data are presented in Table V. Null hypotheses 1a, 2a, 3a, 4a, 5a, 6a, and 7a were all tested by means of a three-way ANOVA with repeated measures on one factor to determine if differences detected by the multivariate analysis were a result of differences on the MST. Hypotheses 2a and 4a were rejected at the .05 level of significance as a result of a significant main effect for sex and a significant main effect for time of measurement, respectively. This supports the significant multivariate statistic of multiple dependent variables by sex (MVAR x S) and multiple dependent variables by time of measurement (MVAR X P). Hypotheses 1a, 3a, 5a, 6a, and 7a all failed to be rejected indicating no group difference and no two- or three-way interactions on the MST.

Julian Elementary Test of Geometry Achievement ANOVA

The results of the ANOVA on the JETGA are presented in Table VI. Null hypotheses 1b, 2b, 3b, 4b, 5b, 6b, and 7b were all tested by means of the three-way ANOVA with repeated measures to determine if differences detected by the multivariate analysis were a result of differences on the JETGA. The only significant ($\underline{p} < .05$) result on the JETGA was for the main effect time of measurement, therefore hypothesis 4b was rejected. The significant main effect for repeated measures on the JETGA contributed to the significant multivariate MVAR X P. No other main effects or interactions were significant, therefore, hypotheses 1b, 2b, 3b, 5b, 6b, and 7b all failed to be rejected.

TABLE V

RESULTS OF THE FACTORIAL ANOVA WITH REPEATED MEASURES ON THE PRETEST AND POSTTEST FOR THE MONASH SPATIAL VISUALIZATION TEST DATA

Source	df	MS	F
Between Ss			
Group (G)	2	26.619	.70
Sex (S)	1	168.583	4.44*
G X S	2	8.190	.22
Error between	36	37.996	
Within Ss			
Time of measurement (P)	1	250.298	36.44*
P X G	2	18.905	2.75
P X S	1	.964	.14
P X G X S	2	11.571	1.68
Error within	36	6.869	

*$p < .05$

TABLE VI

RESULTS OF THE FACTORIAL ANOVA WITH REPEATED MEASURES ON THE PRETEST AND POSTTEST FOR THE JULIAN ELEMENTARY TEST OF GEOMETRY ACHIEVEMENT DATA

Source	df	MS	F
Between Ss			
Group (G)	2	60.940	.64
Sex (S)	1	68.762	.48
G X S	2	69.869	.60
Error between	36	134.190	
Within Ss			
Time of measurement (P)	1	1612.190	92.63*
P X G	2	6.512	.37
P X S	1	.762	.04
P X G X S	2	32.726	1.88
Error Within	36	17.405	

*$p < .05$

Crandall Intellectual Achievement Responsibility Questionnaire for Success ANOVA

The results of the ANOVA of the IARS data are presented in Table VII. The three-way ANOVA with repeated measures was performed on the IARS data to test hypotheses 1c, 2c, 3c, 4c, 5c, 6c, and 7c to determine if diffe-ences detected by the MANOVA were a result of differences on the IARS. Hypothesis 2c was rejected resulting from a significant ($p < .05$) main effect for sex on the IARS, therefore contributing to the significant multivariate statistic MVAR X S. A significant ($p < .05$) three-way interaction between time of measurement, treatment groups and sex was detected resulting in the rejection of hypothesis 7c. This is the only significant three-way interaction, and therefore is the main contributor to the significant multivariate statistic for multiple dependent variables by time of measurement by treatment groups by sex (MP X GS).

Crandall Intellectual Achievement Responsibility Questionnaire for Failure ANOVA

Table VIII presents the results of the ANOVA for the IARF data. Hypothesis 1d, 2d, 3d, 4d, 5d, 6d, and 7d were tested using a three-way ANOVA with repeated measures on the IARF data. Since significant differences were detected by the MANOVA, the ANOVA was performed to determine if any differences were a result of the IARF.

Hypotheses 2d and 6d were rejected by a significant ($p < .05$) main effect for sex and also a significant ($p < .05$) two-way interaction between time of measurement and sex on the IARF. The sex difference again contributed to the multivariate statistic MVAR X S; however, since

TABLE VII

RESULTS OF THE FACTORIAL ANOVA WITH REPEATED MEASURES ON THE PRETEST AND POSTTEST FOR THE CRANDALL INTELLECTUAL ACHIEVEMENT RESPONSIBILITY QUESTIONNAIRE FOR SUCCESS DATA

Source	df	MS	F
Between Ss			
Group (G)	2	2.726	.32
Sex (S)	1	88.048	10.37*
G X S	2	1.298	.15
Error between	36	8.492	
Within Ss			
Time of measurement (P)	1	.048	.02
P X G	2	1.940	.79
P X S	1	5.762	2.34
P X G X S	2	13.369	5.43*
Error within	36	2.460	

*$p < .05$

TABLE VIII

RESULTS OF THE FACTORIAL ANOVA WITH REPEATED MEASURES ON THE PRETEST AND POSTTEST FOR THE CRANDALL INTELLECTUAL ACHIEVEMENT RESPONSIBILITY QUESTIONNAIRE FOR FAILURE DATA

Source	df	MS	F
Between Ss			
Group (G)	2	2.477	.18
Sex (S)	1	107.440	7.60*
G X S	2	.619	.04
Error between	36	14.135	
Within Ss			
Time of measurement (P)	1	.5883	.16
P X G	2	4.333	1.22
P X S	1	22.012	6.19*
P X G X S	2	3.619	1.02
Error within	36	3.556	

*$p < .05$

the MANOVA did not reveal an interaction between time of measurement and sex (MP X S), the significant ($p < .05$) two-way interaction (P X S) must be interpreted with caution. Hypotheses 1d, 3d, 4d, 5d, and 7d all failed to be rejected at the .05 level of significance.

Specific Comparisons

To further examine the significant results, specific comparisons using BMD4V, which allows factors to be held fixed, were computed to isolate differences within each variable. Direction on which specific comparisons to report is taken from the significance revealed in the univariate results.

The main effect of sex is significant when all four variables and their pretests and posttests are treated as single variables as indicated in Table IV. Specific comparisons on the pretest and posttest reveal that when all four variables are considered, significant ($p < .05$) effects are indicated for both the pretests and the posttests as shown in Table IX.

TABLE IX

MULTIVARIATE STATISTICS ON THE PRETESTS AND POSTTESTS FOR SEX

Source	Statistic	df	multi-variate	df	uni-variate
Within Ss					
MVAR at Pre X S	TSQ	3,34	3.53*	3,108	2.44
MVAR at Post X S	TSQ	3,34	3.64*	3,108	4.24*

*$p < .05$

Both the locus of control variables of IARS and IARF, as well as the spatial visualization variable MST, reflected a significant main effect for sex. See Tables V, VII, and VIII. Table X presents the results of the specific comparisons performed on these variables for the pretest and posttests and also for sex in each of the treatment groups.

The results in Table X indicate the significant main effect for sex is primarily due to the sex differences on the IARS and IARF. In examining the mean scores in Table III, it is evident that females have higher internal scores than males on both locus of control variables. Even though the MST showed a significant main effect for sex, specific comparisons on the pretest and posttest data did not show significance at the .05 level. The results of the analysis of pretest scores on the MST had a probability level of .058 and a probability level of .061 for the results of the analysis of scores on the posttest. Therefore, whatever sex difference existed before the treatment appears to continue after the treatment. Further examination of mean scores reported in Table III indicates that males have higher scores than females on the MST. Since significance was detected for time of measurement, several specific comparisons were made with time of measurement and sex. The results of these comparisons are presented in Table XI. The analysis of the data collected from both treatment groups E_1 and E_2 showed significance for time of measurement, while the analysis of data yielded by the control group did not. Also, a significant interaction appeared for time of measurement for the treatment groups for males, but not for females.

Although the MANOVA did not show any significant interactions for time of measurement and sex on all the variables together, when the

TABLE X

SPECIFIC COMPARISONS FOR THE MAIN EFFECT OF SEX

Source	df	MS	F
Within Ss			
IARS at Pre X S	1,36	24.381	6.00*
IARS at Post X S	1,36	69.429	10.08*
IARS at E_1 X S	1,36	18.893	2.22
IARS at E_2 X S	1,36	28.000	3.30
IARS at C X S	1,36	43.750	5.15*
IARF at Pre X S	1,36	16.095	2.43
IARF at Post X S	1,36	113.357	10.24*
IARF at E_1 X S	1,36	26.036	1.84
IARF at E_2 X S	1,36	43.750	3.10
IARF at C X S	1,36	38.893	2.75
MST at Pre X S	1,36	72.024	3.83
MST at Post X S	1,36	97.524	3.74
MST at E_1 X S	1,36	30.036	.79
MST at E_2 X S	1,36	38.893	1.02
MST at C X S	1,36	116.036	3.05

*$p < .05$

TABLE XI

SPECIFIC COMPARISONS ON THE MONASH SPATIAL VISUALIZATION TEST DATA

Source	df	MS	F
Within Ss			
MST at E_1 X P	1,36	180.036	26.21*
MST at E_2 X P	1,36	85.750	12.48*
MST at C X P	1,36	22.321	3.25
MST at E_1 X S X P	1,36	15.75	2.29
MST at E_2 X S X P	1,36	.321	.05
MST at C X S X P	1,36	8.036	1.17
MST X G at Male X P	2,36	30.024	4.37*
MST X G at Female X P	2,36	.4523	.07

*$p < .05$

univariates were performed a significant interaction was detected for time of measurement and sex (P X S) for the IARF (see Table VIII). Table X shows the specific comparisons on the pretests and posttests for which there is a significant F-ratio for the posttest but not the pretest on IARF. Table XII presents results of specific comparisons for time of measurement and sex. A significant effect for time of measurement for males, but not for females, provides support for the interaction between time of measurement and sex.

TABLE XII

SPECIFIC COMPARISONS ON THE CRANDALL INTELLECTUAL ACHIEVEMENT RESPONSIBILITY QUESTIONNAIRE FOR FAILURE

Source	df	MS	F
Within Ss			
IARF at Female X P	1,36	7.715	2.17
IARF at Male X P	1,36	14.881	4.19*

*p < .05

The significant MANOVA interaction for multiple variables, time of measurement, group, and sex (MVAR X P X G X S) indicates the need for a number of specific comparisons. The results of the univariate analysis indicate that the IARS contributed the most to the significant interaction since that is the only result where significance was obtained.

Table XIII presents specific comparisons calculated using data collected on the IARS and the IARF. There are significant interactions for time of measurement and sex for both E_1 and E_2 treatment groups, while there is no significant time of measurement effect for the control group on the IARS. The only specific group by sex by time of measurement interaction that was significant was for males on the IARS (IARS X G at Male X P). The significant group by sex by time of measurement for the IARF occurs in treatment group E_2 (IARF at E_2 X S X P).

Summary

Results from the four-way multivariate analysis of variance with repeated measures on two factors were presented in this chapter. The MANOVA was used to test overall significant differences for multiple dependent variables. To determine which of the four dependent variables were contributing to the significance of the MANOVA, analysis of variance with repeated measures was used. Specific comparisons were then made, when appropriate, to locate the differences between treatment groups and sexes and to determine where interactions were significant.

There was an overall significant sex difference which was detected on the Monash Spatial Visualization Test, Crandall Intellectual Achievement Responsibility Questionnaire for Success, and the Crandall Intellectual Responsibility Questionnaire for Failure. Males had a higher mean score than females on the MST, while females had higher scores than males on both the IARS and IARF.

There was no overall significant main effect for treatment groups, but there was a significant overall group by sex interaction using pretests and posttests of all four variables as single dependent variables.

TABLE XIII

SPECIFIC COMPARISONS ON THE CRANDALL INTELLECTUAL ACHIEVEMENT RESPONSIBILITY QUESTIONNAIRE FOR SUCCESS AND FAILURE

Source	df	MS	F
Within Ss			
IARS at E_1 X P	1,36	2.893	1.18
IARS at E_2 X P	1,36	.143	.06
IARS at C X P	1,36	.893	.36
IARS at E_1 X S X P	1,36	12.893	5.24*
IARS at E_2 X S X P	1,36	11.572	4.70*
IARS at C X S X P	1,36	8.036	3.27
IARS at Female X P	1,36	2.381	.97
IARS at Male X P	1,36	3.429	1.39
IARS X G at Female X P	2,36	4.167	1.69
IARS X G at Male X P	2,36	11.143	4.53*
IARS at Pre X GS	2,36	11.167	2.75
IARS at Post X GS	2,36	3.500	.51
IARF at E_1 X P	1,36	8.036	2.26
IARF at E_2 X P	1,36	.893	.25
IARF at C X P	1,36	.323	.09
IARF at E_1 X S X P	1,36	6.036	1.70
IARF at E_2 X S X P	1,36	22.321	6.28*
IARF at C X S X P	1,36	.893	.25
IARF X G at Female X P	2,36	4.786	1.35
IARF X G at Male X P	2,36	3.167	.89

*$p < .05$

When using the four variables as a repeated measures across groups, the main effect for sex was still significant. Here the four variables were treated as a single conceptual variable so the results differed from the group by sex interaction when all variables were treated as single dependent variables. No significant group by sex interactions were detected when ANOVA's were performed on each variable.

The MANOVA detected significance for time of measurement when all the variables were used as a single conceptual variable. The interaction between time of measurement, groups, and sex was also significant on the MANOVA. The analysis of data collected using MST and JETGA achieved significance for the repeated measures when ANOVA's were performed. The IARS was the main contributor to the significant interaction between time of measurement, groups, and sex while the IARF showed significance for the interaction between time of measurement and sex.

Specific comparisons were performed to determine where the interactions were located. The discussion of these results and interpretations of the specific comparisons through graphic illustrations are presented in Chapter V. Conclusions from the study, educational implications, and recommendations for further study are also reported in Chapter V.

CHAPTER V

INTRODUCTION TO CHAPTER, SUMMARY OF RESEARCH METHODS, DISCUSSION OF RESULTS, CONCLUSIONS AND IMPLICATIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Introduction to Chapter

Chapter V contains a summary of the research methods and a discussion of the results. Conclusions and implications for education were formulated from the results of the study. Recommendations for further study were made as a result of the questions left unanswered and the additional questions that surfaced throughout the study.

Summary of Research Methods

The purpose of this study was to investigate the effects of supplementing traditional textbook instruction of geometric concepts with microcomputers. Subjects for the study were forty-two sixth-grade students in two different self-contained classrooms in a heterogeneously grouped elementary school. The subjects were randomly assigned to three treatment groups who each interacted in a distinct manner with the microcomputer during instruction for six weeks on geometric topics in their mathematics class. The E_1 treatment group used computer assisted instruction on geometric topics, the E_2 treatment group interacted with Logo by programming which was then applied to geometric concepts, while the control group used computer assisted instruction unrelated to geometry. Pretests and posttests scores for all subjects were obtained on the Monash Spatial Visualization Test, the Julian Elementary Test for Geometry Achievement, and the Crandall Intellectual Responsibility Questionnaire.

Discussion of Results

Multivariate analysis of variance (MANOVA) was performed with two repeated measures, one on the pretest and posttest and one on the four distinct variables across groups, to determine the equality of mean vectors of groups. The results of the MANOVA indicated statistical significance at the .05 level for the main effect of sex using all the variables. Statistical significance (.05) was indicated when using both the between groups design ($F = 2.50$, $p = .034$), and the within groups ($F = 4.28$, $p = .012$). The between groups analysis uses the pretests and posttest for the four variables as separate dependent variables and detects differences between the sexes on all eight variables, while the within group analysis uses the four variables as a single conceptual variable to detect differences.

Specific comparisons on the pretests and posttests for each of the variables give some indication where the sex differences are the greatest. A comparison was made using all variables on the pretest to determine if sex differences existed prior to the treatment. The analysis of the pretest and the posttest scores indicated significant sex differences for the multivariate statistic, while only the posttest results were significant on the univariate. The results indicated significant sex differences on both the pretest and posttest scores on the IARS and the posttest data only on the IARF.

Main effect differences are usually only meaningful when the interaction is not significant; therefore, interpretation of main effects should be further qualified since the existence of significant interactions limits the generality of statements about the main effects. The presence of an interaction indicates that a given factor does not have constant effects, but rather that the effect varies depending on the treatments of the other factors with which it is combined (Pedhazur, 1982).

When considering all eight variables in the between groups analyses, there is a significant group by sex interaction (F = 2.44, p = .007). However, the within groups analysis using the multiple variables across the groups by sex (MVAR X GS) does not indicate a significant interaction. In examining the statistics for the between groups pretest and posttest, most of the significant group by sex interaction is a result of the pretest on the IARS which has an F ratio of 2.75 with 2 and 36 degrees of freedom while all the other variables have relatively small F ratios. Since the degrees of freedom when all the variables are used increases to 16 and 58, the probability for this interaction to be due to chance becomes .007.

Although the within analysis did not reveal a significant interaction of group by sex, there was a significant interaction when time of measurement was combined with the group by sex interaction (MP X GS). As previously stated, significant higher order interactions limits the interpretation of main effects, as well as interpretation of the lower-order interactions. Therefore, the significant main effects for sex and time of measurement must be considered in light of the significant three-way interaction.

Interpretations of results of a factorial MANOVA such as this is, in a sense, hierarchical. Significant interactions should be considered first and then, if those are significant, tests of simple main effects should be interpreted. When an interaction is significant, it is generally not meaningful to interpret the main effects. The task analysis must be continued since the MANOVA only presented overall differences. The significant results of the repeated measures MANOVA indicates overall differences exist when the variables are considered as a single conceptual variable, which was designed to detect differences within subjects when some conditions are highly correlated and others not well correlated. To determine explanations for the overall significant findings, it is appropriate to calculate ANOVA's for each of the dependent variables to determine which of the four variables contribute to the significance.

MST Results

The analysis of variance with repeated measures indicated statistical significance for the main effects of sex and time of measurement. Figure 4 illustrates that the significant sex difference is due to males scoring higher than females on the MST. The time of measurement was also a significant effect and is illustrated in Figure 4. Both females and males improved significantly on their spatial visualization ability as a result of the treatment.

Specific comparisons that were later performed on the pretest and posttest were not significant. However, when all variables with their pretests and posttests were used as single variables the multivariate statistic (TSQ) for between groups was significant ($F = 2.50$, $p = .034$). The F ratios for the pretests and posttests are larger than the overall

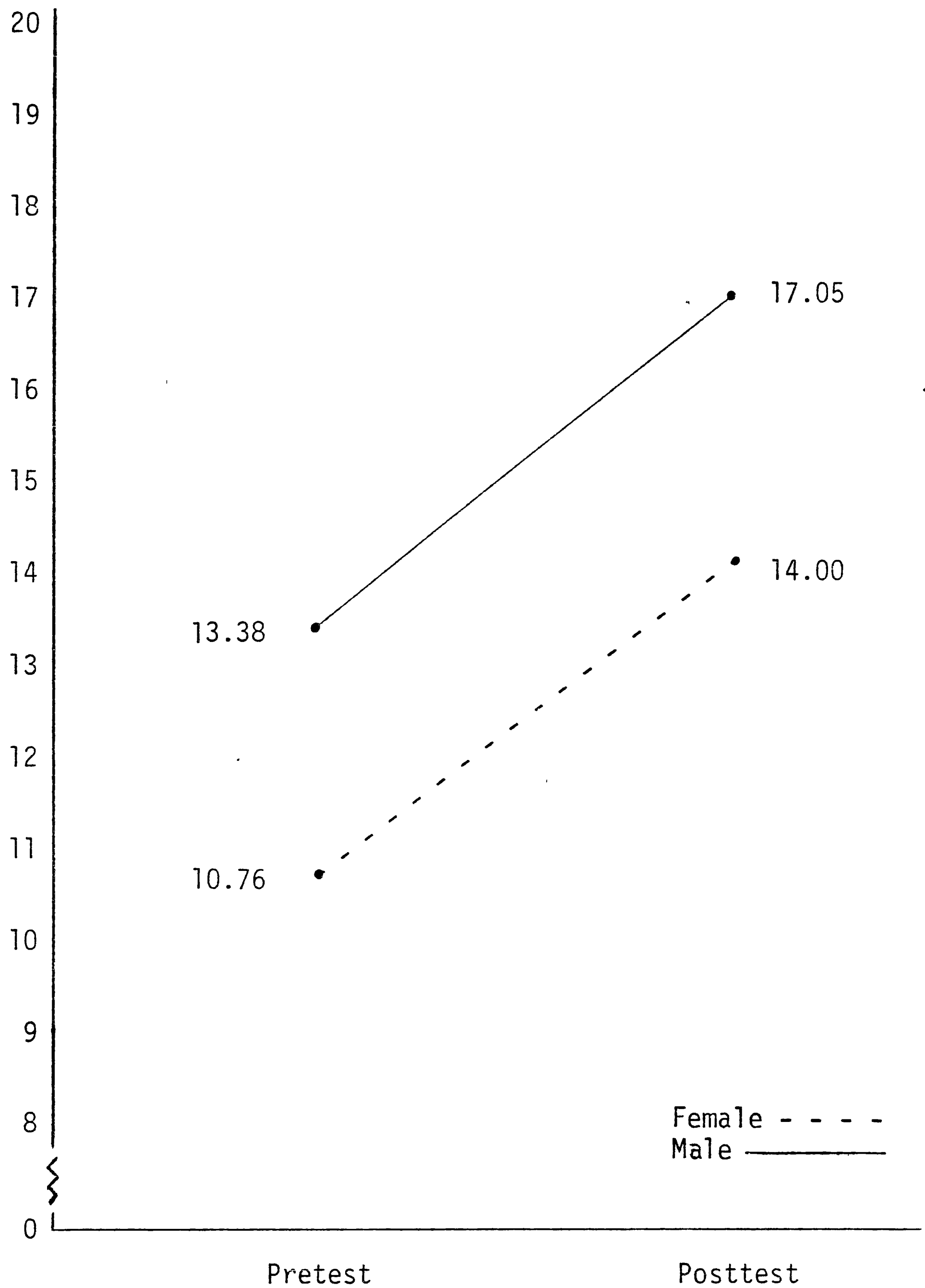

Figure 4. MST Means for Males and Females on the Pretest and Posttest

critical value of 2.50 being significant with 8 and 29 degrees of freedom because of the eight dependent variables.

The MANOVA revealed an interaction for the time of measurement by groups. Although not statistically significant, it may be educationally significant. Figure 5 illustrates the largest increase was by subjects in the E_1 group, and the smallest increase was by subjects in the control group. Specific comparisons indicated a significant effect due to time of measurement for the E_1 and E_2 groups, but not for the control group. The graph in Figure 6 indicates that the males in the control group scored much higher (16.14) on the pretest than any other group, but did not increase their score in the same manner as the other groups did. In addition, the scores of the males in the E_1 group increased more than the scores of any other group. Specific comparisons detected this difference showing the groups at male by time of measurement (G at Male X P) source of variance to be significant ($F = 4.37$, $\underline{p} = .02$). Discretion must be used in interpreting these specific comparisons and are reported here only for further interpretation of the results of the ANOVA.

JETGA Results

The only statistically significant result for geometry achievement was for the main effect of time of measurement. Figures 7 and 8 illustrate that all students made large increases from the pretest to the posttest. Since no interactions were significant, no specific comparisons were performed.

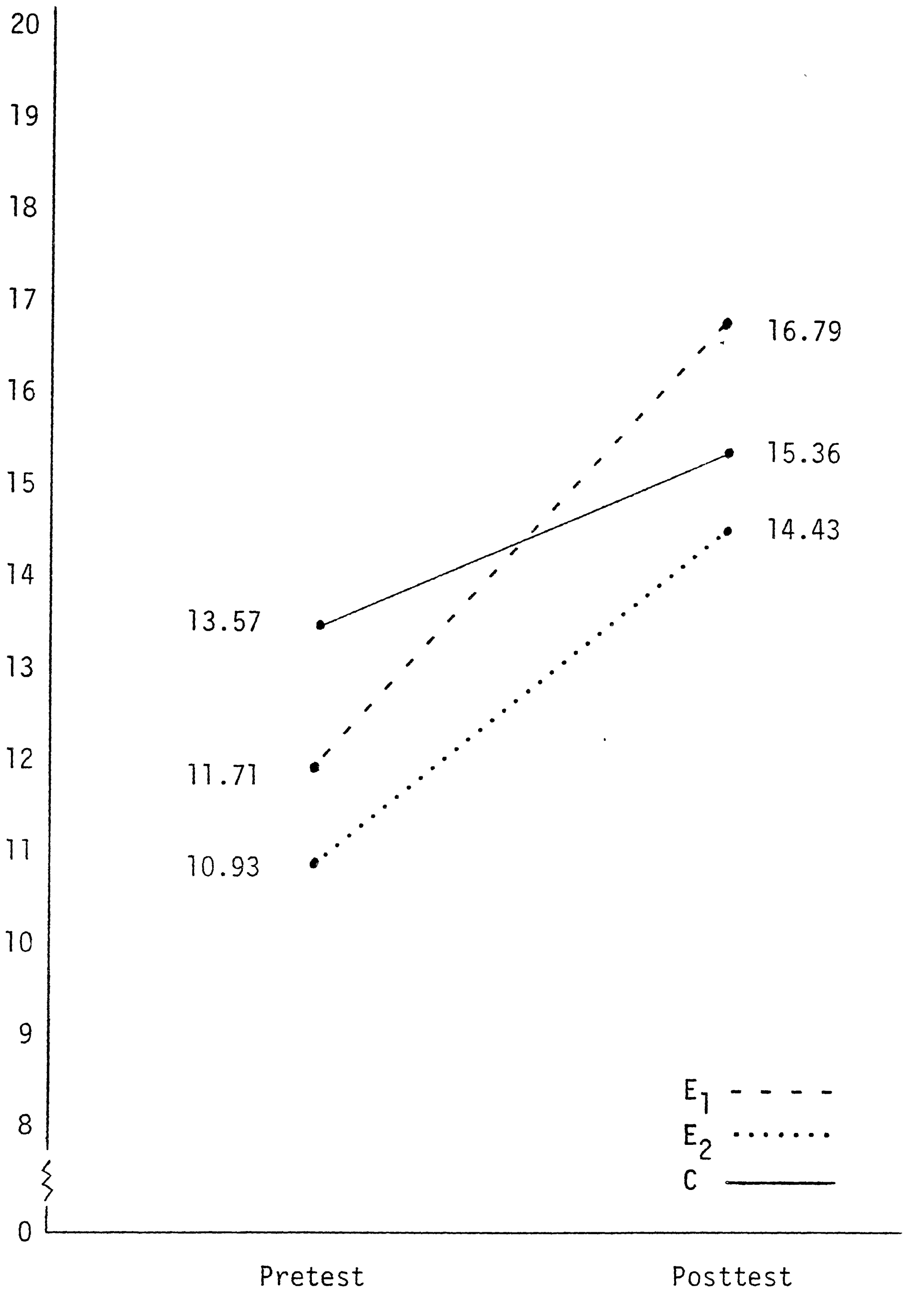

Figure 5. Group Means for the Pretest and Posttest on the MST

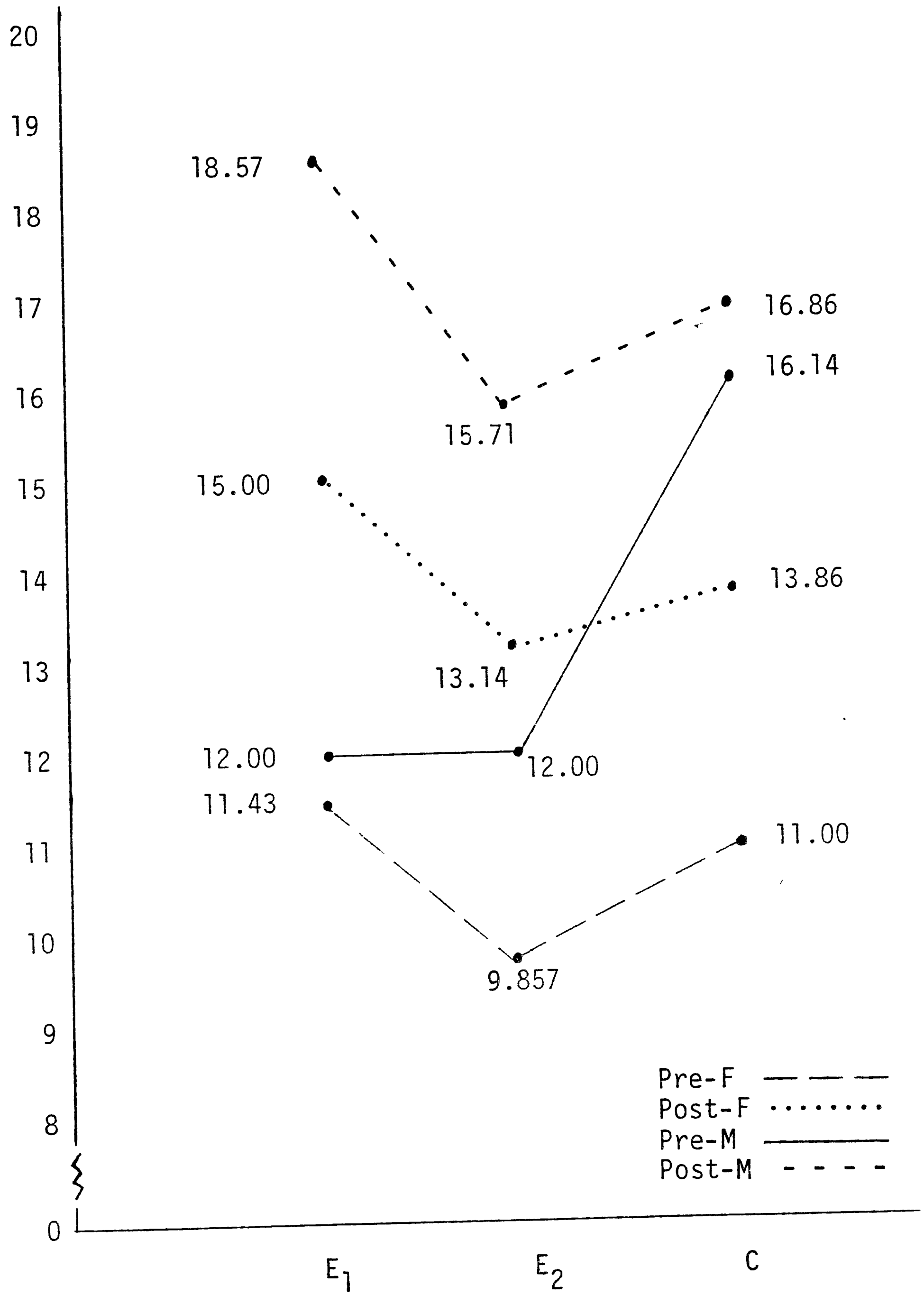

Figure 6. Group and Sex Means for the Pretest and Posttest on the MST

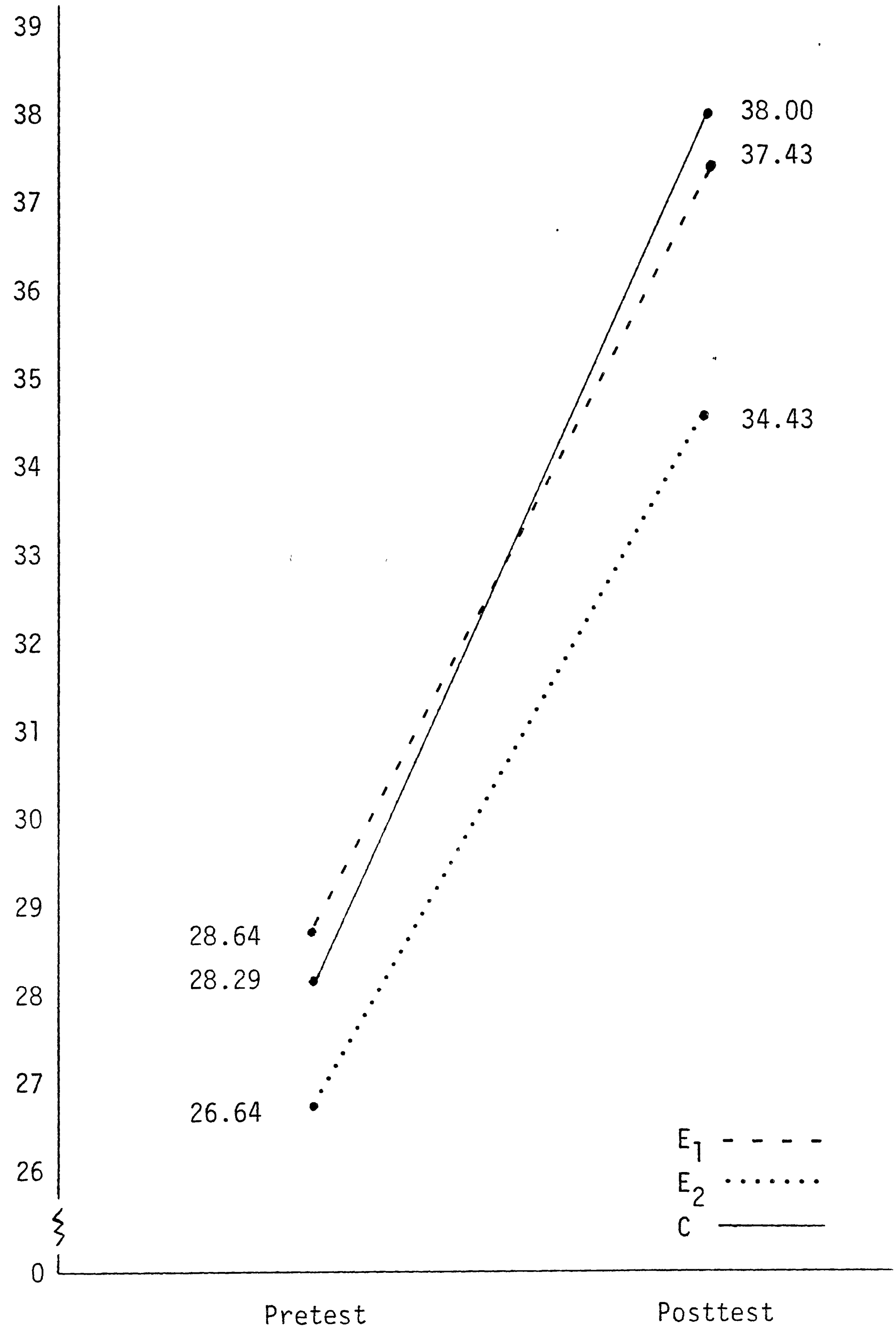

Figure 7. Group Means for the Pretest and Posttest on the JETGA

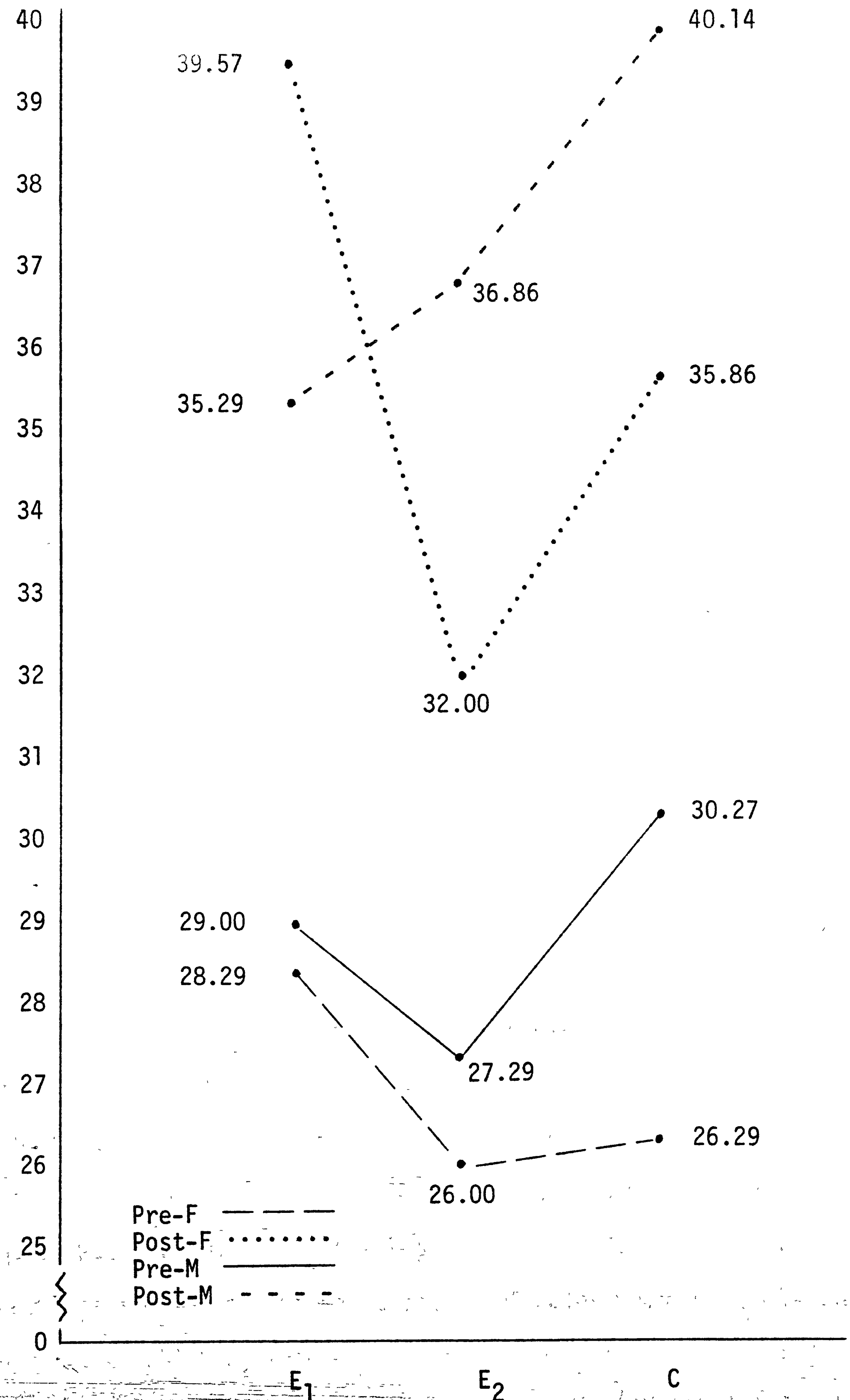

Figure 8. Pretest and Posttest Means for Males and Females by Groups on the JETGA

IARS Results

The ANOVA of the IARS scores revealed a strong sex effect having an F ratio of 10.37, $p = .003$. This statistically significant main effect must be interpreted in light of the significant three-way interaction between time of measurement by treatment groups by sex (P X G X S). Figure 9 is a graph of the cell means of females and males on the pretest and posttest. The significant sex difference results from females having higher internal control for success than males as indicated by scores on the IARS instrument. Figure 10 is a graph of the cell means of the groups on the IARS instrument and Figure 11 is a graph of the pretest and posttest cell means of males and females in the three groups. This three-way interaction has an F ratio of 5.43, $p = .009$. When specific comparisons were made using scores on the IARS there was a significant effect for only the control group (IARS at C X S on Table X). The control group, however, did not yield a significant result when an interaction of sex and time of measurement was examined (IARS at C X S X P) whereas the results for both E_1 and E_2 groups did reveal a significant interaction (IARS at E_1 X S X P and IARS at E_2 X S X P).

The difference between the means for females and males in the control group is larger (14.14 and 10.57) on the pretest than on the posttests (13.43 and 12.00). The means for E_1 and E_2 show the opposite effect of being more similar on the pretests (E_1 females mean was 13.43 and E_1 males was 13.14 while E_2 females mean was 13.43 and E_2 males was 12.71) but less similar on the posttests (E_1 females mean was 14.14 and E_1 males was 11.14, while E_2 females was 14.86 and E_2 males was 11.57). The sex difference that existed overall became greater as the females have

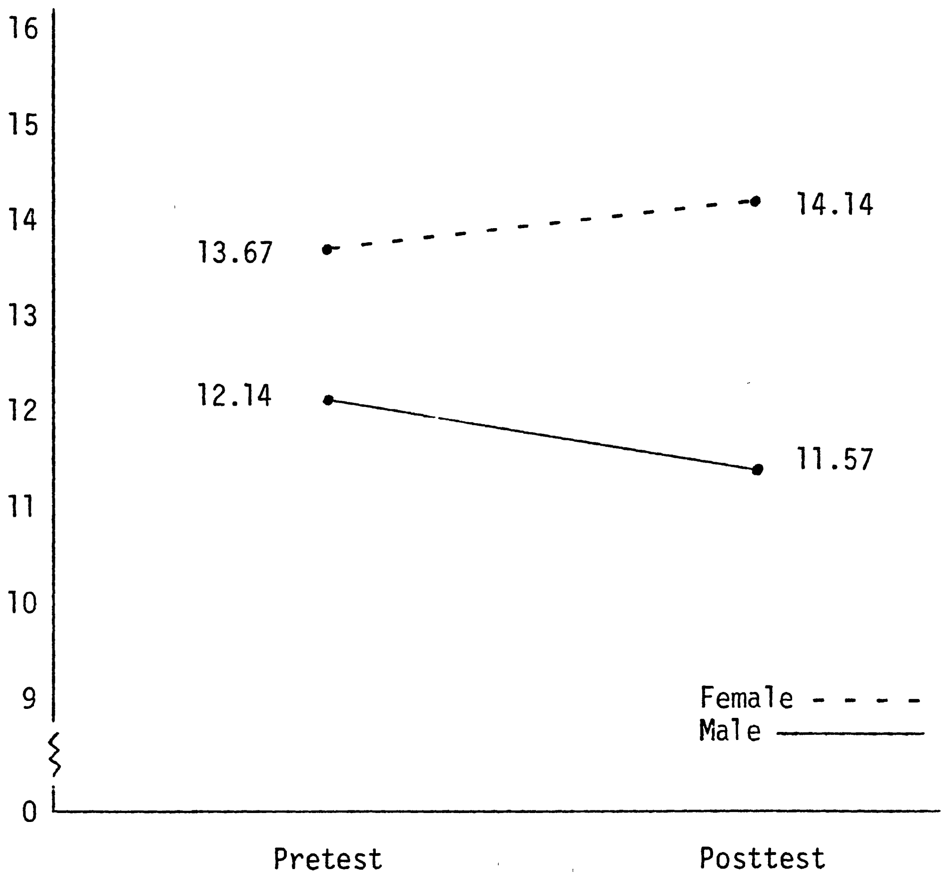

Figure 9. Male and Female Means for the Pretest and Posttest on the IARS

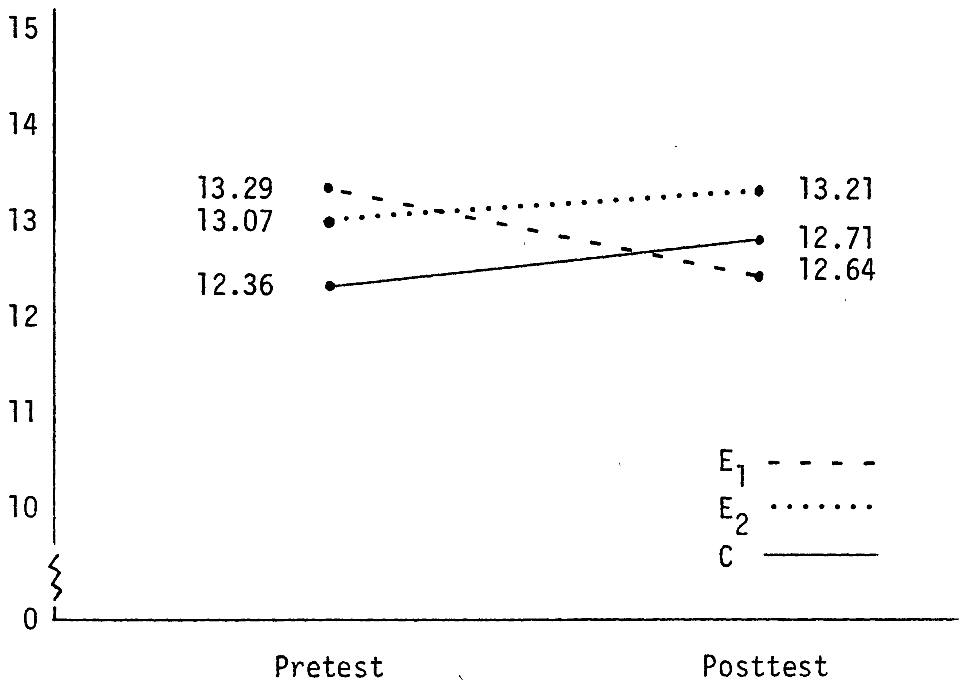

Figure 10. Group Means for the Pretest and Posttest Internalizing Success on the IAR

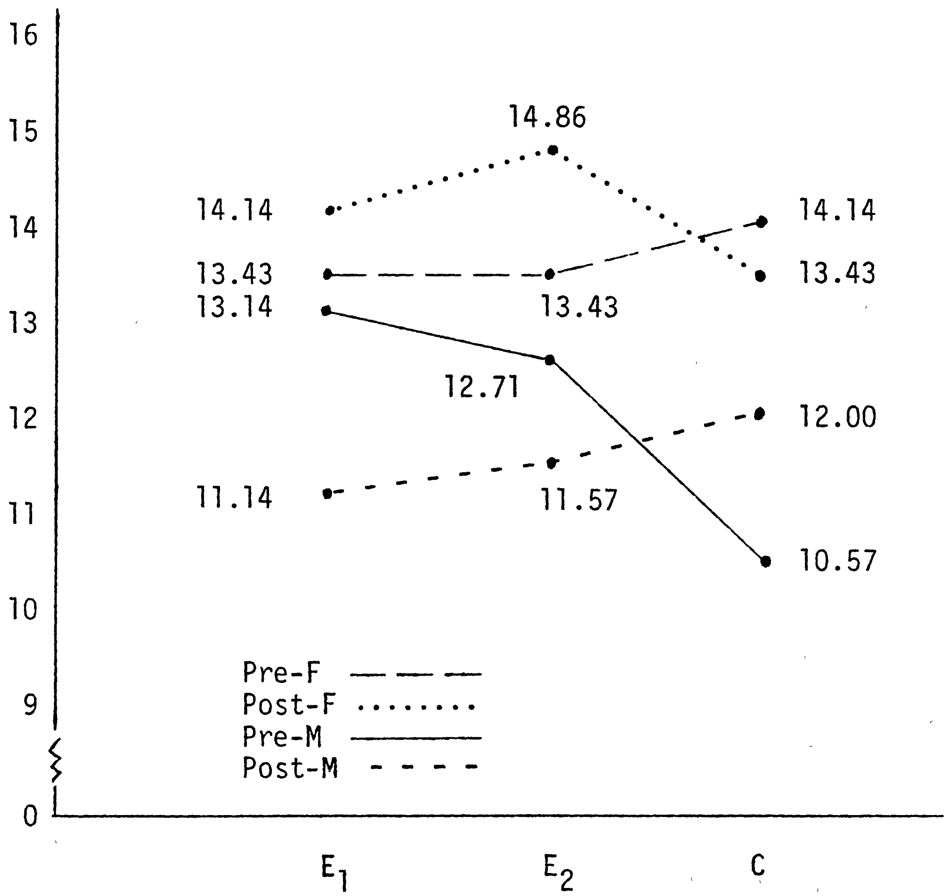

Figure 11. Male and Female Means on the Pretest and Posttest by Groups on the IARS

even larger means than the males. Obviously, the two treatments had an effect on males and females that was not replicated in the control group.

IARF Results

The ANOVA of the IARF data indicated a statistical significant main effect for sex, therefore contributing to the overall sex difference. The specific comparisons on the pretest and posttest revealed a significant sex difference on the posttest but not on the pretest. The graph of cell means in Figure 12 illustrates this overall sex difference. As on the IARS instrument, females are more internal than males.

The graph of cell means in Figure 13 also helps explain the significant two-way interaction between time of measurement and sex that was detected on the ANOVA of the IARF results. Specific comparisons indicate that the time of measurement at female (IARF at female X P) is not significant while time of measurement at male (IARF at male X P) is significant.

The graph of cell means in Figure 14 illustrates how the sexes within the groups responded on the IARF. There are sex differences in all the groups with females remaining more internal. Specific comparisons indicate that the differences in the scores of females and males are greater on the posttest than on the pretest. Since the females in the E_1 group and the males in the control group have similar means on the pretest and the posttest, respectively, there is no significant interaction involving these groups. The females in the E_1 group had a pretest mean score of 12.14 while the posttest mean score was 12.00, and the males in the control group had a pretest mean score of 10.57 and a posttest mean of 10.43. However, specific comparisons did reveal a

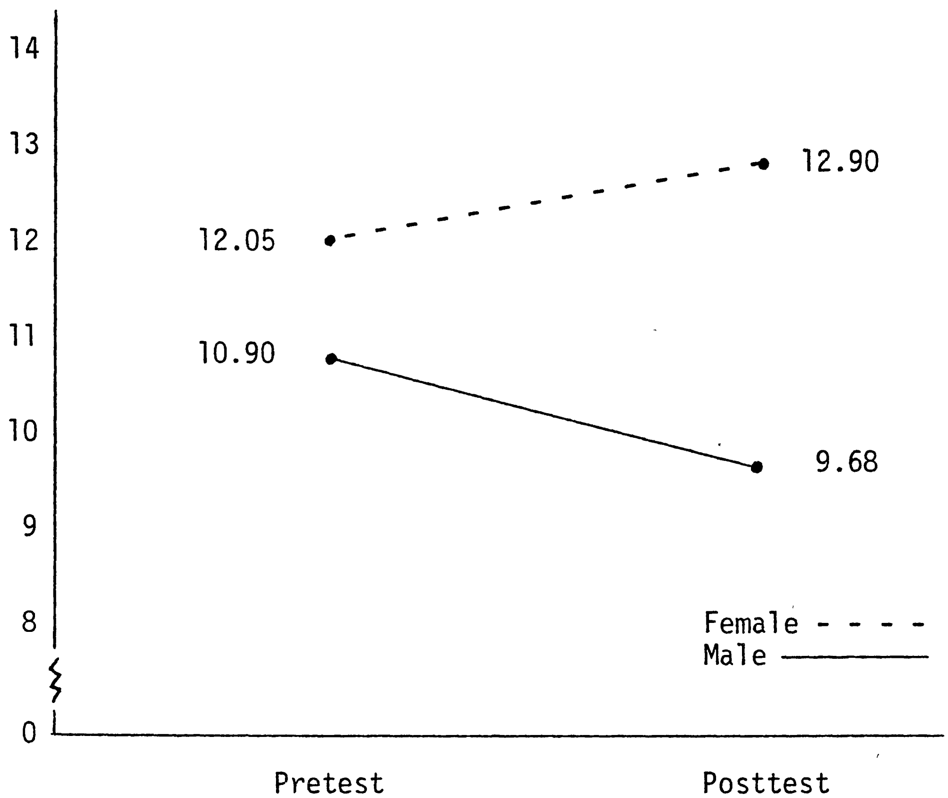

Figure 12. Male and Female Means on the Pretest and Posttest for the IARF

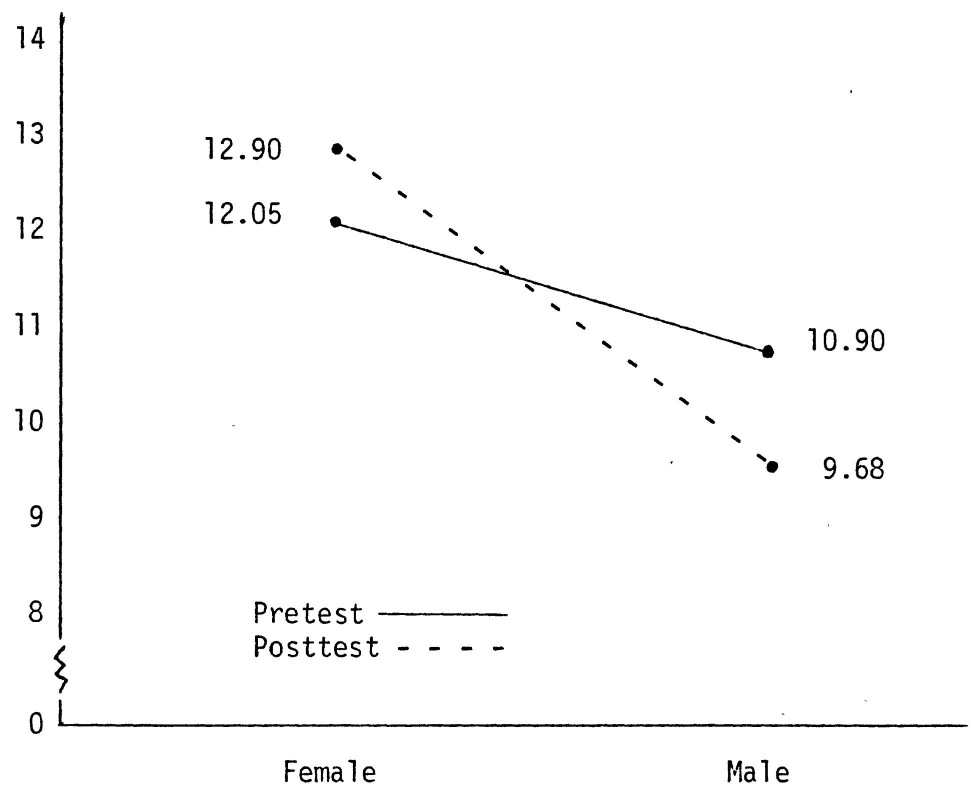

Figure 13. Means for Females and Males on the Pretest and Posttest for the IARF

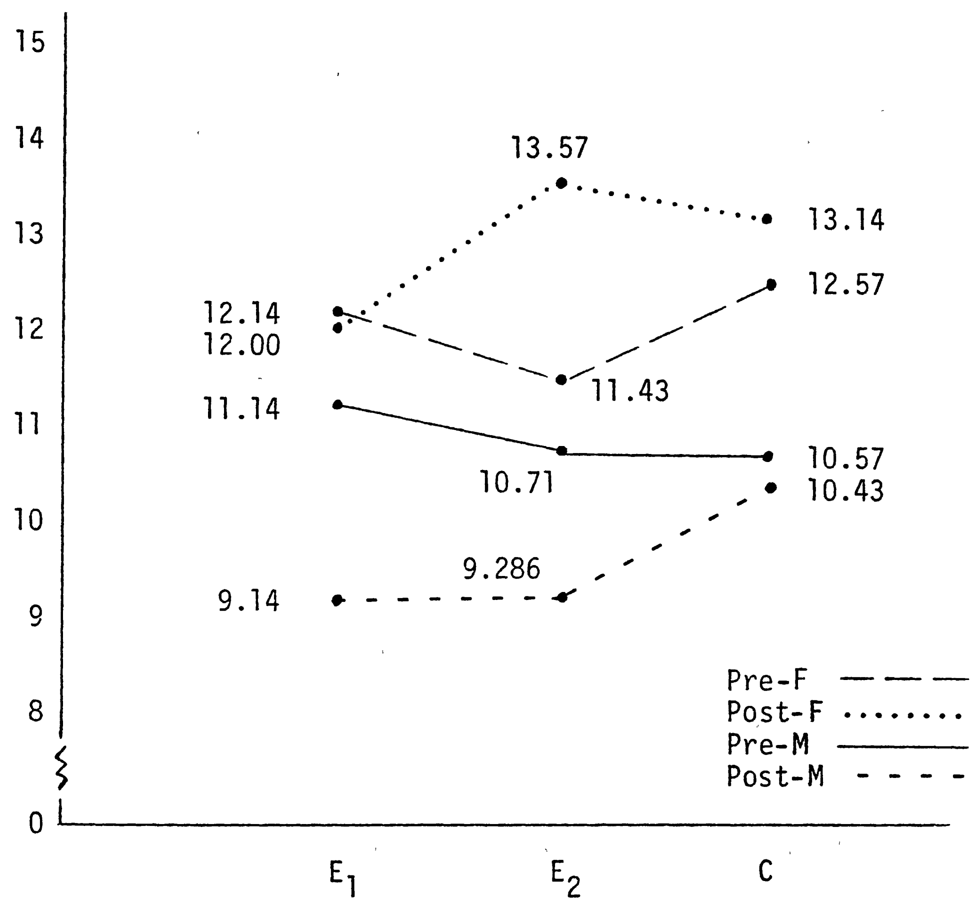

Figure 14. Means for Females and Males on the Pretest and Posttest by Groups on the IARF

significant interaction for sex and time of measurement at E_2 (IARF at E_2 X S X P). Figure 11 illustrates this interaction as females show an increase in internality while males decrease in internality.

Conclusions and Implications

This study did demonstrate that significant improvement in geometry achievement can be made through instruction. Since the National Assessment for Educational Progress (Carperter et al., 1975) pointed out the weaknesses of students in geometry, it is helpful to know that significant changes can be made. This study also demonstrated that this improvement in achievement can come about by using the traditional textbook materials along with manipulatives. If geometry achievement is measured on a paper and pencil test similar to the JETGA, it is important to note that achievement scores can be increased with instruction such as was outlined in the design. However, what is not known, is how much the use of manipulatives contributed to the increase in the achievement scores, or if the sole use of textbook materials would also bring about that achievement.

The supplementary work on the computer does not appear to have a differentiating effect on all the students or on the two sexes, since the data indicated that all groups and both sexes increased significantly from pretest to posttest. This finding can be an important implication for educators making decisions on what software to use in the elementary school classroom. Schools purchase software under "instructional materials" and typically allocate $20 per student. For the $20, schools can get 1000 hours worth of curriculum in printed materials. A typical software package is good for 100-200 hours of student use and costs between $20 and $70; therefore, to be competitive with traditional materials, a software package should cost only $2 to $4 (Luehrmann, 1984). However, since Logo can be in constant use, its cost per student hour is much less than other educational software. As reported, the students in the Logo treatment group made significant gains in geometry achievement from pretest to posttest. This occurred even though the geometric topics covered in Logo were less directly related to the textbook materials than were the CAI programs which were directly matched to the geometric topics taught in the mathematics class. Students in the Logo group worked through specific materials and topics, but were also encouraged to explore the potential of the language. Therefore, not only can Logo be used as a programming language for thinking and problem solving skills, but it can be integrated into the curriculum to supplement traditional instruction in geometry as effectly as CAI can.

The results of this study support previous research (Guay and McDaniel, 1977; Moses, 1982; Sherman, 1980; Wattanawaha and Clement, 1982) that indicates an existence of a sex difference in spatial visualization ability. Several research studies have indicated only a sex difference for high spatial tasks (Wattanawaha and Clements, 1982; Guay and McDaniel, 1977). The Monash Spatial Visualization Test contains items of two and three dimensionality, but no firm conclusions can be drawn from this study on the nature of the sex difference regarding dimensionality since no item analysis was performed. However, since there were thirteen two-dimensional items and seventeen three-dimensional items, the existing sex sifference was likely on both types of items.

Even though the initial sex difference continued after the treatment, the fact that time of measurement was significant for both females and males is encouraging to educators. An appropriate intervention can be used to affect a difference in students' spatial visualization ability. Indicators are that both of the treatments were effective in increasing spatial visualization whereas students in the control group did not increase their spatial visualization skills as much. Although the time of measurement by groups (P X G) was not statistically significant ($p > .05$), the educational implications are that there could be differences at which the small sample size only hinted. When specific comparisons were made, both E_1 and E_2 groups showed a significant effect for time of measurement, but the control group did not. A further specific comparison revealed a significant interaction for groups at male by time of measurement. A graph of the cell means indicated that this was a result of the males in the control group having a large mean (16.14) on the pretest and gaining very little on the posttest (16.86). At the same time, the males in the E_1 group had the same means as the males in the E_2 group on the pretest (12.00) and both gained significantly with the males in the E_1 group gaining more than the males in the E_2 group. With a larger sample, the differences that existed among males on the pretest would be less of a concern, and the power of the test to reject the null hypothesis would be greater since the degrees of freedom depend upon sample size.

We can conclude that for both females and males the CAI and Logo treatments were effective in improving spatial visualization. It would be difficult to determine specific software from the CAI treatment that was responsible for the improvement in spatial visualization. However, we do know that Logo was effective in improving spatial visualization through its supplementary use in teaching geometric concepts. These positive findings for the use of Logo is exciting news for the classroom teacher who is looking for spatial activities which will generalize easily into the mathematics curriculum. It is not necessary to expend a great deal of time and energy searching for appropriate software that can be integrated into the curriculum for the purpose of improving spatial visualization when a single piece of software, Logo, has been proven to be effective. Logo provides a "mediated experience" between the student and the environment (Feuerstein, 1980) that enhances spatial visualization ability.

Both Moses (1980) and Sherman (1980) related the importance of improving the spatial visualization skills of females; therefore, these findings on the use of Logo in the classroom have significant educational implications for females. Sherman (1980) found that spatial visualization ability correlated with confidence in learning mathematics and predicted mathematics performance in geometry for both females and males, but was a better predictor for the females. Therefore, the use of Logo may contribute to success and confidence in learning mathematics through the improvement of spatial visualization ability. This may be even more important for females because of Fennema's (1982) reports of females having less confidence in learning mathematics.

Analyses of data collected using both the JETGA and the MST indicated a main effect for time of measurement and all groups of students increased their mean scores. Therefore, it can be concluded that instruction in geometry assisted the students in developing a concept of space within the curriculum in a manner suggested by Martin (1976). Since the

Logo group significantly improved in both geometry achievement and spatial visualization ability, it appears that Logo is indeed an effective supplement for the teaching of geometric concepts and for increasing spatial visualization. Even though the CAI group also improved in geometry achievement and spatial visualization, Logo can be more easily integrated into the mathematics curriculum because it is often difficult to find quality software to augment the curriculum. The CAI software used in the study was not necessarily chosen for the quality of the programs, but rather were state-of-the-art programs most likely used in a typical classroom.

The Logo treatment used in this study demonstrates a method of developing spatial visualization ability which is carefully planned and organized into the teaching of geometric concepts, as Yakimanskaya (1978) suggests should be done. Therefore, for the classroom teacher, Logo provides an efficient and effective means for integrating microcomputers into the elementary mathematics curriculum to produce achievement in geometry while improving spatial visualization skills. As a result of conducting the study, the investigator concludes that a longer treatment period along with more teacher questioning would have produced a significant group effect favoring Logo.

The significant sex difference on both locus of control measures (IARS and IARF) provides revealing information for educators. The results from this study support research indicating females have a more internal feeling for responsibility than males, especially from grade 6 upward (Crandall and Lacey, 1972). Although Crandall and Lacey did not report a significant sex difference, results of this study indicate a significant main effect for sex on both the success and failure subscales of the IAR.

Locus of control appears to be a developmental construct, since students' responses tend to become slightly more internal with age. In the study by Crandall et al., (1965), girls did not show a significant increase in the IARS scores, but did significantly increase on their IARF scores. In this study, there was no significant main effect for time of measurement for the IARS or IARF scores, indicating all students did not become internal as a result of time.

Instead, the overall significant sex difference must be viewed in light of the fact that there was a significant interaction for time of measurement by groups by sex on the IARS. For females in both the E_1 and E_2 groups, there was an increase in the internal feelings for success while the males in these two groups experienced a decrease. In the control group the females felt less responsible for their success and the males felt more responsibility.

There could be several reasons for the group by sex by time of measurement interaction. Taking the societal situation with computers along with the investigator's observations, a possible explanation is proposed. Several recent articles have described the existing situation in microcomputer usage and addressed the equity issue (Alvarado, 1984; Anderson, Welch and Harris, 1984; Becker, 1983-1984; Fisher, 1984; Gilliland, 1984; Lockheed and Frakt, 1984; Marrapodi, 1984; Miura and Hess, 1984; Sanders, 1984; Schubert and Bakke, 1984; Watt, 1984a). The agreement is that there are no sex differences in interest and understanding of microcomputers, but the difference exists in access and use. "By male selection and female default the computer becomes defined as 'male turf'" (Lockheed and Frakt, p. 17). In the early elementary years, youngsters start out with equal access, but after a few years, boys outpace girls and by seventh grade there is an overwhelmingly male representation. As reported by Becker (1983-1984), one-half of first grade students learning to program computers were boys, two-thirds of sixth graders were boys and four-fifths of ninth graders were boys.

The environment in which this study was conducted was not unlike the Educational Testing Services study that found that only 8% of the girls ever used the school's computer outside of classes while 60% of the boys used the computer on their own, before or after school (Sanders, 1984). In the study presented here, every student had equal access to the computer and the amount of time on the computer was controlled as much as possible. Therefore, females who may not have interacted with the computer prior to this study were now in a situation where their time on the computer was equal to every other student.

This equal access did not have the same effect on all females, however, as the females in the control group decreased in their feelings of success while all the other females increased. Girls tend to prefer cooperation where they can work together to solve a problem or do a project (Sanders, 1984). The students in both the E_1 and E_2 groups were given this opportunity. The E_1 group used software that was primarily tutorial or drill and practice with no competitiveness or gender orientation built in and the simulation and game software was instructional and problem solving in nature. The E_2 group used Logo, which allows for cooperative programming and the use of imagination. Indications that Logo appeals to females comes from a study by Fisher (1984) where 50% of the students in a Logo class were girls while only 30% of the students in a BASIC class were girls. However, the software used in the control group was often in a competitive game format and some programs had games of various sports as a motivator to do math computation. The gender-orientation and the built-in competitiveness of the software in the control group obviously produced feelings within the females that were reflected in a decrease in their IARS scores.

The results indicate there was a feeling of success for the females in the E_1 and E_2 groups where they saw a relevance for their interaction with the computer and could relate to the cooperative mode. However, it appears that the females in the control group did not see any relationship with what they were doing on the computer to their mathematics class and had negative reactions to the competitiveness of the software. Comments made by the students and observations by the investigator support this conclusion. One female student in the control group commented that she was anxious to see the study terminated so she could learn something besides "how to push return".

The results of the analysis of the IARF scores, on which there was a significant two-way interaction for time of measurement by sex, indicate a differentiating change from pretest to posttest for the sexes. Females responded more internally than males before the treatment and after the treatment the sex difference was significantly greater. Although the group by sex interaction was not significant, specific comparisons did indicate that the sexes differed significantly on time of measurement for E_2, as is shown on Figure 14. The females in the E_2 group responded more internally while the males responded less internally for failure after the treatment. The females in the E_1 group seemed unaffected and the males internalized failure less, while in the control group, the males seemed unaffected and the females internalized failure more.

Other than the fact that Crandall, Katkovsky, and Crandall (1965) reported that females increased their IARF scores during this age, no other firm conclusions can be drawn because no three-way interaction of time of measurement by group by sex was significant. It might be noted that the males in both the E_1 and E_2 groups internalized success and failure less after treatment while the females in E_2 internalized both success and failure more after the treatment. The females in E_1 became more internal for success but not for failure. In the control group, females internalized failure more and success less while the males internalized success more and had no change on their failure. The interaction with the computer that females had in the control group seemed to be detrimental, but males seemed to respond reasonably well to the software used in the control group. This is probably due to the game-like competition that males seem to enjoy.

The conclusions reached from the results of this study have several implications for education. The significant increase in females internality for success in the CAI group and the Logo group and decreases in the control groups cannot be overlooked in today's increased emphasis on using computers in education. Strickland's (1977) summary of locus of control and an individual's perception may help explain the students' behavior in this study:

> When an individual perceives oneself as powerless and unable to influence events, one's beliefs may become more external. When things appear to be going well and this positive state of events is perceived as contingent on one's own effort, internality increases (p. 259).

One could conclude that the females in the control group felt powerless while the females in the E_1 and E_2 groups felt positive about their experiences.

The total internal score was not used in the analysis because it combines self responsibility for success and for failure and may have masked important differences. Researchers (Messer, 1972; McGhee and Crandall, 1968) reported conflicting results on the differentiating predictability of the success (I+) and failure (I-) scores for females and males. However, Crandall, Katkovsky and Crandall (1965) have shown that the total internal scores correlated positively and significantly with almost all achievement test measures.

Although the total internal score was not used in the analyses of this study, the experiences females had in the Logo group were reflected in an increase in both their internal score for success and for failure. Self-responsibility seems to be a motivational factor in achievement performance; therefore, a student who feels responsible for her successes and failures should show greater initiative and have persistence. In fact, Dweck and Rupucci (1973) did find that those children who did not persist in the face of failure took less responsibility for their success and failure. Can we then deduce that children who take responsibility for their success and failure will be more persistent? This becomes a powerful message to educators in light of the concerns Fennema (1982) has issued regarding females lack of persistence in mathematics. If Logo can provide a means for increasing the internality of females, which in turn may provide greater initiative and persistence in mathematics, we have a tremendous educational opportunity before us. This could improve females' success in mathematics, especially if females see any relationship between their success in Logo and their success in mathematics. By supplementing the teaching of geometric concepts with Logo, the relationship between success in Logo and mathematics will be more evident to females.

We can also conclude that the increased feeling of responsibility and personal control can be a reflection of females feelings of control of Logo in creating their own language. Inherent in the use of Logo in the classroom is a means for allowing students a feeling of being in control of their learning. The results of this study suggest that Logo has provided females with an interaction with the computer that is less intimidating and more under their control than previous experiences which is then reflected in their locus of control. The fact that the females in the CAI group also took more responsibility for their success, implies that positive outcomes result for females when they gain equal access to relevant computer experiences. This impresses upon educators the need to ensure that all students have equal access and that computer activities are well chosen to provide relevant experiences. Therefore, if all children are introduced to computers and have equal access, females should be as well-qualified in the computer profession as males are. Unfortunately, the world of computing is still primarily dominated by males and females are not leaving school with the same computer proficiency as males. Women hold 60% of the nonprofessional computer jobs, but only 17% of the professional positions (Watt, 1984a). Females need to be encouraged to pursue computing as a prerequisite for careers in technology. Since both programming and application programs prepare students with skills in our technological society, females need to have exposure to both so that the norm in society does not become computers for females versus computers for males. Kolata (1984) has suggested that elementary school teachers are the key for getting females involved with computers. This study has shown that through the use of Logo in the elementary school classroom, females can be introduced to programming in a manner that produces success feelings. Therefore, if females have successful experiences in the elementary school, the likelihood of females continued participation in programming courses may extend beyond the elementary school years.

In this study, Logo has been shown to produce feelings of success for females and was effectively integrated into the elementary mathematics classroom to produce improvement in geometry achievement and spatial visualization for all students through its supplementary use in teaching geometric concepts. At the same time, programming experiences were provided for all students in the classroom. Even though the CAI treatment group was found to be an effective means for improving geometry achievement and spatial visualization and also produced some feelings of success for females, there was no comparison in the enthusiasm and interest between the CAI and Logo groups. The contrast in the enthusiasm shown by the groups was especially evident among the females, but was also present among the males. Since each of the three groups was assigned to use one of the computers, it was easy to observe the atmosphere present in each of the three groups. While both the E_1 and the control group tended to have a subdued and, at times, bored atmosphere, there was a sense of stimulation and even electrified excitement coming from the Logo group. The control group produced some feelings of success for males, but not for females, and both females and males in the control group repeatedly voiced a feeling of a lack of challenge in the software. Logo does indeed provide an exciting challenge for students while remaining nonthreatening by allowing students to progress at their own developmental level.

Most teachers do not have the time to develop new curriculum and prepare additional materials. Since children can basically develop their own Logo language, it can be used with little extra preparation of curricular materials. However, teachers do need to learn the Logo language so they can teach the necessary Logo programming before integrating it with a subject matter. The classroom teacher's investment in time and energy comes in the scheduling process, in the physical organization of the classroom to provide a positive Logo environment, and in knowing when and when not to intervene in questioning to allow students opportunities to develop confidence while offering help and direction at appropriate times. Teachers have experience in how to provide for individual learning in the classroom and have an understanding of and experience with how children learn that can prove invaluable in integrating Logo into the classroom.

Both the philosophies of Papert (1980) and the Edinburgh research work (Howe, O'Shea, and Plane, 1980; Boulay, 1980; Ross and Howe, 1981) were employed in this study. Logo was integrated into the curriculum to supplement the teaching of mathematics while at the same time students were given freedom to explore and discover the potential of the language. Students seemed to appreciate the direction the written materials gave them, as well as the group instruction time to discuss the mathematical concepts involved. By learning to program Logo using a geometrical context, students learned to control their programming tool while seeing some relevance in their efforts. It is likely that females' need for relevant experiences was found in the use of Logo to learn geometric concepts, whereas previous experiences of programming in BASIC were seen as programming for its own sake; and therefore, not as useful. However, students did not hesitate to use Logo in a creative and imaginative manner for discovery in developing projects and students' individual styles were still evident in their own work.

For educators searching for a means of integrating microcomputers into the curriculum, this study has demonstrated the use of Logo for the supplementing of geometry. Both the cognitive and affective domains were found to be significicnatly affected by the use of Logo. Students using Logo significantly improved in both geometry achievement and spatial visualization ability, while females also had significant increases in their internal feelings of personal control for successes and failures in achievement situations. Therefore, the use of Logo in the elementary school classroom has been shown to have positive outcomes and should, in some way, be integrated into the elementary school curriculum.

Recommendation for Further Study

This study raised many questions for which answers were not generated. Since no definite conclusions can be drawn from this study regarding the treatment groups as a main effect, further study should be done in which the use of manipulatives is controlled to examine their role in the increase in geometry achievement and spatial visualization. Also, questions regarding the effectiveness of Logo in comparison to other computer experiences on geometry achievement and spatial visualization were left unanswered. Since there was no significant main effect for the treatment groups nor interactions for the MST or JETGA, Logo appears to be as effective as the other two means of interactions with the computer. The effectiveness of Logo could be studied further by teaching the students programming in Logo for a longer period of time before the applications to geometric concepts. In this study too much time was needed to familiarize the students to Logo and teach them programming techniques, therefore the time left for specific geometric concepts was limited.

Within this study, it should be investigated as to the manner in which internals reacted differently from externals. Also, the IAR should be explored further to determine within success and failure if students are attributing their feelings to ability or effort. This especially is important for the Logo group where females responded more internally for success and for failure while males' responses became less internal for both success and failure.

The main effect for sex on the MST should be looked into further to determine if it holds true for both two-dimensional and three-dimensional tasks. Since the data indicates a high correlation between the MST and the JETGA, it would be informative to examine that correlation on two-dimensional versus three-dimensional tasks.

Although many of the variables were controlled, there were others beyond the researcher's control. Therefore, it is recommended that the study be replicated with a larger sample over a longer treatment period of time. The differences found on the IAR, indicate that some significant changes occur in locus of control due to the type of intervention. As a result of the changes recorded in this study, the locus of control construct should be studied further as both a predictor of success and in light of the changes that occur as a result of a variety of instructional environments. If we can make a difference in students' locus of control and that difference affects their performance in the classroom, as well as their interactions in the world around them, we need to explore further the types of learning environments that bring about those desirable changes.

No doubt, the most important issue needing further study is that of computer equity. The significance of the females in the control groups decreasing in their success feelings in this study should be further explored in light of Dweck and Bush's (1976) reports that girls have a greater tendency to avoid situations in which failure is likely and to show decreased achievement strivings under failure. It has been shown in this study that some computer experiences produce feelings of success and some produce feelings of failure and those feelings are different for females and males.

There is a need for research to determine further what effect computer usage has on the affective domain as well as the cognitive. The effects of Logo, CAI, and gamelike educational software have been examined in this study. What about BASIC and other programming languages, as well as application software? Would programming in any language have the same effect on locus of control?

Equal computer access is important to provide equal opportunities for equal educational outcomes for all students. But even more important is how the computer is used in the classroom. Dweck and Bush (1976) found that children of each sex responded to feedback from different agents in different ways, both in the way they interpreted that feedback and how it affected their performance. This appears to be just as true about the feedback students receive from the computer. Further research on what computer software and feedback will produce the best educational outcomes for students is needed.

Without appropriate uses of computers in the schools, we may be faced with the same issues of sex-related differences in computer education that have existed and are still reported in mathematics (Fennema, 1982). Females, more than males, have less confidence in learning mathematics, perceive mathematics to be less useful to them and attribute success and failures in mathematics differently. It is up to researchers and educators to assure that the same path is not taken by computer education.

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APPENDIXES

APPENDIX A

SAMPLE OF MATERIALS USED IN TREATMENT GROUPS

LIST OF GEOMETRY TOPICS AND MANIPULATIVES USED DURING THE STUDY

Week 1

Textbook Topics Covered in Math Class:

Line Segments
Rays
Angles
Perpendicular and Parallel Lines
Measuring Angles

Manipulatives Used:

DMP[a] D-Stix for activities on angles
DMP Geometric pieces for two-dimensional spatial skills and activities in the math learning center
Miras[b] for developing concepts of perpendicular and parallel lines

Week 2

Textbook Topics Covered in Math Class:

Polygons
Quadrilaterals
Perimeter

Manipulatives Used:

Pattern Blocks[c] in the math learning center for activities with polygons
Pattern Blocks for developing perimeter concept
DMP Geometric Pieces for polygon identification

Week 3

Textbook Topics Covered in Math Class:

Graphing
Triangles
- Identification
- Measuring Angles of Triangles
- Similar Triangles

Manipulatives Used:

Geoboards[d] for plotting points and used in the math learning center for activities on Triangles, Quadrilaterals, Polygons, Similarity and Circles.

Week 4

Textbook Materials Covered in Math Class:

Circumference of Circles
Slides, Flips, Turns
Symmetry
Congruency

Manipulatives Used:

String and common cylinders for developing concept of circumference
Mirror Cards[e] for symmetry
Miras and Pattern Blocks for symmetry and congruency

Week 5
Textbook Topics Covered in Math Class:

Area of rectangles, triangles and circles

Manipulatives Used:

Triangles and rectangles paper cutting activity from DMP
Graph paper to estimate area of circles
DMP geometric pieces to compare areas

Week 6
Textbook Topics Covered in Math Class:

Solid Figures
Rectangular Prisms
Faces, Vertices and Edges - Euler's Formula
Pyramids

Manipulatives Used:

Geoblocks[f] in math learning center to examine Triangular and Rectangular Prisms and discover Euler's Formula for Faces, Vertices and Edges

Week 7
Textbook Topics Covered in Math Class:

Volume of Rectangular Prisms
Surface Area
Review

Manipulatives Used:

Michigan State Spatial Visualization Unit using cubes and building plans[g]

[a]Developing Mathematical Processes. Wisconsin Research and Development Center for Cognitive Learning. Chicago: Rand McNally and Co., 1975.

[b]Mira Math For Elementary School Geometry. Palo Alto, California: Creative Publications, 1973.

[c]Pattern Blocks. Elementary Science Study Webster Science Division. New York: McGraw-Hill Book Co., 1970.

[d]Geoboard Activity Card Kit. New Rochelle, New York: Cuisenaire Company of America, Inc., 1971.

[e]Mirror Cards Reflection and Symmetry. Elementary Science Study Webster Science Division. New York: McGraw-Hill Book Co., 1974.

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[g]Middle Grade Mathematics Project. Department of Mathematics. Michigan State University, 1983.

LIST OF SOFTWARE USED BY E_1 TREATMENT GROUP

Week 1

Elementary Volume 8 - Geometry
Points and Angles
Minnesota Educational Computing Consortium (MECC)

Elementary Volume 9 - Geometry
Lines
MECC

Geometry and Measurement Drill and Practice Volume 2
Angles Drill
Apple Computer, Inc.

Week 2

Computer Math Activities Volume 2
Polygon Identification
Addison Wesley

Computer Math Activities Volume 5
Name That Shape
Addison Wesley

Moptown
Learning Company

Mathematics for the Middle School
Classification of Quadrilaterals
Microcomputer Curriculum Project (MCP)

Problem Solving Strategies
Diagonals and Squares
MECC

Week 3

Mathematics for the Middle School
Perimeter
MCP

Elementary Volume 9 - Geometry
Triangles
MECC

Mathematics for the Middle School
Classification of Triangles
MCP

Mathematics - Volume 3 Plane Facts About Geometry
Shapes
MECC

Gertrudes Puzzles
Learning Company

Week 4
Geometry and Measurement Drill and Practice Volume 2
Circle Drill
Apple Computer, Inc.

Mathematics for the Middle School
Circumference
MCP

Geometry
Circumference of a Circle
MCP

Week 5
Geometry
Line Symmetry
MCP

Bumble Plot
Learning Company

Mathematics for the Middle School
Plotting Points in the Coordinate System
MCP

Week 6
Mathematics for the Middle School
Area of Rectangles
MCP

Elementary Volume 10 - Geometry
Area and Perimeter
MECC

Mathematics Volume 3 - Plane Facts About Geometry
Rectangle, Square, Parallelogram, Trapezoid and Triangle Areas
MECC

Week 7
Mathematics for the Middle School
Volume and Rectangular Prisms
MCP

Geometry and Measurement Drill and Practice Volume 2
Volume and Area Quiz
Apple Computer, Inc.

Mathematics for the Middle School
Classification of Solids
MCP

Mathematics for the Middle School
Properties and Patterns - Solids
MCP

Week 8
Rocky's Boots
Learning Company

WORKSHEET FOR E_1 TREATMENT GROUP

Name____________________

SESSION 2

LINES

Use MECC Disk, Elementary Geometry Vol. 1.
Choose Program 1--Lines. Read and work through the program. Take the quiz.

Record your score.

Number of Questions__________

Number Correct__________

ANGLES DRILL

Use GEOMETRY AND MEASUREMENT Disk, Vol. 2.

Choose Program 2--Angles Drill. You will need a protractor and a pencil. Do all four of the options. Do five problems in each.

Record your score below.

Option 1--Estimating measure of angles in standard position.

Correct on first try________
Correct on second try________

Option 2--Measuring angles in standard position.

Correct on first try________
Correct on second try________

Option 3--Estimating the measure of angles in any position.

Correct on first try________
Correct on second try________

Option 4--Measuring angles in any position.

Correct on first try________
Correct on second try________

WORKSHEET FOR E_1 TREATMENT GROUP

Name____________________

SESSION 4, 5 and 6

MOPTOWN

Use the MOPTOWN disk. There are eleven programs on the menu. Do all eleven programs. Do them in order. Play each several times or until you understand.

Check the programs off as you complete them.

1. Make My Twin_________
2. Who's Different?_________
3. What's the Same?_________
4. Who Comes Next?_________
5. Moptown Parade_________
6. Who's Next Door?_________
7. Secret Pal_________
8. Change Me_________
9. Clubhouse_________
   (Play both single rule and double rule)
10. Moptown Map_________
    Score_________
11. Moptown Hotel_________
    (You will need an entire session for this program. Two players are required. Type in the players names as A and B. You will be both players.)

    Record the dollars earned below.

Player A_________

Player B_________

WORKSHEET FOR E_1 TREATMENT GROUP

Classification of Solids

1. Use diskette "Middle School - Disk #2".

2. Choose B - Classification of Solids.

3. Pick Option 1 - Review Terms.

4. Continue to the Next Section.

5. Have a pencil, eraser and ruler ready to do some sketches.

6. Follow directions and sketch a rectangular prism below--label the points as you sketch.

7. Sketch a cube 2 cm on a side.

8. Sketch another rectangular prism. Change your rectangular prism into a triangular prism by following the directions given.

9. Sketch a cylinder below by following directions.

10. Sketch a pyramid below. Follow directions by beginning with a rectangular prism.

11. On the Layout Pattern of Solids, you were correct on your first try_________times.

LOGO RESOURCES USED TO ASSEMBLE BOOKLETS

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Bearden, Donna, Kathleen Martin and Jim Muller. _Turtle Sourcebook_. Reston, Virginia: Reston Publishing Co., 1983.

Bitter, Gary and Nancy Watson. _Apple Logo Primer_. Reston, Virginia: Reston Publishing Co., 1983

Daugherty, G., D. Larrabee, P. Likely, and M. Swang. _Try It and See_. Brighton Central Schools, Summer, 1982.

Minnesota Educational Computing Consortium. _Apple Logo in the Classroom_. St. Paul, Minnesota: February, 1983.

Moore, Margaret L. _Geometry Problems for Logo Discoveries_. Palo Alto, California: Creative Publications, 1984.

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Papert, Seymour, Daniel Watt, Andrea diSessa and Sylvia Weir. _Final Report of the Brookline Logo Project_. Cambridge: MIT Logo Memo #53, September, 1979.

Ross, Peter. _Introducing Logo_. Reading, Massachusetts: Addison-Wesley, 1983.

Thornburgh, David. _Discovering Apple Logo_. Reading, Massachusetts: Addison-Wesley, 1983.

Watt, Daniel. _Introducing Turtle Geometry Student Activities Booklet and Teacher's Guide and Background Information_. Logo Curriculum Materials Specially Adapted for the Brookline Public Schools, June, 1981.

Watt, Daniel. _Learning with Apple Logo_. New York: McGraw-Hill, 1984.

LOGO TOPICS FOR THE E_2 TREATMENT GROUP

Getting to know the Turtle
Talking to the Turtle in the immediate mode
Typing hints and correcting errors
The Print command
Ways of using the screen-splitscreen, fullscreen, text
Exploring the turtle screen
Predicting Turtle tracks
Turtle obstacle course and mazes
Drawing shapes with the Turtle - squares
Turtle Turnabout - Total Trip Theorem
Turtle tricks - HT, ST, PU, PD
Drawing triangles and stars - external angles
Using REPEAT to make patterns
Predicting with REPEAT
Choosing colors for the Turtle's ink and for the background
Initializing a disk
Defining procedures
Learning new commands - POPS, POTS, ERALL
Using DOS commands - SAVE, CATALOG, LOAD, ERASEFILE
Editing procedures
Using subprocedures as building blocks
Discovering designs and creating projects
Using variables to change the size of shapes
Calculating polygons
Curves and circles
Making projects using circles and arcs
Making repeating designs with recursion
Turtle projects

ASSIGNMENT FOR E_2 TREATMENT GROUP

Logo Assignment Using Geometry

Write Procedures that will do each of the following and then save them under the file names:

ASSIGNMENT I

ASSIGNMENT II

ASSIGNMENT III

ASSIGNMENT IV

ASSIGNMENT V

ASSIGNMENT I

1. Write a procedure TO RIGHT.ANGLE that will draw a right angle and print below it "This is a right angle. It measures 90 degrees."

2. Write a procedure TO ACUTE.ANGLE that will draw an acute angle and write below it "This is an acute angle. It measures less than 90 degrees."

3. Write a procedure TO OBTUSE.ANGLE that will draw an obtuse angle and write below it "This is an obtuse angle. It measures more than 90 degrees."

4. Write a procedure TO INTERSECT.LINES that draws two or more intersecting lines.

5. Write a procedure TO PERPENDICULAR.LINES that draws perpendicular lines that form right angles.

6. Write a procedure TO PARALLEL.LINES that draws parallel lines.

7. Save these procedures under the file name of ASSIGNMENT I.

ASSIGNMENT FOR E_2 TREATMENT GROUP

Assignment III

1. Write a procedure that draws a square with 50 turtle Steps (TS will represent Turtle Steps) on a side.

   What is the perimeter of the square?____________

   What is the area of the square?____________

   (Draw it on graph paper if you need help)

2. Write a procedure that draws a square with 70 TS on a side.

   The perimeter is____________

   The area is____________

3. Write a procedure that draws a rectangle with dimensions of 7 TS by 3 TS.

   The perimeter is____________

   The area is____________

4. Write a procedure that draws a rectangle with dimensions of 5 TS by 4 TS.

   The perimeter is____________

   The area is____________

5. Write a procedure that draws an equilateral triangle with 60 TS on a side.

   The perimeter is____________

6. Write a procedure that draws an equilateral triangle with 30 TS on a side.

   The perimeter is____________

7. Write a procedure that draws an Isosceles traingle with two of the sides 40 TS and then use HOME to draw the third side.

8. Write a procedure that draws an Isosceles traingle with two of the sides 65 TS and then use HOME to draw the third side.

9. Write a procedure to draw a Scalene triangle.

10. Write a procedure to draw a Regular Pentagon with sides of 50 TS.

The perimeter is____________

11. Write a procedure to draw a Regular Hexagon with sides of 35 TS.

The perimeter is____________

12. Write a procedure that draws an Acute triangle. Print at the bottom "An acute triangle ..... (you complete the definition).

13. Write a procedure that draws an Obtuse triangle. Print "An obtuse triangle .....

14. Write a procedure that draws a right triangle. Print "A right triangle .....

15. Write a procedure that draws a right triangle with sides of 30 TS and 40 TS.

16. Write a procedure that draws a triangle with angles measuring 35 degrees and 120 degrees.

What will the measure of the third angle be?____________

17. Write a procedure that draws a triangle with angles measuring 40 degrees and 60 degrees.

What will the measure of the third angle be?____________

18. Save these procedures under the disk file name of ASSIGNMENT III.

ASSIGNMENT FOR E_2 TREATMENT GROUP

Assignment V

1. Use the following procedure to draw a right triangle:

```
TO RIGHT.TRI
FD 30 RT 90 FD 30 RT 135 FD 42
END
```

2. Write a procedure that uses the procedure RIGHT.TRI to do a turn, slide and flip.

3. Write a procedure to draw a square 30 TS on a side.

   The area is___________

4. Edit the procedure to draw a diagonal in the square by using RT 45 FD 42.

   What is the area of each of the triangles formed by the diagonal?

   ____

5. Write a procedure to draw a figure which is symmetrical. Edit the procedure to draw the line of symmetry.

6. Write a procedure to draw 2 pairs of congruent figures.

7. Save these procedures under the disk file name ASSIGNMENT IV.

8. BE SURE TO LEAVE YOUR DISK IN THE FILE BOX FOR ME TO CHECK.

WORKSHEET FOR CONTROL GROUP

Fractions

1. Use Diskette "Middle School Disk 4"

2. Choose "A Common Fractions - Concept Building"

3. Do (1) Introduction

4. Choose (1) Continue

5. Choose (4) Exit the program after going through the Introduction, Parts of One, and Naming the Fraction Model.

6. Choose "B Common Fractions - Equivalent"

7. Choose "A Review Equal Numbers"

8. Choose "B Learn About Equal Fractions"

9. Begin with (1) Starters

   You answered_______ of _______problems correctly

10. "Go on to the next level"

    You answered_______ of _______problems correctly

11. "Go on to the next level"

    You answered_______ of _______problems correctly

12. "Go on to the next level"

    You answered_______ of _______problems correctly

WORKSHEET FOR CONTROL GROUP

Meteor Multiplication or Demolition Division

1. When "press any key to begin" appears, press CTRL-p to set the level.

2. Set the Skill Level between 1-3 at first and then work up.

3. Choose #5 to get back to the program.

4. Use → ← to find the target (multiplication) or to move the number from one alligator to another (division).

5. Use "W" to shoot the meteors (multiplication) or tankers (division).

6. Use "S" to increase the number.

7. Use "X" to decrease the number.

Record below.

WORKSHEET FOR CONTROL GROUP

Woodchuck Record Sheet

Players ____________________

____

____

____

Directions: Enter the following information when the computer asks for it. Record the result of your games below. Take this sheet to your teacher when you are finished.

Options: _______ 1 Addition   ___X___ 3 Multiplication

_______ 2 Subtraction   ___X___ 4 Division

Range (0-255):

__X__ 1 Computer picks numbers on dice from range you set.

First die, lowest number: __10__ Second die, lowest number: __10__

First die, highest number: __100__ Second die, highest number: __100__

_____ 2 You specify the number to be used on the dice.

Numbers for first die: __________

Numbers for second die: __________

Game Number	Option	Goal	Range First Die	Range Second Die	Scores
1					
2					
3					
4					
5					
6					
7					

WORKSHEET FOR CONTROL GROUP

Asteroid Record Sheet

Players ______________________

____

____

Directions: Enter the following information when the computer asks for it. Record the result of your games below. Take this sheet to your teacher when you are finished.

Number of rounds: 10

Options: X 1 Whole numbers   X 3 Fractions Choose #1 proper and improper fractions

X 2 Integers   ___ 4 Decimals

Maximum value: 1000 / 9   Minimum value: 10 For Whole Numbers / -9 For Integers

		Player 1	Player 2	Player 3
GAME 1	Rank			
Whole Numbers	No. of hits			
	No. possible			
GAME 2	Rank			
Integers	No. of hits			
	No. possible			
GAME 3	Rank			
Fractions	No. of hits			
	No. possible			
GAME 4	Rank			
Your Choice	No. of hits			
	No. possible			

APPENDIX B

DIPT CLASSIFICATION SYSTEM AND CLASSIFICATION OF JETGA ITEMS

THE DIPT CLASSIFICATION SYSTEM FOR THE MST

Symbol	Name	Value Labels, and Corresponding Definitions
D	Dimension (3 values) 1, 2, 3	1: A task requiring 1-dimensional thought. 2: A task requiring 2-dimensional thought, but not 3-dimensional thought. 3. A task requiring 3-dimensional thought.
I	Internal-ization (3 values) 0, 1, 2	0: The task can be done at the perceptual level. There is either no need for a 'mental picture' to be constructed, or the only mental picture needed is a 'duplicate' or a given stimulus, or a picture corresponding to a simple translation of the stimulus or parts of it. 1: There is a need for a 'mental picture' to be constructed, but in order to do the task, thinking only needs to be about aspects of this picture, i.e. it can remain fixed in the mind. 2: There is not only a need for a 'mental picture' but in order to do the task this picture must be operated upon (transformed) in the mind.
P	Presenta-tion (3 values) 0, 1, 2	0: The expected answer form does not require a final mental picture to be described, identified, or drawn on paper. 1: The answer is a picture which has to be identified from a number of different pictures which are presented in diagrammatic form, or are described by words or actions. The picture to be identified must correspond to the final 'mental picture' associated with the task. 2: The answer requires that the final 'mental picture' be drawn on paper, or be described in words or by hand or other movements.
T	Thought Process (2 values) 0, 1	0: The task specifies the mental operation which needs to be carried out. 1: The task does not specify the mental operation but enough information is given for this to be determined.

SAMPLE QUESTION FROM THE MST

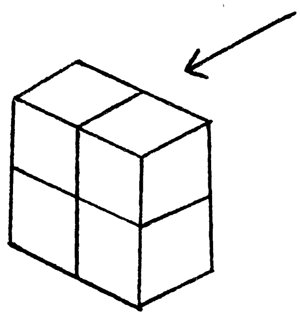


Figure 1

Suppose you looked at the shape in Figure 1 so that your eyes were looking along the arrow.

The shape you would see would look like Figure 2.

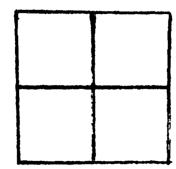


Figure 2

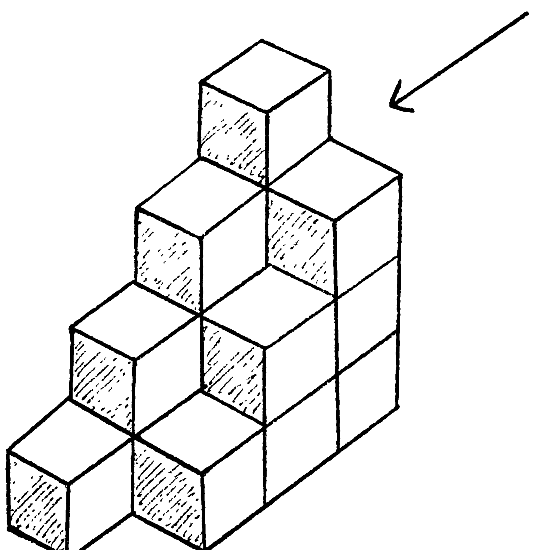
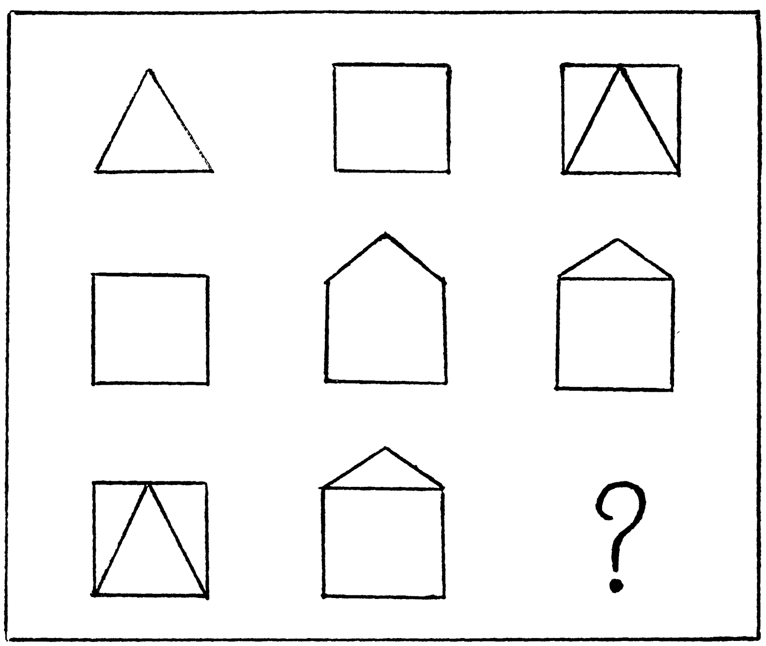


Figure A

Suppose this time you looked at the shape in Figure A, so that your eyes were looking along the arrow. In the answer square provided on your answer sheet draw the shape that Figure A would look like to you.

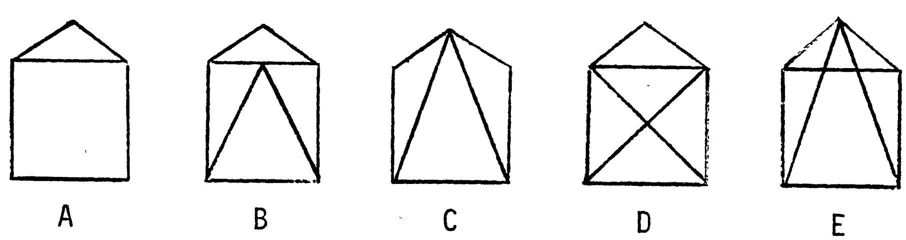
A Spatial Question with DIPT Classification (3,2,2,0)

SAMPLE QUESTION FROM THE MST



Which of A, B, C, D, E below should replace the question mark in Figure 1?

Fig. 1



A Spatial Question with DIPT Classification (2,1,1,1)

DIPT CLASSIFICATION FOR ITEMS ON THE MST

Item No.	DIPT Classification	Item No.	DIPT Classification
1	(3,2,1,0)	16	(3,1,0,0)
2	(2,2,0,0)	17	(3,2,0,1)
3	(2,1,1,0)	18	(2,2,2,0)
4	(3,2,1,0)	19	(3,1,0,0)
5	(2,2,1,0)	20	(3,2,0,0)
6	(2,1,1,0)	21	(2,1,2,1)
7	(3,2,0,1)	22	(2,2,2,1)
8	(2,1,1,0)	23	(3,1,0,0)
9	(3,2,0,0)	24	(3,1,0,0)
10	(2,1,1,1)	25	(2,2,0,1)
11	(3,2,1,0)	26	(3,2,2,0)
12	(3,2,1,0)	27	(3,2,2,0)
13	(3,2,0,0)	28	(3,2,2,0)
14	(2,2,1,0)	29	(3,1,0,0)
15	(2,2,1,0)	30	(2,2,2,1)

CLASSIFICATION AND DISTRIBUTION OF TEST ITEMS
FOR THE JETGA

GEOMETRY AREA	Distribution of Items in Bloom's Categories of Knowledge	Application	Understanding
ANGLES			
Acute	1	0	0
Right	0	1	1
Point Ray	0	1	0
Adjacent	0	0	1
Measure	0	2	0
AREA			
Rectangle	0	2	0
Triangle	0	0	2
General	0	0	1
CIRCLES			
Radius	1	0	0
Diameter	1	0	0
Chord	1	0	0
Circumference	0	1	0
Area	0	1	1
CONGRUENCE	1	1	2
CUBE			
Volume	0	1	0
Vertices	0	1	0
Planes	0	1	0
CURVES	1	1	0
CYLINDER	0	1	0
IDENTIFICATION			
Polygon	2	0	0
Trapezoid	1	0	0
Ellipse	0	0	1
Squares	1	0	0

	Knowledge	Application	Understanding
LINES			
Line	2	0	0
Line Segment	1	2	1
Parallel	0	1	0
Perpendicular	1	0	0
Rays	2	1	0
Diagonals	0	1	0
Intersect	1	2	0
PERIMETER			
Rectangle	0	2	1
Triangle	0	2	0
Polygon	1	0	0
PLANES			
Rectangle	0	1	0
Intersection	0	1	1
POINT			
Inside, outside	1	0	0
Characteristics	1	0	1
Representation	0	1	0
PYTHAGOREAN THEOREM	1	0	0
SYMMETRY	1	0	1
TRIANGULAR PYRAMID	1	0	0
64 Total Items	23	27	14

APPENDIX C

RAW DATA

RAW DATA

Subject No.	Group No.	Sex	Monash Spatial Visualization Scores (MST)		Geometry Achievement (JETGA)		Internal Locus of Control for Success (IARS)		Internal Locus of Control for Failure (IARF)	
			Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
1	E_1	M	11	24	35	41	12	09	08	09
2	E_2	M	12	19	46	53	12	11	08	08
3	E_2	F	10	16	32	38	13	14	14	16
4	E_2	F	06	05	24	25	10	12	10	16
5	C	F	09	10	26	34	14	15	13	15
6	E_1	F	11	13	36	43	15	17	11	15
7	E_1	F	10	14	26	41	16	15	14	15
8	E_1	M	17	23	36	46	15	12	09	09
9	C	F	08	14	16	25	12	13	13	14
10	E_2	M	10	13	32	32	13	15	12	11
11	E_2	M	08	12	25	33	13	14	10	12
12	C	M	19	20	31	45	11	11	09	08
13	E_2	F	12	23	34	45	16	14	15	15
14	C	M	25	25	41	57	12	16	12	15
15	E_1	F	15	17	30	37	14	15	12	12
16	C	F	10	10	29	28	17	16	15	14
17	E_1	F	12	17	36	48	14	12	13	15
18	E_1	M	19	24	47	42	13	13	13	13
19	C	M	15	11	26	27	12	15	14	16
20	C	F	17	21	33	50	16	15	10	10
21	E_1	F	10	18	29	46	13	13	13	12
22	C	M	04	08	22	32	07	13	06	10
23	E_2	M	16	20	22	33	10	06	08	07
24	C	M	09	14	22	35	09	09	10	06
25	E_1	M	05	10	20	22	12	11	09	05
26	C	M	22	22	49	47	11	08	14	10
27	E_1	M	12	16	26	39	14	11	14	11
28	C	F	08	14	23	29	10	08	13	14

RAW DATA (continued)

Subject No.	Group No.	Sex	Monash Spatial Visualization Scores (MST)		Geometry Achievement (JETGA)		Internal Locus of Control for Success (IARS)		Internal Locus of Control for Failure (IARF)	
			Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
29	E_2	F	13	18	26	37	15	15	12	13
30	E_2	F	09	13	29	31	14	16	12	12
31	C	F	13	19	35	48	15	11	12	11
32	E_2	M	14	22	28	38	12	08	13	06
33	E_2	M	08	13	21	35	15	16	11	09
34	E_1	F	11	12	19	36	13	14	16	12
35	E_1	M	08	19	16	29	11	08	10	02
36	E_1	F	11	14	22	26	09	13	06	03
37	E_1	M	12	14	23	28	15	14	15	15
38	E_2	F	06	06	18	22	15	17	08	10
39	C	F	12	09	22	37	15	16	12	14
40	E_2	F	13	11	19	26	11	16	09	13
41	E_2	M	16	11	17	34	14	11	13	12
42	C	M	19	18	21	38	12	12	09	08

VITA

Judith Kay Olson

Candidate for the Degree of

Doctor of Education

Thesis: USING LOGO TO SUPPLEMENT THE TEACHING OF GEOMETRIC CONCEPTS IN THE ELEMENTARY SCHOOL

Major Field: Curriculum and Instruction

Minor Field: Elementary Mathematics Education

Biographical:

Personal Data: Born at Jamestown, North Dakota, August 10, 1947, the daughter of Arthur and Katie Schaffer.

Education: Graduated from Montpelier High School, Montpelier, North Dakota, 1965; received the Bachelor of Science degree in Education from Valley City State College, Valley City, North Dakota, 1968; received the Master of Science degree in Teaching Mathematics from the University of Wyoming, 1981; completed requirements for the Doctor of Education degree from Oklahoma State University, Stillwater, Oklahoma in December, 1985.

Professional Experience: Entered the teaching profession in Michigan, North Dakota in 1969 as an elementary teacher for grades 5 and 6 for two and one-half years; mathematics teacher at Elkins High School, Elkins, Arkansas, 1971-72; Director of Redbrick Afterschool Enrichment Program, 1971-72; graduate assistant and part-time instructor at Oklahoma State University, 1973-75; graduate assistant at University of Wyoming, 1979-81; graduate assistant at Oklahoma State University, 1981-82; instructor at University of Wyoming, 1982-85.

Professional and Honorary Organizations: Member of the Honor Societies of Phi Kappa Phi and Phi Delta Kappa, National Council of Teachers of Mathematics, Research Council for Diagnostic and Prescriptive Mathematics, Wyoming Council of teachers of Mathematics, School Science and Mathematics Association, Association for Supervision and Curriculum Development, American Educational Research Association.