1986

Evaluation of a Logo computer curriculum for upper level elementary school students

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EVALUATION OF A LOGO COMPUTER CURRICULUM FOR UPPER LEVEL ELEMENTARY SCHOOL STUDENTS

Iowa State University PH.D. 1986

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Evaluation of a Logo computer curriculum for upper level elementary school students

by

Marilyn Hecht Blaustein

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Professional Studies in Education
Major: Education (Research and Evaluation)

Approved:

Members of the Committee

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

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For the Major Department

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For the Graduate College

Iowa State University
Ames, Iowa

1986

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CHAPTER I - THE PROBLEM

Introduction

In 1978, Molnar identified the lack of computer literacy as a "crisis" in American education and advocated that computers be introduced in the schools as early as possible. He described the computer as a "powerful, general, problem-solving tool that permits students to cope with problems of complexity" (Molnar, 1978, p. 37).

In recent years, the number of computers in the schools has multiplied rapidly. From the Fall of 1980 to the Spring of 1982, the number of computers available for instructional use in the United States increased three-fold, and by January 1983, at least one microcomputer was available for instructional use in 42% of the elementary schools (Center for Social Organization of Schools, 1983a). It has been projected that by 1986 nearly every school in the United States will have at least one microcomputer (Ingersoll & Smith, 1984).

However, it is the opinion of some that "computer aided instruction has not brought the revolution it was predicted to bring" (Jernstedt, 1983, p. 97), and that the "crisis" in American education has not been resolved. Unfortunately, the reality is that the amount of time students spend using computers in the schools is minimal, due in part to the number of computers available for instructional use as well as a lack of knowledge of how to integrate them into the curriculum. This is further compounded by the poor quality of much of the educational software on the market. Instead of addressing these issues, educators have been investing more of their time and effort on the acquisition of hardware. "Right now schools seem so caught up in buying the promise of this new hardware that no one has the time or the inclination to do the hard work of shaping that promise to meet the needs of learners" (Komoski, 1982, p. 24).

It appears that we are reaching a transition in educational computing. One area receiving much attention in the popular press as well as in professional journals is the quality of the educational software or "courseware". In recent years, thousands of pieces of educational software have become available; however, the programs are largely unevaluated. Bell (1984) described the majority of the educational software on the market as "electronic page turning" that "has little advantage over a well-illustrated book" (p. 81). According to Grayson (1984), over 20,000 pieces of educational software had been written, but less than 10% had been rigorously evaluated. In her evaluation of educational software that was produced by some of the major publishing companies, Cohen (1982) found that the programs tended to emphasize recall and were lacking in their ability to teach higher order cognitive skills such as critical thinking and problem solving. Thus, it appears that gradually, the emphasis is switching from the acquisition of hardware to the acquisition of quality software and integration of the computer into the curriculum (Ingersoll & Smith, 1984).

There is consensus that children of all ages should be exposed to computers. Beyond this, there is little agreement as to the nature of the computer experience. Furthermore, educators cannot agree on a definition of computer literacy. "To some, a general awareness of computers is sufficient; to others, a technical skill that can only be acquired by hands-on experience is mandatory; to others, students must learn to write programs that do things--solve differential equations or create poetry" (Deringer & Molnar, 1982, p. 5).

There are a number of taxonomies that attempt to classify educational computing applications. Some describe the instructional use (Becker, 1982), others examine the role of the computer (Feurzeig, Horowitz & Nickerson, 1981; Taylor, 1980) and others (Thomas & Boysen, 1982) utilize a student-centered approach to classify these computing applications. Because computer applications are largely referred to by their instructional use in the literature, this convention will be used to identify the major kinds of computer programs.

Becker identified six kinds of instructional applications of the computer:

1. Drill and Practice: Using computers for student practice of skills whose principles are taught by the teacher in traditional ways;

2. Tutorial dialog: Using computers to present information to students, diagnose student misunderstandings, and provide remedial instructive communication and individually-designed practice;

3. Management of instruction: (tied either to computer-based drill and practice or to a separate test-scoring system--or independent of either one.) Using computers to provide the teacher with automatic reporting of individual student performances and appropriate assignment of skill levels;

4. Simulation and model-building: Using computer programs to demonstrate the consequence of a system of assumptions, or the consequences of varying an assumption, usually in conjunction with instruction in science or social studies;

5. Teaching computer-related information skills: Using the computer to teach students and have them apply such skills as typing, editing text, and retrieving information from computer systems;

6. Teaching computer programming: Having students learn to program computers to solve problems that are a part of their mathematics curriculum or simply for the understanding of programming itself (Becker, 1982, p. 15).

At the elementary school level, two primary uses of the computer have been identified. According to a survey by The Center for Social Organization of Schools (1983a), computer literacy, defined as a general introduction to computers, was the most popular. Drill and practice was the second most common application. One of the advantages of an application such as drill and pratice is that teachers do not have to change the content of the curriculum. Although the medium is the computer rather than the teacher or a workbook, the method of presentation is not drastically different. However, one of the disadvantages of this approach is that it prevents the exploration of new methods and approaches to learning.

Another school of thought advocates capitalizing on the strengths of computer technology and introducing new forms of learning in the classroom (Dwyer, 1974; Howe, O'Shea & Plane, 1979; Luehrmann, 1980; and Papert, 1980a). This is especially applicable in the area of mathematics and problem solving skills, two areas in which students have experienced declines in achievement in recent years (National Assessment of Educational Progress, 1979). The National Assessment of Educational Progress has recommended that greater emphasis be placed on problem solving. "The ability to analyze a problem situation is equally as important as the correct solution" (1979, p. 27).

One alternative to drill and practice is the computer programming language Logo which also addressess the mathematics and problem solving needs. Logo was developed in the late 1960s at Masssachusetts Institute of Technology (MIT) by Seymour Papert and his colleagues, and is based on Piagetian theory. Papert maintained that Logo challenges students to think creatively. With the turtle graphics component of the Logo language, the child tells the "turtle," represented by a triangle on a video screen, what to do by a series of commands indicating direction and distance. Emphasis is placed on learning without being taught, enabling the student to be in charge of her/his own learning. This allows children to express themselves and explore their own intellectual styles. Because of the structure of the language, Logo can be taught to very young children using only the primitive or basic commands, but it has also been used by students at the college level where sophisticated programming techniques, similar to those used in other structured programming languages, are possible. It is purported that Logo promotes logical thinking and problem-solving skills as well as an understanding of geometric concepts and mathematical principles. Working with Logo the child "both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics and from the art of intellectual model building" (Papert, 1980a, p. 5).

Research findings, particularly comprehensive evaluation studies examining computer curricula are limited. Moursund (1982) cited a severe shortage of strong research results, particularly in areas related to computer programming. Chambers and Sprecher (1980) conducted a comprehensive review of work done in the United States in the area of computer assisted instruction (CAI), typically drill and practice and tutorial applications. Only one of the major programs reviewed involved elementary school children. Some of their conclusions were, that when compared to the traditional classroom approach, CAI either improved learning or showed no difference and that student attitudes toward the use of computers in the classroom improved. In most respects, student gains were not drastically different from the traditional approach.

With respect specifically to Logo, the more extensive studies in the United States have been conducted by the MIT Logo group. Although they present persuasive reasons in favor of adopting a Logo curriculum, the generalizability of these studies is limited for a variety of reasons. Typically, these studies employed relatively small groups of students. Additionally, these studies tended to examine qualitative rather than quantitative differences using extensive observational techniques (Papert, 1980a; Papert, Watt, diSessa & Weir, 1979; Solomon, 1982). Evaluations of this nature are consistent with the philosophy that Logo helps to develop one's own intellectual style. They tend to corroborate the claim that Logo is a flexible computer programming language that is suitable for children of all ages and academic abilities. Many of the reports describing a Logo curriculum are anecdotal in nature and rely heavily on personal observation (Feurzeig et al., 1969; Papert, 1980a; Papert et al., 1979; Solomon, 1982). Finally, the Logo instructors in these studies were generally members of the Logo team, or had received extensive training in the Logo language. This is atypical of most classroom applications and impractical as well for most classroom teachers from a standpoint of time.

Outside of the United States, the Artificial Intelligence Laboratories at the University of Edinburgh have also worked with Logo extensively. This group has implemented Logo in populations ranging from the junior high school students (Howe et al., 1979) to a group of prospective teachers (DuBoulay & Howe, 1982). In contrast to the MIT Logo group, they feel that quantitative methods are important for the purpose of evaluation because of practical constraints. Although the ideal is to revolutionize education with innovations such as the Logo language, the reality is generally educational reform. Therefore, the evaluator must "tease" out the effects of these changes using quantitative methods (Howe, O'Shea & Plane, 1980). Howe, Ross, Johnson, Plane and Inglis' (1982a,b) research findings generally supported integrating Logo into the curriculum and were substantiated by statistical analysis. However, their generalizability, particularly to an American school system, is questionable.

The small amount of research that has been conducted outside of the MIT and University of Edinburgh Artificial Intelligence Laboratories on Logo appears to be problematic. One of the earlier studies of the Logo language was conducted by Milner (1973) using a group of fifth grade students. His findings supported the hypothesis that fifth grade students could learn the concept of a variable using Logo. However, only the cognitive aspects of the experience were examined and a relatively small sample was used. Rampy and Swensson (1983) employed observational methods to examine the programming styles of a small group of fifth graders using Logo. Although of interest, this pilot study was narrow in scope and limited in size. In another study, Badger (1983) used a larger sample size and employed multiple measures to examine the effect of Logo on fifth and sixth graders. Unfortunately, this study suffered from poor design. Logo was implemented in two different schools whose students differed in mathematics and socioeconomic backgrounds. Different versions of Logo were used in each of the schools. Further, the researcher's initial expectations of the students may have been too high, which could have resulted in a negative evaluation of certain aspects of the program, particularly the cognitive benefits of Logo.

There is also a shortage of studies which have examined computer programming ability and its relationship to other academic or personality characteristics in elementary school students. Milner (1973) also examined the influence of higher versus lower ability level students on performance and found no significant differences. The sample employed was quite small (n=18). At the secondary school level, DeBlassio and Bell (1981) attempted to characterize students' like or dislike of computers. Computer programming achievement was one of several factors that was related to their like or dislike of the computer. High computer programming achievement was related to liking the computer while average computer programming achievement was related to disliking the computer.

At the university level, efforts to determine predictors of programming ability have been more common (Alspaugh, 1972; Cheney, 1980; Hostetler, 1983; Peterson, 1976). This is due in part to the need to advise and place prospective computer science students and identify those students who have the potential of being successful in computer science (Stephens, Wileman & Konvalina, 1981). Generally, results have not been consistent and predictors of success have included mathematical background (Alspaugh, 1972), college grade point average (Peterson, 1976 and Hostetler, 1983), and cognitive style (Cheney, 1980).

Although the computer science literature, particularly at the pre-collegiate level, is in an early stage of development, a common observation is that there are differences between males and females in their interest and experience with computers. These differences have been evidenced in children's preferences of computer games (Malone, 1981), the nature and extent of their experience with computers (Revelle et al., 1984), and their perceptions of what a computer can do (Stage & Kreinberg, 1982). Some of the preliminary findings regarding sex differences in computer science parallel those in the mathematics literature where an extensive body of research exists. This similarity is not surprising since abilty in computer science has often been paralleled with ability in mathematics or science. Based on a review of the mathematics literature, sex differences were often found between males and females in their attitudes towards mathematics and mathematics achievement (Fennema, 1974; Fennema & Sherman, 1977, 1978; Hilton & Berglund, 1974; Maccoby & Jacklin, 1974). There was a greater tendency for these differences to be exhibited at the onset of adolescence and beyond. Various explanations for these differences have emerged, ranging from innate differences to sociocultural ones. A similar literature, although largely anecdotal. There is also a shortage of studies which have examined computer programming ability and its relationship to other academic or personality characteristics in elementary school students. Milner (1973) also examined the influence of higher versus lower ability level students on performance and found no significant differences. The sample employed was quite small (n=18). At the secondary school level, DeBlassio and Bell (1981) attempted to characterize students' like or dislike of computers. Computer programming achievement was one of several factors that was related to their like or dislike of the computer. High computer programming achievement was related to liking the computer while average computer programming achievement was related to disliking the computer.

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Statement of the Problem

Based on the fact that computer hardware is present or becoming increasingly available, it appears that the majority of the elementary schools in the United States have the technology to begin to implement a computer curriculum. However, the school systems have little basis on which to make this judgement because of the limited research in the area of educational computing. Presently, the majority of computer applications for instructional use are not drastically different from traditional classroom instruction and do not capitalize on the strengths of the computer. The gains are questionable as well. As computers become more widespread in the schools, it becomes increasingly important to determine the kinds of experiences that benefit the child, beginning at the elementary school level. This requires developing better ways of evaluating the materials as well as the overall computer experience.

Although there are some large scale studies that are largely evaluations of curricula employing drill-and-practice and tutorial applications, there have been few large scale empirical studies conducted at the elementary school level which evaluate computer curricula. Unfortunately, these studies in most cases did not consider the students' prior experience with computers. With respect to computer programming languages, Logo is one of the more popular languages at the elementary school level, however, evaluation studies outside of the MIT Logo group and the Artificial Intelligence Laboratory at the University of Edinburgh are often limited in scope and sometimes lacking in objectivity. In particular, the MIT evaluation studies conducted generally focused on the qualitative rather than quantitative aspects of the experience. These methods are less practical and feasible on a larger scale, particularly in the classroom. There is a need to identify factors that influence attitudes towards and performance with a computer language such as Logo. This is of critical importance in a technology that is growing rapidly.

One method of evaluating computer curricula is to examine a specific application using objective as well as subjective measures and to focus on the student user. This study will take such an approach. An empirical model will be developed and tested that will attempt to identify factors that affect a student's attitudes and performance using a specific computer programming language, Logo. Factors that will be considered include student entry characteristics, attitudes towards the computer experience, and subjective and objective measures of achievement.

The computer programming language Logo was selected as the object of this evaluation for several reasons. Generally, Logo has been received positively by the educational community, as well as the general public as one computer application that purports to satisfy some of the more stringent definitions of computer literacy. Second, it is a structured programming language that can be taught to young children. Third, it claims to teach mathematics principles and problem solving skills and, thus can be generalized to other areas of the curriculum. Fourth, it is flexible in that it can be adapted to different ability levels and cognitive styles. Finally, it requires relatively little training on the part of the teacher; inherent in the philosophy of the developers of the Logo language is that teacher and students work collaboratively to solve problems (Papert, 1980a). This is important from a practical standpoint because teachers are more apt to select a curriculum that requires a smaller time investment to learn as well as to implement.

A secondary area of emphasis is the effect of gender on attitudes, experiences and performance using a computer language such as Logo. Although Logo is a specific application, it is an important step in establishing an empirical body of literature in the area of computers. The largely anecdotal findings in the computer literature suggest that males, especially in the higher grades, exhibit a greater interest and higher performance levels in computer-related activities than their female counterparts. This study will attempt to gather statistical evidence to support or reject this claim for a specific application. Second, it will be possible to ascertain if findings in this study correspond to the findings in the mathematics literature relating to gender differences. It is important to determine if there are differences between males and females, especially in a society where facility with a computer is becoming increasingly important in education as well as in the job market.

An effort will be made in this study to begin to explore the factors that influence the implementation of a Logo curriculum at the elementary school level, specifically grades 4, 5 and 6, using the student as the unit of analysis. Ultimately, in this study, an attempt will be made to identify both cognitive and affective measures that influence the attitudes and performance of upper elementary school students using the Logo programming language.

The hypothesized model will be tested using the statistical technique of path analysis or causal modeling. This method was developed by Sewall

Wright in the early 1900s (Wright, 1934) and has been used widely in the social sciences but less frequently in educational applications. In the context of education, path analysis has been used primarily to test educational attainment models (e.g., Duncan, Featherman & Duncan, 1972). The indicators in the model are ordered temporally and derived from a number of sources. Although not tested as a path model, Dunkin and Biddle (1974) proposed a model for the study of teaching with a causative sequence of variables associated with classroom learning. This study will adapt portions of this model, specifically the student context and product variables. Additionally, variables were derived from the computer literature and related fields such as mathematics. The theoretical model is illustrated in Figure 1. The major conceptual areas are:

1. Student demographic characteristics. These include gender and grade in school.
2. Student entry characteristics. Four major categories were included: mathematics achievement, attitudes towards mathematics and learner characteristics, prior experiences with computers and attitudes and preferences towards computers.
3. Attitudes towards the computer experience and preferences of Logo versus other activities.
4. Self-evaluation of performance.
5. Performance on an objective measure.

Although of interest, teacher variables are beyond the scope of this study.

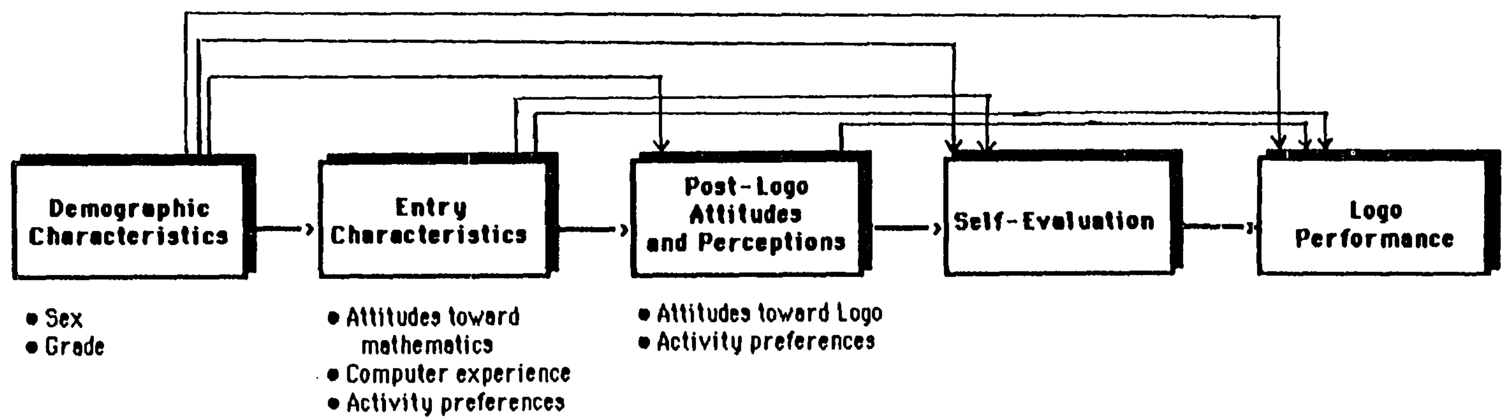


Figure 1. Theoretical causal model of measures influencing attitudes and performance of students using Logo

The theoretical concepts were operationalized using individual items and factors derived from instruments administered to students. The questionnaires were administered to approximately 400 fourth, fifth and sixth grade students attending three elementary schools. During Spring semester, 1983, these schools participated in a pilot study in which the goals were to implement a Logo curriculum. First, Logo was introduced to the classroom teachers through a series of four-two hour workshops. Teachers subsequently introduced Logo to their students with the assistance of the project directors, this investigator and undergraduate students. On the average, the students worked with Logo for two to three 20-minute sessions per week for approximately 15 weeks. During this time, students completed three questionnaires and one objective test.

Instruments were administered at three points during the study. The first was administered prior to the introduction of Logo to the students and attempted to determine prior experience with computers and attitudes towards computers. The second, a mathematics inventory, was administered during the first few weeks of the project. The final two instruments were administered at the termination of the project. The former examined students' attitudes towards Logo and self-evaluation of performance while the latter was an objective measure of performance. All students completed the two final instruments whereas students at two of the schools completed all of the evaluation instruments. Therefore, the complete model will be tested for 188 students and only the post-Logo variables will be tested for the entire group (n = 338). Additionally, a mathematics achievement measure was available for a subset of students (n = 126) in the two schools. The achievement measure will be tested as part of the larger model for this group of students.

A secondary purpose of this dissertation is to identify similarities and differences between the mathematics and computer literature. Although the effect of gender will be tested in the causal model, it will also be examined on a bivariate level. Of particular interest are those variables related to students' mathematics achievement, attitudes toward mathematics and learner characteristics, prior experience with computers, attitudes towards computers, perceptions of the Logo program, self-evaluation of performance and an objective measure of performance. Gender differences will be tested using the variables that were developed empirically and will be used in the causal model. When these differences are significant, age or grade differences will be examined to determine if there is a differential effect based on age.

Hypotheses to be Tested

Causal Model

Based on the hypothesized causal model, the following linkages are proposed:

- Performance on the objective test is directly influenced by the combined influence of demographic variables, entry characteristics, post-Logo attitudes and perceptions, and self-evaluation of performance.
- Self-evaluation of performance is influenced by demographic variables, entry characteristics and post-Logo attitudes and

perceptions.

- Post-Logo attitudes and perceptions are influenced by demographic variables and entry characteristics.
- Entry characteristics are influenced by demographic variables.

Gender Differences

Based on the mathematics and computer science literature, it is hypothesized that if significant sex differences occur, males will demonstrate higher achievement and/or more positive attitudes and perceptions with respect to

- mathematics achievement
- attitudes toward mathematics and learner characteristics
- computer experience prior to Logo
- attitudes toward computers prior to Logo
- attitudes and perceptions of the Logo experience
- self-evaluation of performance
- objective measure of performance

When these differences are present, it is hypothesized that they will be more apt to occur in the higher grades. Consistent with the research findings, it is also anticipated that differences on the affective measures as opposed to the achievement measures would be more likely to occur.

Delimitations

1. This study examines only one computer programming language, Logo. The results of this study are not generalizable to others using different programming languages.

2. The students in this school district were a relatively homogeneous group of students with achievement test scores above the national norms. Results of this study may not be generalizable to all upper elementary populations.
3. Implementation of Logo varied from school to school and from teacher to teacher. Although a school variable will be introduced to test for these differences, differences at the classroom level were not tested.
4. This study did not employ an experimental design. Intact classrooms were used and there was no control group. Therefore, any assignment of cause and effect will be based on the theoretical model proposed.
5. One of the problems inherent in a study of this nature is that of measurement error. Because all but one of the instruments rely on self-report, respondents may have given systematically erroneous information. Additionally, measurement of the constructs specified in the model may not be completely accurate. This may be attributed to the limited amount of research done in this area, especially with a population of this age and a computer language as specific as Logo.
6. The exploratory nature of this study is stressed. It is the intent of this investigator to develop a preliminary model which can later be refined with improved instrumentation and subsequently be tested on similar populations.

Organization of Dissertation

This dissertation is divided into five chapters, a reference section, and appendices. Chapter I presents an overview of the Logo study and includes an introduction, statement of the problem, hypotheses and limitations of the study.

Chapter II presents a review of the literature. It is divided into six major sections which, 1) examine the status of educational computing at the elementary school level, 2) describe the Logo programming language and results of applications in the schools, 3) discuss large scale evaluation studies of computer curricula other than Logo particularly at the elementary school level, 4) review research studies that examine predictors or correlates of computer programming ability, 5) examine gender differences in the computer science and mathematics literatures, and 6) describe the history and method of path analysis.

Chapter III describes the methods and procedures used in this study. The evaluation instruments will be described, the results will be reported and the variables and factors derived from these instruments and used in the path model will be identified.

Chapter IV reports the findings of this study. They will be discussed in relation to the hypotheses stated.

Chapter V presents a summary of the problem, findings of the study, conclusions, interpretations and recommendations.

CHAPTER II - REVIEW OF THE LITERATURE

Status of Educational Computing

Introduction

Although the first computers were introduced in 1945, the entry of computers into the pre-collegiate curriculum on a large-scale did not occur until the latter half of the 1970s. With the advent of the microcomputer, acquisition became more practical from a financial standpoint and computers became more prevalent at the elementary and secondary levels (Moursund, 1982). Since the 1970s there have been at least three generations of microcomputers used for educational purposes. Over time, the cost of the equipment has decreased dramatically while the sophistication, reliability, ease of use and portability of the computer has increased. The first generation machine, the Altair 8800, introduced in 1975 was expensive, had a front panel and lights for displaying the contents of the memory and switches for entering information (Aiken & Braun, 1980). In contrast, the new generation of microcomputers is less expensive, more powerful and "user friendly," enabling even a young child to operate them. Options include color graphics, hard disks, voice synthesizers and a "mouse" that allows the user to bypass the keyboard for data entry. Microcomputers cost less than $1,000 per machine and it is predicted that by 1990 the cost for a comparable machine will be less than $100 (Otte, 1984). These factors have contributed to the broad acceptance of computers in the schools as in the rest of the public sector (Becker, 1982; Grayson, 1984). This is not to say that problems do not exist. Although computers are more widespread, many teachers may know little about the equipment and therefore use them infrequently. Alternatively, they may use computers, but not use them effectively (Neibauer, 1985) or to their fullest extent (Grayson, 1984).

This section will examine the issue of computers in the school in more detail. It will describe the current status of educational computing with emphasis on activities at the elementary school level. In particular, it will focus on 1) access to computers in the schools, examining the proliferation of computers in the schools as well as the actual uses of computers; 2) educational computing applications, describing the major educational applications as well as the more common applications in the schools, 3) evaluation research, focusing on studies that have formally evaluated computer curricula; and 4) educational software, describing the kinds of materials used in the schools and the issue of evaluating educational software.

Microcomputers have proliferated in the schools in recent years. This may be attributed to a combination of factors. First, the decreased cost of microcomputers has made them more affordable for schools and school districts. Second, parents have been exerting pressure on the schools to acquire them (Newsweek, 1982; Sanger, 1983) and have provided financial assistance by sponsoring fund raising drives (Time, 1982). Finally, implementation of computers into the curriculum has been advocated at the federal (Aiken & Braun, 1980; Molnar, 1978), state, and local levels (Ingersoll & Smith, 1984). The computer has been recommended as a means by which schools can improve their reputation and teach problem solving skills (Ingersoll & Smith, 1984).

In 1974, it was reported that less than four percent of the elementary schools in the United States used the computer for instructional applications (Splittberger, 1979). These numbers have increased dramatically since the early 1970s which is evidenced by more recent surveys. Whereas 31,000 microcomputers were available for instructional use in the Fall of 1980 (National Center for Educational Statistics, 1982), in the beginning of the 1981-82 academic year, there were approximately 79,000 microcomputers in the schools. The computers were concentrated primarily at the senior high level (26%); only 11% of the elementary schools had at least one microcomputer (*Learning*, 1982). By the Spring of 1982 the number of microcomputers had increased to 96,000 (National Center for Educational Statistics, 1982). Results of a survey conducted by the Center for Social Organization of Schools in January of 1983 (1983a) revealed that there was at least one computer available for instructional use in 42% of the elementary schools in the United States. Consistent with previous reports, and despite the abundance of software marketed for use at the elementary school level, a smaller proportion of the elementary schools versus secondary schools (42% versus 52%) owned computers. At this time, the percentage of elementary schools with computers was comparable to that for secondary schools two years previously. Further, secondary schools were purchasing computer equipment such as disk drives at a faster rate than the elementary schools. Only 12% of the secondary schools lacked computers with disk drives compared with 37% at the elementary level.

In addition to the disparities between the lower and upper grades with respect to ownership of computers, other differences have been noted. Schools located in the wealthiest communities were more likely to own computers (30%) when compared with those residing in the poorest communities (12%) (Learning, 1982). Results of the survey conducted by the Center for Social Organization of Schools (1983c) suggested that these differences were more apt to occur at the elementary school level. In addition to socioeconomic class, numbers of computers were related to factors such as geographic location, ethnicity, and school affiliation. While the overall percentage for elementary schools was 42%, parochial schools (25%), schools with families of lower socioeconomic levels (31%) or minority populations (34%) and smaller school districts (33%) were less apt to have computers. In contrast, schools in the western United States (57%) and rural midwestern counties (60%) had a greater likelihood of owning a microcomputer.

Sheingold (1981) also noted that there was differential access to computers in her case study of computer use in three school districts. In some schools, computers were used primarily for remediation; in others, the brighter students had greater access; specific schools had more computers within the districts and finally, there was differential access among the sexes, particularly at the secondary level.

Although the numbers of computers in the school are increasing rapidly, the amount of time a child spends on a computer has been described as "miniscule" (Becker, 1982). The Center for Social Organization of Schools (1983b) found that, in a given week, approximately 16% of the students in a "typical" elementary school used a microcomputer. On average, the computer was used for a total of 11 hours per week, although one fourth of the elementary schools surveyed used the computer for no more than one hour per day. It was estimated that one third of the elementary school users had access to the computer for 15 minutes or less during a given week, while only two percent of the student users received more than one hour of time on a computer in the same time period.

These findings are exemplary of the problem of student access to computers. It is difficult to implement an instructional plan that involves the computer, especially when there are a limited number available (Becker, 1982). Ingersoll and Smith (1984) predicted that even with the rapid growth of computers in the schools, it would take at least 10 years for there to be enough computers to allow the average student enough time for the computer to have a significant impact on her/his learning. The educational computing movement in the schools has been described in the following manner, "One thing about the computers-in-the-schools story is sure; most of it must be written in the future tense" (Learning, 1982, p. 30).

School uses of microcomputers

As a consequence of the increased numbers of computers in the schools, èducational applications and means of integrating the computer into the curriculum have become priorities for many educators. Although the amount of educational software has increased dramatically in recent years, the basic applications that were developed for mini- or mainframe computers have remained relatively the same. With the increased capability of the microcomputer, much of the software previously available for larger systems has become available for the microcomputer (e.g., PLATO and Logo), and other materials have been developed for the microcomputer. A selected number of major educational computing activities will be described to provide an overview of the primary applications. Then, some of the more common applications in the schools will be described.

One of the first applications of computer assisted instruction (CAI) to be developed was drill and practice. This was one of the simpler applications because it involved automation of a preexisting instructional process, and unlike other aspects of CAI, it was considered non-experimental (Ellis, 1974). From a practical standpoint, drill and practice was easy to implement, was easy to use in conjunction with other instructional material, freed the teacher from repetitive activities and could be tailored to the student's needs. The strongest criticisms of drill and practice are that 1) it simply employs a new technology to substitute for old methods of instruction (Becker, 1982; Ellis, 1974, Luehrmann, 1980; Papert, 1980a), 2) it fails to integrate research findings concerning information feedback versus reinforcement feedback in its design (Cohen, 1982; Howe & DuBoulay, 1979) and 3) in general, individualized instruction implies individual access to computers as opposed to instruction that addresses the student's strengths and weaknesses (Howe & DuBoulay, 1979).

One of the earliest and most renowned computer assisted instruction projects began in 1966 under the direction of Patrick Suppes at Stanford University. It was later marketed commercially by the Computer Curriculum Corporation (CCC) and was one of the most widespread computer curricula at the elementary school level. While approximately 1,500 students were using the material on a regular basis in 1966 (Ellis, 1974), in 1979 over 150,000 students in 24 states used it on a daily basis (Kearsley, Hunter & Seidel, 1983b). Software was developed for basic reading and language skills, and elementary mathematics skills and concepts. These were generally supplementary to classroom instruction although tutorials were provided as well. Instruction was aimed particularly but not exclusively at disadvantaged children (Suppes, 1980a). The material developed did not result in major changes in the content of the curriculum. Rather, the computer was used to "fine tune" the existing curriculum to the need of individual students. A major innovation of this courseware was its ability to branch. If a certain number of problems were incorrect, the child was directed to a branch which presented the concept again in a slightly different way. Alternatively, if the student made enough correct responses initially, the branch was skipped and the student proceeded to the next concept (Suppes, 1980b).

A second application of computers in the schools is tutorial instruction. The basic design is generally similar to drill and practice. Whereas drill and practice is used to supplement instruction, presentation of new information and new concepts distinguishes tutorial from drill and practice (Becker, 1982). Again, the strength of tutorial lies in its ability to individualize instruction and diagnose student weaknesses. Unfortunately, most applications fail to achieve this goal and are not much more than "electronic programmed textbooks" (Howe and DuBoulay, 1979, p. 241).

Although used less frequently in the schools, a more advanced mode of tutorial which goes beyond programmed instruction is intelligent CAI (ICAI). The computer's role is more similar to a human tutor and provides the student with more individualized instruction. ICAI is also innovative in its ability to diagnose the learner's problems. One example of ICAI is the SCHOLAR system which was developed by Carbonell. A graphics component was subsequently added to Map-SCHOLAR, a geography tutorial; maps were displayed in conjuction with the verbal material. The intent of SCHOLAR was to provide greater flexibility in the interactions between tutor and tutee. The computer could present information to the student, ask her/him questions, evaluate the answers, correct errors, and respond to the student's questions. Its flexibilty was a result of the ability of the program to separate teaching strategies from conceptual knowledge (Collins & Adams, 1977; Collins, Adams & Pew, 1978). Still, a major criticism of ICAI is its inability to replicate dialogue between teacher and student and the risk it runs of oversimplifying this process (Ellis, 1974).

Despite the potential of programs such as intelligent CAI, none of the programs has had any real impact on the educational practice. Major obstacles are suitable computers at affordable prices and wider availability of ICAI knowledge and skills (Kearsley, Hunter & Seidel, 1983a).

A third educational application that has become popular as a means of instruction is simulation. This method instructs the students about real life situations and enables them to actively experience a similar situation that they might not otherwise engage in (Becker, 1982). At the elementary school level, two of the more popular programs are Oregon Trail and Lemonade Stand. The former is a simulation of a family's journey to the West in a covered wagon in the 1800s. The user is given allocations of food, money and ammunition and required to make choices at certain points along the way. The latter simulates a small business operation. The user must decide how many glasses of lemonade to produce and how much to charge for them.

One of the problems with simulations is that they require large amounts of time when used as intended. Additionally, the younger student's ability to explore a system logically without close supervision has been questioned (Howe & DuBoulay, 1979). Although studies have shown improvement in student attitudes, they have not found improvements in learning (Becker, 1982).

A fourth application is computer programming. This classification includes traditional programming languages such as BASIC as well as non-traditional and more "user friendly" languages such as Logo. Unlike other applications, in this mode the user tells the computer what to do and student control of learning is emphasized. Programs of this nature were "reactions or alternatives to the original philosophy of CAI in which computers were used to 'deliver' instruction" (Kearsley, Hunter &

Seidel, 1983a, p. 93). A programming language affords the child many opportunities. First, it allows the child to formulate a problem. Second, construction of a computer program can provide the learner with insights into specific areas of the subject being explored (Howe & DuBoulay, 1979). Third, in the process of writing programs, the child learns valuable debugging skills that can generalize to solving other problems (Papert, 1980a).

There are also several drawbacks to computer programming applications. From a practical point of view, programming activities generally require a greater time commitment as well as a greater number of computers. Most schools do not have enough equipment to allow equal access for computer programming activities. Additionally, most teachers have not received adequate training to assist their students with programming activities. Finally, there is a lack of research results to support many of the claims of the advocates of programming activities. In particular, there is a lack of empirical evidence to support the claim that computer programming improves problem solving skills (Howe & DuBoulay, 1979).

Two of the earliest programming applications were the Soloworks Project at University of Pittsburgh and the Logo Project at Massachusetts Institute of Technology. The objective of Soloworks was to combine the characteristics of an open learning environment with those of a structured one. The class was organized around computing and computer-related planning whose aim was to integrate secondary school mathematics and computing. In this setting, "dual mode learning" or traditional classroom instruction gives way to "solo mode" or student controlled learning. It was organized around five laboratories, a computer, dynamics, logical design, synthesis and modeling/simulations laboratories (Dwyer, 1974).

Using a programming language such as Logo, a child can instruct the computer to draw pictures. The language has the sophistication of a structured programming language, yet is appropriate for a young child because it uses simple commands that are similar to spoken language. Projects such as Logo gave impetus to the "computer literacy movement" (Kearsley, Hunter & Seidel, 1983a, p. 94) and will be discussed in greater detail.

A final application in the educational computing framework is teaching computer-related information skills (Becker, 1982). Although this mode has widespread use outside of education and at the university level, it has been used with less frequency by students, especially at the lower levels. Activities of this nature include word processing, data processing and statistical analysis (Taylor, 1980). Nevertheless, there have been programs developed for use in the lower grades such as the Bank Street Writer, a word processing program. With this software, students can compose and revise papers with relative ease, thereby allowing the student to focus on the content of the paper rather than the mechanics of copying it over or retyping it.

This is not an exhaustive list of educational computing activities, but a sampling of the kinds of applications that exist. Thus, it appears that there is not a paucity of applications. Despite the wide range of activities, the most common, although not exclusive, application at the elementary school level is drill and practice which has been described by some as a "passive learning mode" (Bork, 1984). Most reports of computer use in the schools are anecdotal, although there are some empirical data obtained through survey research. Two of the more recent studies were sponsored by the National Center for Educational Statistics (NCES) (1982) and the Center for Social Organization of Schools (1983a,b,c). While both examined school uses of computers, the latter was more comprehensive and examined specific school applications.

Results of the NCES survey (1982) indicated that teaching of computer literacy or computer concepts (29%) and teaching of basic skills (29%) were the most popular applications at the elementary school level. Only seven percent of the respondents identified computer science as a major use of the microcomputer. Similar results were reported by the Center for Social Organization of Schools less than a year later. With the exception of Introduction to Computers (64%), 59% of the elementary school teachers reported they used drill and practice activities regularly or extensively. Programming instruction was used regularly by 47% of the teachers. In these schools BASIC was taught in 98% of the schools, while Logo was used in only five percent. Only three percent of the teachers reported using word processing regularly or extensively.

Examination of teachers' anticipated and actual uses of computers revealed some interesting findings. Teachers who had used microcomputers for three or more years were more apt to report that they used the computer less than they had anticipated for drill and practice activities

(35%). Twenty-one percent reported an increased use for drill and practice over what they had initially anticipated. Approximately equal numbers used the computer for programming activities more than they had anticipated and less than they had anticipated (25% versus 26%). Schools that had computers longest also tended to report the most extensive use of computer programming. Likewise, a decline in use of drill and practice materials paralleled greater experience with a microcomputer. These differences were attributed to either 1) a judgment of greater usefulness of the computer for programming activities after sampling a variety of activities or 2) disenchantment with the earlier drill and practice software that was marketed and a failure to reevaluate more current materials in that mode (Center for Social Organization of Schools, 1983a).

Regional differences were also found in the uses of computers. Teachers in the Northeast reported using the computer for programming more intensively than in the South (32% versus 17%). In contrast, the computer was used intensively for drill and practice by 26% of the respondents in the South while it was used by between 16% and 17% of the respondents in other regions (Center for Social Organization of Schools, 1983c).

Although used infrequently, the Logo programming language was used more in the Northeast (11%). In other regions, three percent or fewer reported using Logo.

Anecdotal evidence of school use of microcomputers provides a variety of applications ranging from drill and practice activities to Logo. An issue of Learning (1982) devoted to school uses of microcomputers described a variety of implementations in several schools. In one, instruction in basic skills using material produced by the Computer Curriculum Corporation (CCC) was used in a lower income and ethnically mixed school system. In another, simulations such as Oregon Trail were used. In a third school, the Lamplighter School in Dallas, Texas, Logo was used extensively. Fifty computers were available for 420 students (Rosen, 1982). Evaluations conducted in each school were generally informal. Significant improvements in mathematics and reading scores were reported for those students using the CCC material; however, the size of these gains was not reported. Additionally, the enrollment which had been declining in this school increased by 28% over a three year period. This increase was attributed to the computer curriculum (Greth, 1982). In others, the only measure used was the enthusiasm generated by the activity (i.e., Oregon Trail)(Branan, 1982). At the Lamplighter School, there was no real interest in a formal evaluation. Again, success was measured by the enthusiasm for learning demonstrated by the children rather than by other objective measures (Rosen, 1982).

Educational software

With the exception of a few school districts, limited access to computers is the rule. The consequences of this lack are significant. First, it is difficult to integrate the computer into the curriculum if there are too few machines available. Second, many educators are relatively unsophisticated users and therefore less qualified to make critical judgments concerning quality software. One outcome is that the majority of the software purchased is drill and practice which is widely available. However, software of this type is often limited in its capabilities due in part to the capabilities of the school equipment (Becker, 1982). Drill and practice material is also the easiest to prepare and can be used to free teachers from the "drudgery" of preparing practice exercises (Magidson, 1978, p. 6).

One of the implications of the rapid growth of computers in the schools is that the educational software has not kept pace with technological advances. According to Bork (1984), much of the growth in terms of numbers of computers in the schools occurred at a time when there was a limited amount of interesting educational software available. Computers were often purchased on the basis of the amount of software available with little consideration to the quality of the materials. "This is a very peculiar argument, one that seems to say that large quantitities of educational garbage are superior to small quantities" (Bork, 1984, p. 24). Feurzeig, Horowitz & Nickerson (1981) attributed the poor quality of software to cost. "The sharp contrast, for example, between the many genuinely intriguing and well-designed computer-based games and the scarcity of equivalent quality in educational materials bears eloquent witness to the fact that market forces have created an imbalance between quality and social utility" (p. 102).

The poor quality of educational software, the failure of the producers to evaluate the material prior to marketing, as well as consumers' indiscriminate purchase of the software have been common criticisms (Becker, 1982; Bork, 1984; Cohen, 1982; Feurzeig et al., 1981;

Sheingold, 1981; Truett, 1984). Komoski (1982) paralleled the indiscriminate purchase of software by schools to their pattern of purchasing textbooks and workbooks from publishers. "Publishers make more of what's selling, and school consumers keep buying it, because other schools are buying it" (p. 24). A first step in resolving the problems with existing educational software is for teachers to begin demanding software that lives up to the potential of the computer (Komoski, 1982). Despite the criticism directed at teachers, the need for suitable educational software has been recognized by educators as well. Almost two-thirds of the respondents in the NCES study (1982) indicated that this was of major importance.

More systematic reviews of educational software have generally concurred that the majority of the materials are found wanting. In recent years, educational software has flooded the market but less than 10 percent of the over 20,000 pieces of software on the market have been evaluated. Although programs of excellent quality do exist, the majority are of poor quality and generally of low-level drill and practice or textbook type tutorials (Grayson, 1984). Chambers and Sprecher (1980) also found computer assisted instruction materials to be poorly constructed with little documentation. In the spring of 1981, an evaluation of the six major courseware programs being marketed for school use by major publishers was conducted (Cohen, 1982). Generally, the evaluations were not favorable. Most of the programs on the market were drill and practice and supplemental to classroom instruction which emphasized the recall of previously learned facts. None specifically stated the objectives. All programs used feedback to reinforce both correct and incorrect responses, which is contrary to recommendations based on research findings (Tait, Hartley & Anderson, 1973). Most did not inform the user why the answer was wrong but did provide the correct responses. Recommendations for improving the quality of the software included: 1) developing programs that teach critical thinking and higher order skills, 2) producing software other than drill and practice and 3) designing software so that there is a motivating device that makes the programs exciting and stimulates the student to learn, and 4) integrating the microcomputer into the curriculum rather than using software with isolated uses (Cohen, 1982).

Another shortcoming in the production and marketing of software is the failure of the producers of the software to adequately evaluate the material before it is marketed. This may be due in part to the absence of a well-established methodology of evaluating computer software (Truett, 1984). Truett (1984) surveyed 406 publishers or producers of educational software. Her response rate was low (14%) and not necessarily representative of the pubishers as a whole. Of those that responded, almost 75% reported some form of evaluation. However, testing of the software was limited to local schools using five or fewer teachers and 50 or fewer students. This limits the generalizability of the results to other school settings. Typically, the evaluation was linked to the teacher's reaction to the materials, not student performance or student evaluation of the materials. Additionally, results of these field tests were not included with the documentation. In general, these evaluations were cursory or non-existent. She also conjectured that the non-respondents were less likely to have conducted any form of evaluation (Truett, 1984).

Improving the quality of educational software has gradually become a priority in education. This is evidenced by increased federal support which is being made available in the form of grants to assist in the development of educational software, dissemination of material describing exemplary uses of computers in the schools and data collection on the uses of computers as well as applied research (Bell, 1984). Examples of projects funded by these monies are MicroSIFT, an educational computing network and the Huntington III Project, a project to develop quality courseware.

In 1979 the National Institute of Education funded the Northwest Regional Educational Laboratory to develop a clearinghouse for educational software (MicroSIFT). This program has resulted in the generation of three documents, a Courseware Description Form, a Courseware Evaluation Form and an Evaluation Guide for Microcomputers. Thorough evaluations of educational courseware have been conducted using from three to six evaluators. MicroSIFT has made available evaluations of aproximately 2,000 programs that can be accessed on line via an educational data base. Feedback is also provided to program developers and publishers to make them aware of deficiencies in a particular piece of software (Otte, 1984).

The goals of the Huntington III Project were to develop quality courseware using a team approach and specific design criteria. Quality programs were defined as being "user friendly," "user proof," and capitalized on the strengths of the computer such as graphics, simulation and immediate feedback. The authors' goals were to develop programs that were highly interactive and involved active participation of the learner (Liao, 1983).

Other efforts to improve the quality of software and disseminate information have extended to the state and local levels. For example, the state of Minnesota established the Minnesota Educational Computing Consortium (MECC) which has evaluated and distributed software to its members as well as purchased microcomputers. Much of the software has been developed by teachers for their own use and has been marketed by MECC (Grayson, 1984).

Private corporations have also demonstrated some concern for improving the existing educational software. Both IBM and Digital have invested large quantities of money in computer curriculum development. High quality software can also be advantageous to these companies in terms of upholding their reputation and increasing their sales potential (Grayson, 1984).

There have also been attempts to develop criteria for evaluating educational software (Cohen, 1983). Cohen identified attributes that should be considered when designing and evaluating a piece of software. Factors to consider include 1) the role of the software in the curriculum, 2) how the student interacts with the material and the computer (e.g., drill and practice, problem solving), 3) the manner in which the student is sequenced through the materials, 4) appropriate use of graphics, 5) display of information on the screen, 6) use of cues or prompts, 7) extent of user control, 8) use of computer managed instruction in conjunction with the program, 9) appropriate use of feedback, and 10) teacher and student manuals.

A persistent concern in the educational computing literature has been the failure of microcomputers to be used to their potential (Aiken & Braun, 1980; Bork, 1984; Molnar, 1978; Neibauer, 1985; Papert, 1980a; Thomas & Boysen, 1982). This failure has been attributed to several factors including the rapid growth of the computer technology. In many settings, use of computers has been judged by the number of computers in a particular school rather than by the nature of the implementation. Issues such as teacher training and selection and implementation of educational courseware have not been dealt with effectively (Neibauer, 1985). Thomas and Boysen (1982) articulated these concerns, "We should be concerned about the lack of computer-based materials, the lack of well-defined instructional strategies and the lack of an adequate philosophy of instruction to capitalize on the potential of the computer as a learning tool" (p. 7).

Evaluation research

Numerous pieces of educational software have been written and a wide range of educational computing applications have been implemented. While intuitively it appears that computers are beneficial, there is a lack of strong research results to support these claims or to support specific applications (Becker, 1982; Eisele, 1984; Moursund, 1982; Sheingold, 1981; Splittberger, 1979). In particular, there are few well-designed

Splittberger, 1979). In particular, there are few well-designed formal evaluations as well as a paucity of theoretical evaluation models (Feurzeig, et al., 1981). Consequently, implementations of computer curricula and selection of educational software have been haphazard. Although this is not unlike other aspects of education, it is still a concern. A lack of research "serves to perpetuate existing paradigms without necessarily proving their value. . .research is needed to determine if existing non-computerized as well as computerized educational processes should be perpetuated" (Milner & Wildberger, 1974, p. 11).

There are several reasons that evaluations of computer curricula have been limited. In the schools there has been little formal evaluation of computer-related activities. Typically, teachers have evaluated the effectiveness of computer-based materials on the basis of their own experiences with the material, how well the students are learning or on students' performance on tests similar to those used with more traditional instruction. Moreover, teachers are apt to emphasize the social outcomes such as social interaction, status and self-esteem rather than what the child is learning through his/her interaction with the microcomputer (Sheingold, 1981). Second, definitions of effectiveness vary along with means of evaluating CAI. For some, effectiveness implies the amount of learning that occurs; to others, it is measured by persistence in a particular course or learning experience; some are concerned with changes in attitudes, while others evaluate the ease in which these materials can be used by others (Chambers & Sprecher, 1980). Third, much of the CAI being used in the schools is supplementary to traditional instruction and does not replace it. This makes it difficult to compare CAI and traditional instruction (Magidson, 1978). Superior performance by an experimental or computer group may be attributed to the instructional method rather than the technology being used to deliver instruction. Finally, it is also difficult to test whether students who have used the computer in a problem solving mode are better able to solve real-life problems (Milner & Wildberger, 1974).

There have, however, been some large-scale evaluations. Generally, they have been conducted on programs such as PLATO, TICCIT and CCC, projects which received federal funding in their development stage. Drill and practice and tutorial were the modes of instruction. A sampling of reviews of these research studies will be described. Although evaluations conducted at the elementary level will be emphasized, others will be described as well. Logo evaluation studies will be discussed in the next section of this dissertation.

The majority of the evaluation studies reviewed in this section examined drill and practice or tutorial applications. Some used a traditional "box score" (Kulik, Bangert and Williams, 1983, p. 20) approach which generally describes the studies reviewed, while others used a more quantitative method of meta-analysis to compare studies reviewed and determine if there were significant effects across experiments for specific variables.

Vinsonhaler and Bass (1972) conducted one of the earlier reviews of three language arts and seven mathematics studies of CAI. These included most of the major drill and practice evaluations at the elementary school level which employed an experimental design. All studies reviewed used drill and practice in mathematics or language arts. Performance was measured using gain scores on standardized achievement tests. The experimental group received traditional instruction which was supplemented by CAI for five to fifteen minutes per day for a period ranging from three to ten months. The control group received traditional instruction without any special assistance. To control for a possible Hawthorne effect, some control groups also received CAI. For the language arts groups using CAI, gains ranging from one tenth to four tenths of a school year were reported. For the mathematics groups, the majority of the studies indicated statistically significant results favoring the CAI group. These findings led Vinsonhaler and Bass to conclude that "CAI plus traditional classroom instruction is usually more effective than traditional instruction alone in developing skills, at least during the first year or two. What remains in doubt is the advantage of CAI over other, less expensive methods for augmenting traditional instruction and the long-term effects of CAI" (p. 31).

A review by Taylor et al. (reported by Splittberger, 1979) suggested similar findings. Based on 33 empirical studies on computer assisted instruction conducted between 1966 and 1973, they concluded the following: 1) Based on student achievement results, CAI proved to be an effective method of instruction; it was more effective in tutorial and drill and practice than problem solving and simulation. 2) Students tended to learn more rapidly if they were allowed to proceed at their own rate, although the retention rate using CAI was generally lower than with a traditional approach. 3) CAI was generally as effective as other individualized supplemental instruction when its function was supplemental. 4) Both teachers and students were generally enthusiastic about CAI. Longitudinal studies were necessary to determine if this were only a Hawthorne Effect. The general conclusion was that there was not enough conclusive evidence to promote school uses of microcomputers.

Chambers and Sprecher (1980) also reviewed the effectiveness of CAI. They restricted their study to large-scale implementations such as TICCIT, PLATO and the Computer Curriculum Corporation materials. PLATO and TICCIT have been used widely in colleges and universities. PLATO has also been used in the primary and secondary grades. In the PLATO system, several hundred terminals were linked to a large computer system. These materials were generally used in conjunction with more traditional instruction. TICCIT was designed for a minicomputer and used a learner-controlled tutorial approach. With respect to PLATO, evaluation studies found no significant differences in achievement or attrition between those students using PLATO and those using more traditional methods. Both students and instructors using PLATO exhibited generally positive attitudes towards the computer. The results for the TICCIT program also suggested improved student achievement for the mathematics and English curricula. Attitudes towards the TICCIT approach versus lecture differed according to the curriculum. However, the attrition rate was significantly higher for the computer group, and the students in this group felt more ignored. The Chicago City Schools Projects which used the CCC materials provided instruction to over 12,000 students in grades four through eight in inner city schools. Results indicated that there was a significant increase in student achievement (Chambers & Sprecher, 1980).

Chambers and Sprecher (1980) also identified consistent findings among the studies they reviewed and concluded the following:

1. The use of CAI either improved learning or showed no differences when compared to the traditional classroom approach.
2. The use of CAI reduced learning time when compared to the regular classroom.
3. The use of CAI improved student attitudes toward the use of computers in the learning situation.
4. The development of CAI courseware following specified guidelines can result in portability and their acceptance and use by faculty (p. 36).

The final reviews to be discussed used the method of meta-analysis. Burns and Bozeman (1981) examined the effectiveness of CAI in mathematics at the elementary and secondary school levels. Forty studies were included that used computer drill-and-practice or tutorial that was supplemental to traditional instruction. Student achievement was examined in each. Significant differences were found favoring the drill-and-practice and tutorial modes over traditional instruction with mean effect sizes of .34 and .45 for drill and practice and tutorial, respectively. This was true at both the elementary and secondary level for drill and practice. While the achievement level of students of average ability was not significantly increased by drill and practice, it was more effective among high achievers and disadvantaged students. At the secondary level, enhanced achievement was demonstrated by boys using drill and practice, while girls showed no change. All studies examining sex differences were at the secondary level. With respect to tutorial, this mode of instruction was more effective at both the elementary and secondary school levels and among disadvantaged students.

Kulik, Bangert and Williams (1983) used a secondary school population to examine the effects of computer based instruction in a classroom setting. Again, student achievement was examined in each of the 48 studies reviewed. In addition, retention, student attitudes toward the subject matter, computer and instruction, and amount of time needed to learn were examined. The results of the meta-analysis suggested that students who received computer based instruction performed at the 63rd percentile on their exams compared with the control group which performed at the 50th percentile. This effect size varied from study to study. Although retention examination scores were higher in four of the five studies reviewed, they were not statistically significant. Of 10 studies which examined student attitudes towards computers, eight favored the computer groups; however, only three found statistically significant differences. Students in the computer groups also rated the quality of instruction higher, however, the effect size was low and the differences were not statistically significant. Finally, based on only two studies, results suggested that the amount of time the students took to learn the material was substantially lower for the computer group.

The research findings across these studies are generally consistent. They show neither overwhelming support in favor of CAI, nor compelling evidence against it. The question remains whether there are enough conclusive results from drill and practice and tutorial evaluation studies to warrant the expenditure of large sums of money for the purchase of computers in the schools for drill and practice activities.

The generalizability of these research results is questionable. Many studies failed to describe the instructional application in adequate detail to allow for generalization from one setting to another (Splittberger, 1979). One of the limitations of most of the research studies is that their findings may not generalize to a more typical school setting where only one computer is available for every 50 students.

"The truth is that we have been sold on the process and not on the product of microcomputer instruction, and few of us actually know if microcomputers are having any worthwhile impact on the effectiveness of schools in improving learning" (Bear, 1984, p. 12). Becker (1982) expressed similar concerns and issued the following caveat:

> "The limited evaluation research shows that computer-based drill programs can be effective-- given enough equipment for each child to have sufficient access and given appropriate content, organization of classroom activity, and monitoring. However, most of this research has been done under organizational conditions that allowed many computers to be in use at one time. Most involved use of time-sharing computer terminals rather than independent microcomputers, and were heavily monitored and well-managed implementations. Research should be conducted to determine whether most of the more typical drill-and-practice materials available for the TRS-80's, Apples and other microcomputers the schools are now buying are as educationally effective under more typical conditions of use as were the pioneer C.A.I. programs." (pp. 20-21).

Logo

Introduction

A common practice in education is to take a new technology such as the computer and rely on old instructional methods to present material. An example is using the computer for drill and practice activities. While there is some practical value to automating drill and practice, this application is not particularly imaginative or creative. A more constructive application is to reassess the educational practices that are being automated and reformulate them to take advantage of the computer. One such application is computer-based problem solving which is characterized by the notion that one should not be able to differentiate between a student's work on the computer and the student's work in another discipline. For example, in mathematics, the student can program the computer to solve mathematical problems, thereby "doing" mathematics with the computer versus learning a concept in the classroom and using the computer to apply it (Ellis, 1974).

Logo, a computer language as well as a philosophy of learning, adopts the learning by doing philosophy. Logo has gained general acceptance in the educational community and is one of the more popular computer languages used at the elementary school level. One of its goals was to demonstrate how computers can be used more "profoundly and more imaginatively" in education (Papert, 1973, p. 8). This section will describe the Logo language, the philosophy of learning espoused by its developers, advantages of Logo over other computer programming languages, educational applications, and a review of the research on the use of Logo in educational settings. Emphasis will be on the student learner at the elementary school level.

History and philosophy of Logo

Logo was developed by Seymour Papert and his colleagues at Massachusetts Institute of Technology (MIT) in the late 1960s. Papert (1980a) viewed the classroom as an "artificial and inefficient learning environment" (p. 8). He was highly critical of the manner in which mathematics were often taught in the schools. This was characterized by rote learning which makes it difficult for students to make sense of what they are learning. Logo was conceived as a means of making learning an active and exciting process, as a vehicle for Piagetian learning or "learning without being taught" (Papert, 1980a, p. 7). This kind of learning does not imply leaving children alone but assisting them as they build their own "intellectual structures" (Papert, 1980a, p. 7).

Logo was designed with two major goals in mind. First, learning to program a computer can be a natural process. An analogy frequently used to describe the Logo environment is learning to speak French by living in France (Papert, 1980a). Using Logo, mathematics can become an active process rather than a passive one. A commonly used metaphor to describe the child's relationship with the computer and mathematics is "Mathland" (Papert, 1980a). Doing mathematics can shift from "meaningless activity imposed from above" to a "purposeful, self-directed" activity (Papert, 1980b, p. 240). Second, learning to program a computer is not an end in itself. This may also affect the way other learning takes place. The role of the computer has been compared to that of the pencil. One can draw, write, scribble or doodle with a pencil. Similarly, the computer is equally as versatile (Papert, 1980b).

Advantages of Logo

Although designed with young children in mind, the Logo language has "no threshold and no ceiling" (Papert, 1980b, p. 236). This language is suitable for young children as well as college students and has been used in a wide range of settings (Watt, 1982a). The Logo language is similar to the spoken English language and therefore easy to learn. Error messages are comprehensible, enabling even a naive programmer to understand them and debug a program. Logo has the versatility to accommodate students of different ability levels, and learning styles. Unlike other modes of learning, there is more than one way to solve a problem and more than one right answer. One of the major objectives of the Logo language is to be able to identify bugs in a computer program, correct them, and ultimately make the program work. Users are also encouraged to explore their own personal learning styles rather than conform to one method of learning.

Papert (1980a) asserted that if a child were allowed to interact freely with the computer, s/he would become proficient at programming. This could be one of the more "advanced intellectual accomplishments" of the child. Added benefits of Logo include the ability to concretize formal operations at an earlier age. These generally develop around fifth or sixth grade.

When compared with other programming languages, Logo has several advantages which include the following: 1) Logo is procedural. It is possible to divide a program into small pieces, writing a separate procedure for each unit. Unlike a programming language like BASIC, one can look at a Logo program and understand what it is doing if structured programming is used. For example, a program to draw a head could be written as follows:

```
TO HEAD
CIRCLE
EYES
NOSE
MOUTH
BEARD
HAIR
EARS
END
```

2) Logo is an interactive language. It allows the user to type in commands that will be carried out immediately. This facilitates revising programs and is especialy helpful in program development and debugging. The disadvantage is that programs that are already written take longer to execute. 3) Logo is recursive. That is, a Logo procedure can be a subprocedure in the same program. This attribute is characteristic of procedural languages such as Pascal but not of languages such as BASIC or FORTRAN. Recursion allows large problems to be stated in a "compact form". 4) List processing. Computer languages such as BASIC, FORTRAN and PASCAL use arrays to group together several pieces of information. Logo's counterpart is list processing. Arrays are constrained by a fixed size and must either be numeric or string characters. In contrast, a Logo list can be a number, a word or another list of variable size. One disadvantage of lists is that processing takes longer in a list than it would in an array. 5) Logo variables are not typed. Unlike most programming languages, Logo variables are not typed. That is, they do not have to be defined as alphabetic or numeric characters. In languages such

as Pascal, the type of variable must be stated in the program; in BASIC, a dollar sign at the end of the variable name indicates a character string; and in FORTRAN, unless otherwise defined, the variable type depends on the first letter of its name. 6) Logo is extensible. While computer languages generally have built-in procedures such as arithmetic operations, extensible languages enable the user to define procedures which are like primitive procedures. Extensible languages can be valuable in teaching (Harvey, 1982).

The Logo environment

Logo is not only the name of the programming language, but a culture or environment as well (Abelson, 1982; Papert, 1980a; Solomon, 1975). Turtle geometry is only one part of Logo but epitomizes the Logo culture (Solomon, 1982). The "Turtle," represented by a triangle on a video screen, transmits this culture to its users, especially beginners.

Unlike the more traditional classsroom, the instructor does not provide answers but guides the child and encourages him/her to play turtle (Papert, 1980a). Working with Logo is treated as a collaborative effort between students and teacher where sharing of ideas is encouraged. This is a learning experience for the teacher as well. S/he is not expected to be able to know how to solve all problems, but work together with the students to achieve that end (Watt, 1982b).

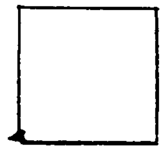
The child's or programmer's role is that of experimenter, trying to understand the turtle and its behavior. In response to the child's query of how to make the turtle do something, the response should be "play turtle" (Solomon 1975, p. 5). Children should also be encouraged to try something and realize that if they don't like what the turtle does, they can "undo it" (Solomon, 1975). Teaching and learning are not concerned with being right or wrong, but with the process of debugging, discovering bugs in programs and correcting them to make them work (Solomon, 1982). Bugs are seen as good things because students can learn from them; learning to recognize and appreciate bugs are attributes of the Logo environment (Solomon, 1975). The computer also serves as a tool with which the child can draw on his or her own intuitive knowledge of geometry (Solomon, 1982).

The Logo language

One of the principal characters in the Logo microworld is the Turtle, "an object to think with" (Papert, 1980a, p. 11). The Turtle has two attributes, heading and direction. Programming is introduced as a metaphor of teaching the Turtle a new word such as square or triangle. Learning Logo is characterized by syntonic learning. Children can identify how the Turtle moves with their own bodies, thereby learning formal geometry. Thus, the turtle (or child) can move forward, backward, left or right.

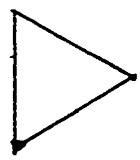
Initially, users are taught four basic or primitive commands: FORWARD, BACKWARD, RIGHT and LEFT. Inputs to FORWARD and BACKWARD indicate the number of steps the turtle wil move, while RIGHT and LEFT indicate the direction and number of degrees the Turtle will turn. One of the most popular introductions to Logo is to teach the Turtle to draw a square or triangle. This is often referred to as "teaching the Turtle a new word." Although there is no single method to draw a square, one of the easiest methods is the following:

```
FORWARD 100
RIGHT 90
FORWARD 100
RIGHT 90
FORWARD 100
RIGHT 90
FORWARD 100
```



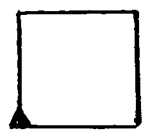
Similarly, an equilateral triangle with length of 100 can be written as follows:

```
FORWARD 100
RIGHT 120
FORWARD 100
RIGHT 120
FORWARD 100
```



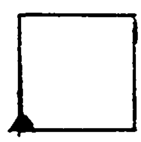
A more elegant approach to draw a square is to use the REPEAT command and is illustrated by the following procedure:

```
REPEAT 4
  FORWARD 100
  RIGHT 90
```



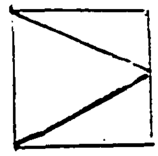
A third, and more sophisticated method of drawing a square is to introduce the concept of variable. The following program will draw a square of any size which will be determined by the input used for the variable SIZE.

```
TO SQUARE:SIZE
REPEAT 4
  FORWARD:SIZE
  RIGHT 90
```



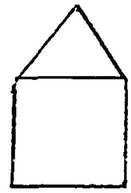
This program has been given the name "SQUARE" and can be saved, modified and/or used as a building block in subsequent programs. For example, the programmer can produce a procedure for a house calling up programs or procedures that have already been written and saved for square and triangle. A common program is the following:

```
TO HOUSE
SQUARE
TRIANGLE
END
```



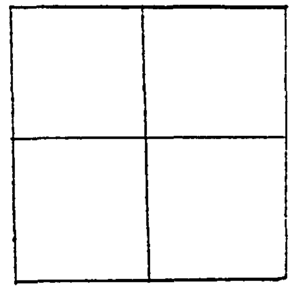
Unfortunately, this program has a "bug" in it. However, the process of debugging is part of the Logo experience. The following program is only one way of correcting the bug. In addition to turning right before starting, the TRIANGLE procedure was also modified. The Turtle was instructed to go LEFT instead of RIGHT:

```
TO HOUSE
RIGHT 90
SQUARE
TRIANGLE
END
```



Many powerful ideas, such as the concept of variable or recursion. are introduced via Logo at an earlier age than would be in a traditional mathematics class. With Logo, recursion is a relatively simple concept for students to learn and can be illustrated by a program calling itself. An example of this is the following program where the SQUARE calls itself:

```
TO SQUARE
FORWARD 100
RIGHT 90
FORWARD 100
RIGHT 90
FORWARD 100
SQUARE
END
```



This is just a brief introduction to the Logo programming language. The intent is to illustrate the power and flexibility of the language using Turtle geometry. Although Turtle geometry is only one part of the

Logo culture, it characterizes the flexibility and ease in which this procedural language can be used.

Educational applications and research studies

There have been numerous implementations of Logo in a wide range of educational settings. Grade levels have ranged from kindergarten to the college level. Students of varying abilities, from the learning disabled to intellectually gifted have used Logo. Settings have been varied as well. Logo has been used in laboratory type settings and the regular classroom where all children have had hands-on experience. Logo has served a variety of functions which include the following: 1) aiding in the development of problem solving skills, 2) providing a medium for a mathematics curriculum, 3) developing computer literacy skills, 4) teaching the principles of a structured programming language, 5) providing a learning environment for children who have been less successful in a traditional classroom setting, 6) serving as a learning environment in a variety of subject areas including mathematics, language arts, fine arts and the sciences, and 7) facilitating Piagetian learning and teaching (Watt, 1982a). This section will describe a sampling of the implementations ranging from the large scale projects conducted by the MIT Logo Group to those implemented on a smaller scale by individuals unrelated to MIT. The projects and their objectives will be briefly described and research results will be discussed.

There have been at least two major Logo research efforts, one by the MIT Logo Group and the other at the University of Edinburgh in their Artificial Intelligence Laboratory. Although differing in philosophy and methodology, both have dedicated a large part of their research efforts to school age children. Major studies conducted by both of these groups will be described. A sampling of other studies by researchers who were not affiliated with either of these research groups will also be discussed.

MIT Logo Group projects Although the MIT Logo group has conducted a great deal of research, it is characterized by largely anecdotal reports and often uses a case study approach (e.g., Papert, 1980a; Solomon, 1982; Watt, 1979). Papert's (1973) approach to research is an idealistic one. According to Papert, a conventional research design implies making a small change to a large and complex system. If the experiment works, a small barely noticeable effect is produced, "just enough to be distinguished from the noise by dint of ingenious statistics" (Papert, 1973, p 32). Papert's approach is to develop an educational theory and implement it on a small scale using all the necessary resources, ignoring issues such as cost, and convincing educators, colleagues and others of its value. According to Papert, when the experiment is run for a specified period of time, one of two things will occur: "SUCCESS: The results are so qualitatively different from what would normally be expected that no sane observer says: "how do you measure that?" or "FAILURE: If under these 'ideal' conditions the results are so poor that the statisticians want to test them for significance you declare the experiment a failure, try to understand why it did not work, perhaps try another" (Papert, 1973, p. 34).

One of the first implementations of Logo was reported by Feurzeig, to determine if a computer language could be used to teach mathematics. Logo was used as a framework for teaching an algebra course to 12 seventh grade students. Their introduction to algebra was solely through Logo. Students worked with Logo for one hour four days a week. The initial introduction to Logo was to write non-numerical procedures. Examples were word games, translating Logo into Pig Latin and other things with which students were already familiar with. Subsequently, Logo was used to teach algebra.

Although the preference of the researchers was to use the judgment of mathematicians and mathematics educators who were directly involved with these students, some objective measures were used as well. Twelve students in the experimental group were matched with 12 students who served as the control group. Both groups were administered the Iowa Test of Basic Skills in the beginning of each academic year. Apparently, because of time constraints, differences between groups were not tested for significance. There were several tentative conclusions drawn on the basis of these tests. When compared with the control group, the computer group exhibited positive changes in areas of vocabulary, reading, use of reference material, reading graphs and tables and arithmetic concepts. Conversely, the control group performed better on capitalization, punctuation, map reading and arithmetic problems. Differences on the arithmetic problems score were not large; it was speculated that this may have been a result of the fact that the computer class did not get much work with standard seventh-grade arithmetic problems. It was concluded, however, that the students' progress in mathematics and other subject areas was not impeded by the Logo experience. The mathematics placement for these two groups lent further support to the computer group's progress in mathematics. The recommendation was made that six of the students advance to a higher phase. In the control group, only three students advanced to a higher phase and one was down phased. The two groups were *not comparable with respect to placement initially. The recommendations* were upheld by mathematics teachers for the computer group the following year. Based on these findings, as well as opinions of evaluators and educators who participated in the project, Feurzeig et al. (1969) concluded that, 1) Logo can be used to express a wide diversity in teaching styles and modes of presentation; 2) it is feasible to teach Logo to average seventh-grade students and 3) it is feasible to develop and effectively teach a mathematics curriculum using Logo. There were other educational and behavioral benefits of Logo as well. Administrators and teachers in the junior high school observed behavioral changes in some of the children which they attributed to students' experience in the course. Examples were increased self-confidence and more positive social attitudes.

A secondary question in this study was the feasibilty of teaching formal thinking via Logo to younger chilren. This was explored on a small scale using a group of "mathematically average" students in grades two through four. The original group of 12 students was reduced to two second graders and six third graders who used Logo for four 20 minute sessions per week for 20 weeks. Logo was taught using a series of interactive programmed lessons that were relatively open-ended. The project was evaluated via a teacher log and samples of student work. General conclusions were the following: 1) children in second and third grades could learn Logo with relative ease; 2) most children could not learn to write or debug relatively complex programs in the four month period allotted for the project; 3) children were able to acquire an understanding of concepts of variable, function and formal procedure and 4) side effects such as an improvement in reading rate were exhibited by these students (Feurzeig et al., 1969).

The Brookline Logo Project was one of the first and most highly publicized projects of the MIT Logo Group. Fifty sixth grade students participated in this project, but the work of only 16 students was documented in detail. This group contained average" students, students with learning disabilities as well as students that were considered to be above average. Groups of four students worked in the Logo classroom for about four hours a week for five to seven weeks. The ratio of students to computers was 1:1. Although goals were set for the students, there was enough flexibility built in to allow for deviations from the pre-determined goals. The general objectives of the project were the following: 1) learning to feel comfortable with and in control of the computer; 2) learning the elements of the Logo language; 3) learning the "subject matter" of Turtle Geometry; 4) understanding the relation between force and motion; and 5) developing problem solving skills. Students received instruction and guidance from a teacher who had been trained in Logo at MIT. Students worked in groups of four and each student had access to a computer. After learning the basic turtle commands, syntax and error messages, students were encouraged to design their own Logo project to develop their own learning styles and to set their own priorities. The role of the teacher was to introduce new Logo concepts when appropriate and assist students in improving their programming. The teacher also provided suggestions for debugging and encouraged students to explore the Logo language more deeply.

Unlike many evaluations, rather than summarizing the performance of students using statistical analysis, other methods were used. Data sources included detailed records of student's work, interviews with teachers, student interviews and formal observation of students in an attempt to identify differences in learning styles, mastery and integration of various Logo concepts, programming strategies and styles, attitudes towards the learning experience as well as possible transfer to other classes. General conclusions were, "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 channeling this learning toward mastery of programming" (Papert et al., 1979, p. 1.15). However, all children did not learn the objectives specified at the outset of the project. The versatility of the Logo language was also demonstrated. Unlike BASIC where it is necessary to understand some of the advanced concepts to write interesting programs, it was possible for students with learning difficulties to learn enough Logo to be able to write interesting programs (Papert et al., 1979).

Transfer of skills were speculative. Some tentative, although not statistically significant, conclusions were made about the transfer of knowledge about angles and measurement from a Logo context to a more general one. The ability of three groups of students to estimate angles given one as a reference point was examined. Performance of the Logo group was highest followed by students participating in a less systematic Logo project and students with no computer experience, respectively. When students were given another task requiring the estimation of length and drawing lines of specified lengths, the differences were in the same direction but less pronounced. It was suggested that transfer would be more apparent after a longer period of exposure to Logo than these students had experienced (Papert et al., 1979). It was also noted (Watt, 1982a) that it is difficult to measure problem solving or procedural thinking objectively.

The second Brookline Logo Project (Watt, 1982a) moved Logo out of the laboratory setting into the classroom. Computers circulated among classrooms in grades four through eight and each classroom had the use of a computer for eight to 12 weeks. Teachers received a small amount of Logo training. Curriculum materials were developed for the project for use by students and teachers. Introductory materials were prepared for grades four through six while a set of dynaturtle games, designed to follow Newtonian Laws, were prepared for the older students. The primary focus of this study was curriculum development. One of the results that emerged, however, was the student's role as teacher of Logo. Some of the students who had participated in the first project became tutors in the second project. Eventually, teachers began to rely on these students for help. The fourth grade students were also assigned a tutor from an upper grade when they were first introduced to Logo. Although noted as an outcome of the project, the student's role of teacher was not studied systematically (Watt, 1982a).

One of the most extensive Logo projects was carried out at the Lamplighter School, a private school in Dallas, Texas, by the MIT Logo Group and Texas Instruments. The goal of this project was to allow unlimited access to computers and to see what students could learn in this environment. Computers were placed in all classrooms from nursery school to fourth grade, allowing all students access to computers. Support was provided by a part-time teacher who was responsible for overseeing the project and providing individual tutorials to teachers. Anecdotal evidence (Turkle, 1984; Watt, 1982a) suggested that children were comfortable with computers and treated them as another learning tool. Children in first and second grades were able to write simple programs and a general interest and excitement about computers permeated the classroom. Although intended, Logo had not been integrated into much of the curriculum. For the most part, formal research studies evaluating the Lamplighter project have not materialized (Watt, 1982a).

One of the frequent topics of study by MIT researchers is the programming styles of Logo programmers (Papert et al., 1979; Solomon, 1982; Turkle, 1984; Watt, 1979). Again, the method used to identify different programming styles was observational.

Watt (1979) examined the learning styles of students participating in the Brookline Logo Project and described the learning styles of two students, representing the extremes. They approached similar projects in very different ways, one using top-down and the other using bottom-up programming. The student using a bottom-up approach used as few commands as possible and was resistant to change. Her approach was an exploratory one, constructing each part of her figure as she went. Despite her inability to plan ahead, her estimating skills were good and she was able to visualize the end product. Her counterpart was the other extreme and was characterized as a planner. Before beginning on his project, he drew a master plan and subsequently worked on subprocedures. His strength was in his ability to solve problems analytically versus visually. The ability of the two extremes to successfully complete a project demonstrated Logo's capacity to foster learning in children of different developmental levels, learning styles and abilities (Watt, 1979).

Solomon (1982) also identified different programming styles using a different classification which was an outgrowth of her own observations and those of Dan Watt from the Brookline Logo Project. Although not exclusive, there were three distinct styles. The "planner," regardless of whether s/he was a top down or bottom up programmer, always had formulated a definite plan. In contrast, the macro-explorer had no specific goals in mind but liked to explore the effects of subprocedures and other building blocks. Finally, gradual exploration characterized the "macroexplorer." Typically, this student used the same commands repeatedly or used the same numbers as inputs.

Turkle (1984) conducted an ethnographic study of computer use in general. One aspect of her study included children using Logo and their approaches to programming. She identified two learning styles similar to Watt's that she described as hard and soft mastery. The former is representative of the stereotypical computer programmer. This individual uses top down programming. S/he develops a global plan and then breaks it into subprocedures. The goal is getting the plan, as it was conceived, to work. In contrast, the soft masters who also had an initial design, were less rigid in their execution. They were more apt to stand back, examine their work and decide what to do next. This style is a more interactive one relying on more concrete elements than that of the hard master. The soft masters typified girls while hard masters were overwhelmingly boys (Turkle, 1984).

Although Logo lends itself to the elementary school level, the MIT Logo group also used it with other age groups, more specifically, teachers and/or students training to be teachers (Austin, 1976). Austin was interested in the kinds of problems that arise when adult teacher trainees learn Logo and when they, in turn, teach it to their students. Austin (1976) worked with 30 undergraduate and graduate students at a teacher's college for 32 hours on Logo. Turtle Geometry as well as other components of the Logo language such as music, juggling and physics were covered. Based on classroom activities and student projects, Austin observed that the students successfully learned material presented and were able to generalize this learning to new situations. However, they were generally less willing to try new ideas and approaches than were children. A general enthusiasm was demonstrated by their desire to teach what they had learned to others.

The Edinburgh Logo studies Another center of Logo activity is the Artificial Intelligence Laboratory at the University of Edinburgh, Scotland. There, several studies have been undertaken using Logo to teach mathematics. Using the computer and a language such as Logo the student can "use the computer as a mathematical 'laboratory' in which to experiment" (Howe, Ross, Johnson, Plane & Inglis, 1982a, p. 85). Writing computer programs has been used to help students to learn to formulate a problem and the steps required to solve it (Howe, O'Shea & Plane, 1980).

There are two major departures by the Edinburgh group from the MIT Logo Group. First, the Edinburgh group has rejected Papert's lightly structured strategy where the teacher's role is to introduce new ideas, concepts and projects as the need arises. In contrast, these researchers (Finlayson, 1984; Howe, O'Shea & Plane, 1980; DuBoulay & Howe, 1982; Howe et al., 1982a,b) favored a more structured approach. Worksheets were developed to accompany computer work so that knowledge could be integrated in a logical way. These worksheets contained information and exercises for the learner to type in, modifications to existing procedures and "seeds" for open-ended programs (Howe et al., 1980). Second, they (Howe et al., 1980) advocated a more quantitative approach to evaluation. One of the priorities in education is to provide supporting evidence that new methods actually help children's learning of mathematics. Unlike Papert (1973), they felt that factors such as cost and objections of parents, teachers and administrators could not be ignored. Current teaching methods and materials were important considerations in the design and implementation of a study. "So while the revolution might suit the need of the experimentalist, in practical teaching situations we are usually only free to introduce reforms, making only slight changes to existing systems" (Howe et al., 1982b, p. 28).

Bearing these values in mind, the approach of this group has been to start with a small laboratory study using a specialized group of students (Howe et al., 1980) and then extending it to a larger more general population (Howe et al., 1982a). In both cases, an experimental design using non-random assignment of control and experimental groups was used. The theory was first tested on the "local" level with a restricted population. The next step in the process would be to obtain results on a "general" level (Howe et al., 1982a,b).

In their earlier study of Logo, Howe, O'Shea and Plane (1980) worked with a group of 11-13 year old boys attending a private school who were of average or below average ability in mathematics and in the lowest mathematics class. The goal of this study was to improve the students' ability with respect to specific mathematics topics, improve their understanding of basic skills and concepts and increase their self-confidence with respect to mathematics. Logo programming activity supplemented mathematics classes. These students spent one hour per week during two school years (1976-1978) working with Logo at the Artificial Intelligence Laboratories at the University of Edinburgh. During the first year, this occurred during regular school hours and in the second year after school. In the first year, these students were taught Logo. In the second year, the students used Logo to explore topics in mathematics that presented difficulties. Self-paced worksheets were developed which introduced computational ideas, problem solving tactics and debugging skills which emphasized using analogy to explain key concepts. Mathematics worksheets were developed too and were structured similar to the Logo materials.

A group of 11 male students who were in the second lowest mathematics group at the same school served as the control group in this study. They received no additional mathematics instruction. At the beginning and end of the study, both groups were administered a test of general scholastic ability, a mathematics attainment test and a basic mathematics test. The groups were not matched on the pretest and the control group scored higher on all three tests. There were significant differences on the test of general scholastic ability and the mathematics attainment test. Post-test scores on the three tests indicated some changes. Differences on the scholastic ability test and basic mathematics tests had decreased and were no longer significant. Differences were greater on the mathematics attainment test, favoring the control group. This difference was attributed to the fact that the control group had completed a larger number of problems than the experimental group, and was not a function of the control group answering more questions correctly. The conclusion that the differences between the two groups were no longer apparent was substantiated by scores on five school mathematics tests that were administered the next year. Based on these tests, almost half of the boys in the experimental group improved their standing while only one boy in the control group improved; one boy dropped to a lower level.

Teachers were also asked to evaluate the students' performance, ability and attitudes towards mathematics. Responses on two of the items on the teachers' evaluation form, "The pupil can explain his own mathematical difficulties clearly" and "The pupil will argue sensibly about mathematics" indicated agreement for the experimental group but a neutral response and disagreement for the control group on the two items, respectively. This led to the conclusion that the Logo group was able to communicate about mathematics in a way which was atypical of their peers (Howe et al., 1980).

The boys' attitudes towards mathematics were examined as well using a semantic differential test. Over a two-year period, the attitudes of the experimental group toward learning mathematics became slightly more positive. In comparison with the control group, this group was much more relaxed about mathematics. The control group described themselves as being "tense."

Attitudes towards the worksheets were examined as well. The initially positive attitudes became less positive towards the middle and neutral by the end of the study. Nevertheless, mathematics performance improved, which suggested that the changes in performance were due to the programming activity, not the motivational effects of the program (Howe et al., 1980).

Despite the generally positive results, it was argued that the changes in performance could be explained by other factors such as a Hawthorne effect, the extra time devoted to mathematics, or the close personal attention received by the students (Howe et al., 1980). This led to a second study which encompassed a larger group of students of both sexes in a regular classroom setting (Howe et al., 1982a,b). Computer programming was integrated into the mathematics class for half of the first year group in a secondary school (n=90). Classroom teachers were initially given a course in Logo and were subsequently responsible for teaching Logo to the students. The researchers' roles were that of observers and being responsible for the teaching material and maintenance of equipment. The topics for the computer-based materials covered many of those studied in the regular mathematics curriculum. Unlike the previous study, Logo was taught in conjunction with the mathematics materials. Because there were only six computers available for approximately 30 children, the amount of time actually spent on the computer was limited. Children worked in pairs and time spent on the computer ranged from six to 11 hours per student.

The evaluation comprised a series of mathematics and attitude tests administered to both a control and experimental group. Both groups were administered a Basic Mathematics Test which was a test of their understanding of mathematical relationships and processes. There were no significant differences between the two groups at the outset or termination of this study. There were, however, some differences on the basis of gender. While performance was stable over time, females in the control group scored lower than the males in the control group. Similarly, there were no significant differences between the experimental and control group on a Mathematics Attainment Test. However, when scores were broken down by sex, there were significant differences between the two female groups. While the control group's score remained relatively the same, the Logo group's score increased. The difference in performance between the male control group and the female experimental group, which initially favored the males, disappeared as well. The male group dropped in performance while the experimental female group improved. Scores on the test containing questions on selected mathematics topics were significantly different for the experimental and control group. Significant differences were found between the two female groups; the Logo females scored higher. Although not significant, when scores on each item were examined, the Logo students outperformed the control group on all but one item. The latter item was a topic not covered with Logo. With respect to attitudes towards mathematics, scores indicated no change in attitudes for the Logo group nor differences between the sexes. In fact, a marginal drop in motivation was noted over the course of the year. Finally, the Logo group's attitudes towards Logo were examined at the end of the study. These were generally negative which would refute a Hawthorne effect.

The general conclusions were that a child's progress is influenced by her/his ability and the amount of exposure to a Logo based curriculum. "Suggestive" rather than "conclusive" results were attributed to the relative short amount of time spent with Logo (Howe et al., 1982a). Under these circumstances it was hypothesized that differences between the Logo and control groups would become more apparent over a longer time period.

Finlayson (1984) also focused on the mathematical learning that results from working with the Logo programming language and tested the transfer of learning from Turtle Geometry to the understanding of angles, shapes and variables. Again, worksheets were used to structure the experience. They introduced programming concepts and provided suggestions for student projects. A classroom of 32 students of mixed ability served as the experimental group and another class at the same grade level and in the same school served as the control group. The grade level was not specified. Children worked on the computer in pairs for at least one-40 minute session per week. On average they spent 70 minutes per week over 28 weeks using the computer.

A pre-test of mathematical attainment and non-verbal intelligence administered to both groups revealed no significant differences between them. At the end of the study, tests of mathematical understanding were administered. While there were no significant differences on tests of reflections and rotations, an estimation of angles test resulted in significant differences. Students were required to estimate the size of an angle from a given one. Over half of the control group scored less than 3 out of a possible 8 points, while two thirds of the experimental group scored 6 or more points. The Logo group also performed significantly higher on the higher level questions on the Chelsea II Test of Algebra which measured the concept of a variable. Finally, seven "mathematical strategies" items were administered. The experimental group's performance was significantly higher on four of five questions on generalization and the abstraction of underlying rules. On the basis of these findings, Finlayson (1984) suggested that children's improved understanding of angles, variables and mathematical strategies was a result of using Logo.

The final study to be reviewed, that was conducted at the University of Edinburgh, had goals similar to those previously described but a different target group, teacher trainees in their second or third year and who were identified as needing remedial work in mathematics (DuBoulay & Howe, 1982). In the second year group, students in a control group (n=6) covered the mathematics topics using a traditional approach. The experimental group (n=6) used a Logo based curriculum covering shapes and numbers. They spent approximately 26 hours working with Logo over the course of a year. The remaining students in the group (n=31) performed satisfactorily in mathematics and did not receive any additional instruction. In the third year group, nine students were identified as needing help although they had received help the previous year. All received supplementary instruction via Logo for 17 sessions over the academic year for an average of 14 hours. The remaining students (n=25) received no instruction.

Results of this study were generally not conclusive. Some of the findings supported the Logo curriculum, while others demonstrated no differences or supported the control group. In the second year study, the Logo group improved significantly on a shapes and numbers test. This gain was not reflected, however, on the group's performance on a general mathematics test. While the experimental group scored significantly higher than the control group on the pre-test, this advantage disappeared by the post-test. The experimental group had a more negative attitude towards mathematics at the beginning of the study which may have affected performance on the mathematics test (DuBoulay & Howe, 1982). The third year group's exposure to the Logo curriculum was more superficial given that they spent fewer hours working with the Logo modules. Scores for this group on the shape test were lower than the second year experimental group and about the same as the second year control group. However, there was no significant improvement between the pre- and post-test. Both groups showed improvement on arithmetic and geometry topics. Since the control group had received no mathematics training, it was suggested that the post-test may have been easier than the pre-test. The researchers suggested a need to control for factors such as mathematics performance and attitudes towards mathematics before making final judgments about the value of Logo in a remedial course of this nature (DuBoulay & Howe, 1982).

Other Logo studies The educational literature contains many articles concerning Logo and its implementation in the classroom. Although there are numerous reports citing the enthusiasm generated and the motivational effects of Logo, these reports are largely anecdotal and are lacking in empirical evidence. However, there have been some studies with more specific objectives and/or preconceived research design. These researchers have investigated a variety of questions, some of which have been similar to those posed by the MIT and Edinburgh groups. A representation of these will be discussed.

The purposes of an earlier study of the Logo language (Milner, 1973) using a group of fifth grade students were 1) to investigate how to teach programming and 2) to determine whether mathematical concepts could be taught through computer programming. Eighteen fifth grade students were randomly selected and were taught Logo. There were three phases; each met twice a week for 40 minutes for five weeks. In the first phase, students were introduced to Logo. In the second phase, students were assigned to a high or low ability group based on their scores on the concept, applications and computation scales of the Stanford Achievement Test and were randomly assigned to one of three instructional methods. The first group was given an algorithm to be programmed in Logo, the second group was given an incomplete Logo program and the third group was given no information except the specific problem, usually tasks requiring variables and generation of arithmetic and geometric sequences. In the third phase, the criterion phase, all students were given tasks similar to the previous phase but no explicit information other than the assigned task. The purpose in this phase was to investigate the effect of instructional method in Phase II and ability in writing Logo programs.

The average number of error free programs written by students during each of the phases was recorded. There were no statistically significant differences between ability groups on the number of programs written. However, instructional method yielded significant differences in the learning phase, but not the final or criterion phase. The number of error-free programs were highest for the incomplete-program group, the algorithm-given group and the no-information groups, respectively, in the learning phase. Because of the size of the instructional ability groups (n=3), these results were tentative and required replication (Milner, 1973).

The hypothesis of concept acquisition via Logo was supported. Both the computer group and a non-computer group, a class of fifth graders attending the same school, were administered a concept test at the begining and end of the project. While there were no significant differences on the pretest, scores on the posttest were higher for the computer group (49 versus 36), suggesting that the concept of variable could be taught using Logo. The control group received no training on the concept of variable; however, the purpose of the study was not to determine which instructional method was better but whether the concept of variable could be learned through Logo (Milner, 1973). Based on observation of the students, Milner concluded that the students were highly motivated, enthusiastic and determined to complete the problems.

Efforts to characterize the programming styles of children using Logo have also been underway outside of the MIT Logo Group. Solomon's classification of programming styles (1982) was the starting point of a preliminary study of fifth graders conducted by Rampy and Swensson (1983). This investigation attempted to characterize the programming styles of fifth graders, the relationship of programming style to cognitive style (field independence or field dependence) and to gender. Six boys and six girls were selected as subjects on the basis of an extreme score on the Children's Embedded Figures Test and worked with Logo for six one and one-half hour sessions.

The preliminary data reported related to the children's programming style. Rampy and Swensson (1983) found Solomon's classification to be limiting and found no student who they would describe as a "planner." They classified the students on the basis of their focus on the process or the product, although these were not mutually exclusive categories.

Students who focused on the product were most interested in drawing a specific picture or design on the screen. Although they understood how to write procedures, they were more apt to work in the immediate mode and were less apt to change their programs if an "interesting" bug was in it. In contrast, the "focus on process" students preferred exploring and were more interested in experimenting with inputs and changing the plan if an interesting bug was encountered. It was hypothesized that the process-oriented person probably learned more about programming and the product-oriented group may have learned more about lines and angles (Rampy & Swensson, 1983).

The question of Logo's flexibility and appropriateness for young children was another area of study. Reimer (1985) attempted to determine the effects of using Logo on readiness for first grade, creativity and self concept. A group of eight five year old kindergarten students used Logo in this study. A curriculum unit was developed and 20 lessons were administered on 20 consecutive school days (Reimer, 1985). When compared with a control group, gain scores were higher on ten of 11 readiness test scores. They were significantly higher for visual discrimination, visual motor skills, visual memory and number recognition variables. Although statistically significant differences were not found, gain scores for the Logo group were higher on two measures of creativity, originality and elaboration. They also exhibited a small but not significant gain in self-concept when compared with the control group. Observations made by the classroom teacher indicated that the Logo group demonstrated greater gains in self-confidence, attention to detail and problem solving.

Results of this study were tentative due to the small size of the group, non-random assignment of subjects and lack of hard data to substantiate some claims such as improved self-concept in the Logo group (Reimer, 1985).

Many of the Logo implementations, particularly the MIT Logo studies and the University of Edinburgh studies, have taken place in a laboratory setting, small classroom or setting where teachers have received extensive Logo training. The feasibility of implementing a Logo curriculum on a large scale in a situation where most teachers were not trained in computer programming and a limited number of computers were available, was explored by Thompson and Blaustein (1985). An evaluation was conducted based on a series of three questionnaires administered to 19 fourth, fifth and sixth grade teachers at three participating elementary schools at three points during the project: 1) the initial contact with teachers, 2) the conclusion of the Logo workshops for teachers and 3) the termination of the project after students had received hands-on experience with Logo. These results will be summarized briefly.

At the onset of the project, teachers were queried about their computer experience and general attitudes towards computers. The majority of the teachers had had a minimum amount of exposure to computers prior to Logo. While the majority had attended a workshop on BASIC, only three of 18 teachers had used the computer for Logo activities. Generally, they were interested in computers and felt computers were important in education, particularly in the higher grades.

At the end of the workshops, teachers rated the Logo training as well as their competence with Logo. Based on a five point scale, familiarity with Logo was rated above average at a 3.8. They also reported their interest in Logo had increased from 3.6 to 4.2 (on a five-point scale) from the beginning to the end of the workshops. Further, over 80% indicated they wanted to continue with Logo. They also rated the educational value of Logo in learning about computers, programming, problem solving and geometry relatively high. Common criticisms were that they would have liked to spend more time on the computer outside of the workshop and that the pace of the workshops was too fast.

In the next phase of the project, Logo was implemented in the classroom. Evaluation of these activities indicated that student levels of accomplishment were higher than teachers had anticipated. Further, teachers rated the educational value of Logo for learning about computers, problem solving and geometry significantly higher than in the previous phase. The teachers were interested in continuing Logo in the classroom (94%), while all teachers indicated they would like to learn more Logo and would be interested in participating in future Logo projects. These generally positive findings suggested that it is possible to implement Logo in the classroom with a limited number of computers and limited computer experience on the part of the teacher. The educational value of Logo was also supported (Thompson & Blaustein, 1985).

The primary focus of another study which evaluated a Logo curriculum was the student. Badger (1983) evaluated a five week course in Logo which was taught to sixth grade students in two schools by student volunteers who were experienced in programming languages, but not Logo.

This study was poorly designed, and, although generally non-conclusive, results of this study are difficult to interpret. First, student populations and implementations were different across the two schools. At School A, the population was largely foreign and many of these students required extra help in academic subject areas due to learning or language problems. The Logo implementation had turtle geometry only and allowed students to save their programs and print them out. Forty-five minutes a day was devoted to Logo. At School B, students came from the immediate area or were bussed from other parts of the city. Students in this school had access to turtle geometry as well as the sprite program, but were not able to save programs with this implementation. A daily period was devoted to Logo; however, membership varied as a function of scheduling of other activities. Second, based on pre-test results, the students' familiarity with mathematical concepts such as angles, estimation and permutations prior to Logo varied among schools. Consequently, scores on a post-test measuring these concepts were generally non-conclusive because of the initial differences between the two schools and the different Logo implementations. In general, students in School B tended to score higher on the post-tests, understood what an angle was, and were able to estimate the size of an angle. There was some improvement observed for students in School A in their ability to draw a 90 degree angle correctly. It was noted, however, that some of the students at that school had received some instruction on angles from their teacher, independent of Logo, which further confounded the results.

Third, the methodology used to investigate student, teacher and tutor attitudes was not described. It was unclear whether this information was gathered in a structured or unstructured manner. Consistent with other outcomes of the study, reactions to Logo were not congruent among the three groups. Teacher reactions were generally positive. While the teacher in School A saw no carry-over to classroom work, she saw improved self-confidence, particularly in those students who were receiving remedial help. The teacher in School B was a mathematics teacher and, despite problems with structure, could see the educational advantages of having computers in the classroom. The tutors, on the other hand, were disappointed with the accomplishments of the students and felt that they had no incentive to develop problem solving skills. Students, however, generally reacted favorably to Logo. Badger (1983) was generally disappointed in the lack of cognitive involvement on the part of the student and felt that most of these students were "stuck at the affective level" which depended on "visual excitement" (p. 137). This lost its appeal with repetition.

Aside from the poor design of this study, it appears that the expectations of the researcher and tutors may have been too high. The role of the computer as "tutee" was used as a model in this study and may have been misinterpreted. According to Papert et al. (1979), the role of the teacher is to provide encouragement but also to introduce new Logo concepts when appropriate, assist students in improving their programming, and provide suggestions for debugging. It is unclear whether the tutors served in this capacity.

Conclusions

This review presents a wide range of Logo applications. Based on these studies, some general, although tentative, conclusions can be drawn: 1) Logo can be successfully taught to average or below average students (Feurzeig et al., 1969; Howe et al., 1980; Papert, et al., 1979), younger children (Feurzeig et al., 1969; Reimer (1985) and teachers (Austin, 1976; Thompson & Blaustein, 1985); 2) teaching mathematics using Logo as a medium can result in improved mathematics performance (Feurzeig et al., 1969; Howe et al., 1980); 3) working with Logo can result in the transfer of learning such as an improved ability to estimate angles and lengths (Badger, 1983; Finlayson, 1984; Papert et al., 1979) and an understanding of the concept of variable (Milner, 1973: Finlayson, 1984); 4) students can successfully program in Logo using a variety of programming styles (Papert et al., 1979; Rampy & Swensson, 1983; Solomon, 1982; Turkle, 1984; Watt, 1979); and finally, 5) there are affective benefits of Logo as well, including improved self-concept and more positive social attitudes (Badger, 1983; Feurzeig et al., 1969; Howe et al., 1980; Milner, 1973).

Several of the studies contained inconclusive results with respect to their stated goals. Explanations for these were attributed to factors such as 1) a small sample size (Milner, 1973; Rampy & Swensson, 1983, Reimer, 1985), 2) a relatively short exposure to Logo (Howe et al., 1982a,b; Reimer, 1985), 3) heterogenous groups (Badger, 1983; DuBoulay & Howe, 1982; Howe et al., 1980), lack of random assignment to groups or a comparable control group (Howe et al., 1980; Milner, 1973; Reimer, 1985) and 5) inadequate methods of measuring problem solving skills (Watt, 1982a). Typically, the research efforts that were not part of a larger research group such as the MIT Logo Group or the Artificial Intelligence Laboratory at the University of Edinburgh tended to suffer more from inconclusive results. In addition, these studies were not often followed up or results of a follow-up study were not published. In contrast, the Edinburgh and MIT researchers had the resources to start with a small scale implementation and build up to a larger one (e.g., the First and Second Brookline Logo Projects; Edinburgh studies) moving Logo from the laboratory to a classroom setting.

However, the generalizability of the Edinburgh and MIT studies to the typical classroom is questionable. Many were in a laboratory setting where students had access to their own computer and received instruction from a trained teacher. Unfortunately, in the typical classroom, this is not always the case; the number of computers available as well as trained instructors are limited (Center for Social Organization of Schools, 1983a). It is possible that the frustrations that Badger (1983) experienced with respect to different implementations of Logo, heterogeneous populations, and lack of structure are more frequent than one would expect. There is a need for more research on implementing Logo in the regular classroom to determine if it can be used successfully with a minimal amount of training and limited number of computers (Thompson & Blaustein, 1985).

Some of these reservations are reflected in the educational community. From the perspective of those individuals who are active supporters of Logo, a major concern is that Logo is being "oversold" and that some people are developing unrealistic expectations of Logo (Moursund, 1983-84). Second, there is the concern (Moursund, 1983-84) that Logo is perceived by some educators as a panacea, that Logo will teach computer literacy, improve problem solving skills and will also "make a major contribution to rectifying many of the current ills of education" (Moursund, 1983-84, p. 3). These claims are not always substantiated in the literature, and there are few studies that exist that make use of regular classroom teachers with minimal computer expertise (Moursund, 1983-84).

Others (Tetenbaum & Mulkeen, 1984) questioned the claim that Logo is a language "for learning how to think" (p. 17) and that using Logo will enhance the development of problem solving skills. First, they questioned the existence of one set of skills called problem solving skills. Second, Tetenbaum and Mulkeen (1984) cited a lack of empirical evidence to support the assertion that Logo enhances the development of problem solving skills. Given a lack of evidence they advocated a "moratorium on the implementation of programming as a generalized problem-solving model until further research can be conducted" (p. 18) or a purpose for using Logo could be defined. The moratorium would allow educators and researchers to test out their hypotheses with small groups of children.

There has also been criticism directed at those individuals who are advocates of the Logo language and have worked closely with Logo. One of these critics has observed that in recent years, despite the attraction of more people to Logo, there has been a failure to generate new ideas. The published articles about Logo tend to range from a restatement of Papert's ideas, anecdotal reporting or "romanticized reporting" that can be misleading (Leron, 1985, p. 44). "It seems that the world has given Logo an enthusiastic albeit conditional acceptance, based more on the promise of Logo than on actual demonstration of its accomplishments" (Leron, 1985, p. 44). While Papert's book, Mindstorms (1980a), is an idealized view of learning with computers, this "Grand Scheme . . .must be elaborated and debugged to become operational, to better fit the real world" (Leron, 1985, p. 45).

Papert recognized the need for constructive criticism but interpreted some of the attacks on Logo as "technocentric" (Papert, 1985). This is the expectation that computers and/or Logo are "agents that act directly on thinking and learning" (p. 56). The implication is that Logo, irrespective of factors such as implementation, teacher and student characteristics, can effect changes in thinking. From a technocentric perspective, one would believe that like a drug treatment, Logo would either have an effect or it would not. However, if Logo is perceived as a "cultural element--something that can be powerful when it is integrated into a culture but is simply isolated technical knowledge when it is not," the context of the learning situation must be considered as well (Papert, 1985, p. 57).

Thus, there seems to be agreement that there is a continuing need to investigate the effectiveness of Logo. There is a need for more comprehensive studies to examine a variety of factors that influence the outcomes of a Logo curriculum. In particular, the need is greatest in the typical classroom where teachers have had minimal exposure to computers, superficial knowledge of the Logo language and limited computer facilities. Until there are sufficient data available, blanket approval or condemnation of Logo as a culture is not possible. In the meantime, the appropriateness of Logo should be judged in each situation and not be generalized to all settings.

Computer Programming Ability

Although computer implementations at the elementary school level have included programming languages such as BASIC or Logo, there is a paucity of studies which examine computer programming ability or interest in computer programming and their relationship to other academic or personality characteristics. With respect to Logo, many of the empirical studies have used the language as a medium to explore a substantive area such as mathematics (e.g., Howe et al., 1980). Others (Papert et al., 1979; Solomon, 1982; Turkle, 1984) have characterized students on the basis of their programming styles, but did not generally relate programming style to intellectual ability or interest in computers.

At the elementary school level, only one study was found that examined the influence of ability level on programming activity. The influence of intellectual ability on the number of correct Logo programs was studied in 18 fifth grade students (Milner, 1973). While the higher ability group had a greater number of correct programs than the lower ability group, no statistically significant differences between the two groups were found.

One of the more comprehensive studies at the secondary school level investigated the relationship between attitudes of 220 high school students toward use of computers in mathematics courses (DeBlassio & Bell, 1981). The best predictors of student attitudes toward the computer were atttitude toward the instructional setting, aptitude for mathematics and achievement in programming, respectively. Students were classified into three groups based on their responses (like, dislike and neutral) to a scale which measured attitudes towards computers. Students in the "like" group were characterized by their enjoyment of the creative, problem solving aspects of writing and debugging programs, were of above average intelligence and were high achievers in mathematics and programming. The "dislike" group was more anxious about the lack of structure and teacher supervision in computer related activities, of average achievement in mathematics and programming, and had unfavorable attitudes toward the instructional setting (DeBlassio & Bell, 1981).

At the university level, efforts to determine predictors of programming ability are more common. This is due in part to the need to advise and place potential computer science students and to identify students who have the potential of being successful in computer science (Stephens, Wileman & Konvalina, 1981). These studies have examined variables such as student aptitude, personality factors, achievement in other academic areas, as well as the relationship of different components of the computer programming process. Because the generalizability of these findings to an elementary school population is questionable, these studies will be reviewed only briefly.

Because of the tendency to place programming courses in mathematics departments, an area of interest has been the relationship of mathematics aptitude to programming ability. In a study conducted at the university level, Alspaugh (1972) found that mathematical background was the best predictor of programming achievement. Impulsivity, sociability and high reflectiveness measured by the Thurstone Temperament Schedule were also significant predictors. Low impulsivity, low sociability and relatively high reflectiveness were positively related to high programming achievement. Verbal and mathematics ability were not significant predictors.

Peterson (1976) used biographic, personality and aptitude factors to predict programming grades in an undergraduate introductory computer course. The best predictor for programming grade was college grade point average. Although biographic variables included mathematics background, they failed to predict computer programming grades.

Cheney (1980) proposed that the cognitive style or problem solving strategies used, (analytic versus heuristic) were better predictors of programming ability and not biased in favor of those with an advantage in mathematics. Thirty-five undergraduates enrolled in an introductory data processing course were administered a cognitive style questionnaire. Two personality types were defined: analytic decision makers who utilize a structured approach to decision-making and heuristic decision makers who emphasize common sense and intuition in decision making. Consistent with the hypothesis, there was a significant positive correlation between cognitive style and programming ability. Students who scored higher on analytic cognitive style tended to attain higher scores on a programming test.

A computer aptitude pretest has been proposed as an alternative to using grades or scores in computer programming courses as a means of assessing computer programming aptitude. Although a test of this nature has yielded only moderate correlations (.46) with final examination scores (Stephens et al., 1981), it is a useful tool to assist students in their decision to take programming courses. Stephens et al. (1981) used a computer aptitude pretest to identify group differences in computer science aptitude based on factors relating to student background characteristics. Only two of the factors, estimated college performance and estimated high school performance, were significantly related to performance on the test as a whole. When the test was broken down into components, students with some computer experience scored significantly higher on the Algorithmic Execution questions, and high school and college performance were significantly related to the Logical Reasoning items. Questions on alphabetic and numeric sequence were also significantly related to high school performance.

Hostetler (1983) also attempted to develop a prediction model of computer programming aptitude that could be a useful technique in counseling students. Cognitive and affective characteristics, which included past academic achievement and performance on a computer programming aptitude test, were hypothesized as predictors of computer programming aptitude. Eighty students enrolled in an introductory college computer course were subjects in the study. The best predictors of computer programming aptitude, defined as final score in the course, were score on the diagramming and reasoning tests of the Computer Programmer Aptitude Battery and college grade point average. Forty-three percent of the variance in the final scores of students was explained. Overall, the model correctly classified 77% of the students into high and low aptitude groups.

With the increasing use of computers in all levels of education, the need has been identified to explore cognitive and affective variables that may affect computer programming aptitude. At the university level, this has been used as a means of identifying students who would successfully complete computer programming courses. Eventually, students with potential ability in the area of computing might be advised to take courses and pursue careers in computer science. Although not consistent across studies, the best predictors have been student grade point average and performance on a test of computer aptitude which measures logical reasoning, diagramming and other skills.

At the elementary and secondary levels, however, the focus is different. Educational objectives, particularly at the lower levels, are not intended to discourage students from developing expertise with computers. Ideally, the goals are to appeal to as large an audience as possible. While identification of students in a high or low achievement group may be important, these data should be used to identify ways to better integrate computers into the curriculum to appeal to all types of students and to enable them to feel successful with computers.

Sex Differences

Introduction

Although largely anecdotal, a body of literature is emerging that supports sex related differences with respect to access to computers, preferences of computer activities, perceptions of what a computer can do and computer programming styles. These differences are an area of concern, because they can result in possible inequities in access to education and employment (Miura & Hess, 1984, Sanders, 1984), particularly at a time where knowledge of computers "may become as necessary a preparation for adult life as a high school diploma" (Sanders, 1984, p. 32).

This section will explore evidence to support the above claims as well as possible explanations for these differences. Finally, sex differences with respect to computers will be compared to a more extensive related body of literature which examines sex differences in mathematics.

Computers

Common observations are that boys display a greater preference for computers than girls, that they dominate the computer room after school and that they are more apt to visit video arcades. When frequent or successful computer users are characterized, they are generally male. For example, Turkle (1984) described the kind of child who became "immersed" in computers as a male who had a strong interest in mathematics, electronics or a technical subject. Classroom teachers in one study described this type of student as a male or a very bright female. These students were also described as being mathematics and science oriented (Loop & Christensen, 1980).

In many school settings all students are given equal access to computers, but differential use of computers by gender is often observed. Sheingold (1981) concluded that this was more apt to occur in the seventh grade and beyond when the computers were moved out of the classrooms or hallways into special subject classes such as the mathematics or business class. Despite the fact that girls were allowed equal access to computers, they were used overwhelmingly by boys. In another report (Boss, 1982), it was observed that junior high school girls were generally not users of computers in the media center, a situation where a limited number of computers were available.

In another setting, where teachers were asked to describe successful computer users, common observations were that boys and girls at the elementary school level were considered equally able; however, boys comprised a larger portion of the computer users that were characterized as successful. By high school, fewer girls were involved (Loop & Christensen, 1980). DeBlassio and Bell (1981) also found no sex differences in attitudes towards computers or performance in high school mathematics classes where computers were used. However, the females were less apt to pursue the interest outside of class. The majority of users who completed various independent study projects were also males. Males were also the predominant users of the computer in a situation where computer use was voluntary. Ramierez reported that two-thirds of all seventh and eighth grade users of a computer text were males. This text was being field tested in 13 school districts (Education Week, 1983).

Other studies have also examined the proportion of users of computers in a variety of settings. A survey of sixth graders found that 20% of the boys but only 17% of the girls had access to a computer at school (Fisher, 1984). When computers were moved out of a school setting, similar differences were found. At home, the differences between boys and girls were greater; 21% of the boys, but only 15% of the girls had access to a computer at home. One explanation is that parents are more likely to encourage sons than daughters to take computer classes (Fisher, 1984). The ratio of boys to girls at computer camps was found to be approximately three to one in one survey of directors of summer computer camps and classes (Miura & Hess, 1984). The proportion of girls decreased as age, grade level and course level increased. The percentage of females enrolled in the beginning, intermediate and advanced classes was 28, 14 and 5%, respectively (Miura & Hess, 1984). Girls comprised only 15% of the campers at another computer camp (Revelle, Honey, Amsel, Schuble & Levine, 1984). Further, the amount of previous computer experience varied by gender. Boys came into camp with significantly higher levels of computer proficiency. They were more likely to have used a computer longer and more frequently than girls, they were more apt to have used it at home or school, and they reported using a computer for games longer and more frequently than girls (Revelle et al., 1984).

Although differences in computer access are not usually documented until the secondary grades, some of the stereotypes about the technology begin to emerge at an earlier age. When children in grades four through 12 were asked to fantasize what a computer would do for them at age 30, girls tended to focus on the robotic aspects of the computer such as cleaning house, fixing meals and selecting a compatible mate. Boys tended to describe ways the computer could be used for finances, data processing or games. These applications were characterized as being more realistic (Kreinberg & Stage, 1983).

Differences in preferences of computer activities, specifically games, have been documented at the primary and secondary levels. Malone (1981) found significant differences between male and female fifth graders in their preferences for versions of a particular computer darts game. Girls were significantly less interested in the version of the game which shot an arrow across the screen each time the player guessed a number. If the answer was correct, a balloon popped. They preferred the version that shot the arrow less often. In another study, one of the significant differences found between boys and girls who enrolled in a computer summer camp was that boys had significantly higher preferences for playing games and programming in BASIC (Revelle et al., 1984). These children were also asked to evaluate specific computer games. The general conclusions were that girls were more apt to like games where they felt they were in control and they understood what was going on. There was a greater likelihood for boys to prefer action-oriented games. Boys were less concerned with being in control or understanding what was happening (Revelle et al., 1984). With respect to strategy games, girls expressed a preference for clear instructions while boys preferred to figure out how the game worked. Girls liked the one mystery game that was evaluated more so than boys. Additionally, build-your-own games were popular with boys while girls found them frustrating and discouraging.

There is also a tendency for males and females to prefer different programming styles. Although not mutually exclusive, girls were described as soft masters. They tended to see computers as "sensuous and tactile and related to the computer's formal system, not as a set of unforgiving 'rules,' but as a language for communicating with, negotiating with, a behaving psychological entity" (Turkle, 1984, p. 108-109). The hard masters, characterized as having "decisiveness and imposition of will," were almost always boys (Turkle, 1984). These generalizations were based on observation of child programmers in a variety of school settings.

There are many explanations for the differences between males and females with respect to preferences and uses of computers. One of the purported causes is bias in the software (Fisher, 1984). Fisher found computer software and games, in particular, to be characterized by competition, aggressiveness and "rapid and violent action," qualities that are more apt to appeal to boys. Aggressive themes dominated a list of readers' favorite games in the October, 1982 issue of Electronic Games. These included titles such as "Defender," "Demon Attack," "Astrosmash," and "Chopper Command" (in Stage & Kreinberg, 1982). In addition, those programs which had no sexual bias tended to use symbols and images with sex biases, for example race cars and rockets. Malone

(1981) also attributed the girls' dislike of the version of the darts game that destroyed balloons with "weapon-like objects" to their dislike of aggressive behaviors.

Advertising and marketing of computers and computer software have also perpetuated the image of the male as user of computers. In the majority of advertisements, boys and men were depicted as users of computers (Sanders, 1984). Further, in general usage, software and computers have frequently taken on the pronoun "he" (Lockheed & Frakt, 1984). Software production and marketing strategies have become self-perpetuating. One explanation is, that since girls may not be attracted to much of the software that is available, software is less apt to be purchased for them. In turn, manufacturers recognize that the female market is limited and continue to produce software that is appealing to a primarily male population. Consequently, they fail to explore the kinds of computer software that might appeal to females (Revelle et al., 1984).

Social factors provide another explanation for the differences between males and females. One reason for the reluctance of females to participate in voluntary computer-related activities has also been attributed to the more aggressive behaviors displayed by boys, particularly adolescent boys (Fisher, 1984). Boys are more likely to intimidate the few girls who attend computer clubs and to interfere with their work which may result in less access and less interest in computers on the part of girls (Fisher, 1984). Similarly, Boss (1982) attributed the lack of junior high school girls' involvement with computers with their desire not to compete with boys for the use of the limited number of computers that were available. Finally, girls attending a computer camp explained their decision not to participate in a software evaluation workshop, which largely involved playing games, because they were not interested in competing with the boys for a place (Revelle et al., 1984).

Several strategies have been proposed to promote equal access to computers. Kreinberg and Stage (1983) made the following recommendations: 1) encourage teachers to require that females comprise 50% of computer classes; 2) encourage community organizations and science centers to provide opportunities for girls to learn about computers in non-threatening environments; 3) encourage parents to use microcomputers, to consider buying one for use at home and to learn how to use it with their children; and 4) encourage more women to learn how to use computers and teach it to other females.

Lockheed and Frakt (1984) focused on the teacher as a major change agent. They suggested that teachers 1) change the stereotype of the computer center as "male turf" by reserving the computers for girls only on certain days of the week; 2) review computer software and eliminate materials that might appeal to one sex, particularly the more aggressive materials; 3) provide access to computers to those students who do not have access to computers at home; 4) explore applications programs such as word processing, personal filing systems and integrated systems which focus on the practical uses of computers rather than the more mechanical aspects of computing.

Finally, Fisher (1984) made several additional recommendations: 1) increase student awareness of the sex bias of computer software; 2) provide female role models in computer-related fields who can speak to the students, and encourage girls to take more mathematics, science and computer classes; and 3) provide programming courses that are appealing to girls as well as boys, using a language such as Logo that will interest both sexes.

Most studies document the existence of a discrepancy between males and females with respect to use of computers. It has been conjectured that the difference is not due to sex differences in interest toward or understanding of the importance of computers, but to sex diffferences in access to and use of computers (Lockheed & Frakt, 1984). There are many possible explanations for the differences and there have been solutions proposed to promote equal access (Fisher, 1984; Lockheed & Frakt, 1984; Kreinberg & Stage, 1983); however, there have been few if any studies that have reliably examined the causes of the problem (Sanders, 1984).

Mathematics

Sex differences with respect to attitudes towards and achievement in mathematics is an area that has been researched more thoroughly than its counterpart in the computer literature. Unlike the computer field, which is still in its infancy, the mathematics literature has a longer history. Some of the preliminary findings regarding sex differences in computer science parallel those in the mathematics literature. This similarity is not surprising since ability in computer sciences has often been paralleled with ability in mathematics and science. Often, the students who have been most involved with computers have been described as having a strong interest in mathematics (Loop & Christensen, 1980; Turkle, 1984).

Although the findings are mixed, results of research studies generally suggest that males have higher achievement scores than females in mathematics from around the time of adolescence and onward. As they get older, when compared with males, a smaller proportion of females elect to take mathematics courses (Ernest 1976; Fennema & Sherman, 1977; Sells, 1980). This lack of preparation in mathematics serves as a "critical filter" (Sells, 1980) for females, subsequently limiting their choice of an undergraduate major and subsequent carreer choices, especially in science and technologly.

With respect to mathematics achievement, the majority of studies demonstrated no sex differences until adolescence. However, when differences were found in the 9 to 13 age group, they tended to favor males. After age 13, boys' performance was consistently higher (Maccoby & Jacklin, 1974). Fennema (1974) examined more specific mathematics skills. Although she found no differences in the early elementary grades, when significant differences did appear in the higher grades, they were more apt to favor boys in tests measuring higher level cognitive tasks. Girls were favored in tasks where lower level cognitive skills such as computation were measured. These results were also supported in the first National Assessment of Educational Progress (NAEP) conducted in 1972-1973 in the 9 to 17 year age group (Herman, NAEP).

When the previous study of mathematics was controlled for, many of these differences disappeared. Using this methodology, Fennema & Sherman

(1977) studied ninth through 12th graders in four schools and found that while males always scored higher on mathematics achievement, the differences were small and statistically significant at only two of the schools studied. Sex-related differences did not increase by grade, although enrollment in mathematics courses decreased more rapidly for females than males as grade level increased. When these same variables were examined in a middle school population (grades 6-8) in the same community, Fennema and Sherman (1978) found few sex-related differences.

There have been numerous attempts to explain the reasons for sex differences in mathematics achievement. Generally, they are broken down into two major categories: 1) biological or genetic differences and 2) environmental factors. Studies in the former area are relatively few and tend to be rejected in favor of environmental factors. This is due in part to a lack of evidence linking heredity with mathematics ability. Within the latter category, socialization factors such as attitudinal and affective variables have been measured. Only those studies examining environmental factors will be reviewed.

There are several hypotheses that attempt to explain the differences between males and females in mathematics achievement in an environmental or social framework. Hilton and Berglund (1974) attributed the differences in achievement to increasing differences in interests between the sexes; these differences were not apparent in grade 7 but increased with age. Males tended to be more interested in mathematics and demonstrated higher achievement than girls.

Social support from significant others to pursue mathematics has been hypothesized as a determinant of mathematics achievement for both sexes. Sells (1980) found a strong relationship between reports of social support from peers, parents and teachers and enrollment in advanced mathematics courses. Ernest (1976) found that for those students who had either a strong like or dislike of mathematics, teachers were one of the most frequently mentioned major influences of their attitudes toward mathematics.

Fennema and Sherman (1977) suggested that socio-cultural factors are important influences of sex-related differences in mathematics achievement. Although they found few cognitive differences between males and females in grades 9 through 12, there were several attitudinal differences. One of the significant findings was that males rated mathematics more as a male domain. They also tended to score higher in mathematics confidence. Girls tended to report that mathematics was less useful than boys and boys reported greater involvement in mathematics-related activities. Fennema and Sherman (1977) also found that there were a greater number of sex-related attitudinal differences in those schools where sex related differences on cognitive variables were found, supporting the socio-cultural hypothesis. A similar study conducted in a middle school (grades 6-8) found that, here too, males were significantly more confident of their ability to learn mathematics and they stereotyped mathematics as a male domain at higher levels than females. Similarly, when sex-related differences were found in favor of males in mathematics achievement, sex-related differences were found on some of the affective variables as well (Fennema & Sherman, 1978).

There are several studies that suggest that teachers, consciously or unconsciously, may interact differently with their male and female students, especially when the subject matter may be sex-typed. Gregory (1977) found that, given a hypothetical situation, elementary school teachers were significantly more likely to refer males with a mathematical disability for help than females with identical problems. Leinhardt, Seewald and Engel (1979) demonstrated that, even in grade 2, girls and boys were treated differently. Girls received more academic contacts and more instructional time than boys in reading whereas the opposite was true in mathematics. The amount of instructional time was significantly related to achievement. Becker (1981) found that in high school mathematics classes, teachers tended to give males more encouragement, whereas females experienced a lack of encouragement and, at times, discouragement. Females also tended to be more passive and quiet in the classroom. Textbooks depicted men rather than women and the classroom materials sex typed mathematics as a male domain. Becker (1981) proposed a three-step pattern of student-teacher interaction. First, teachers have different expectations of girls than boys. Second, these students are treated differently on the basis of sex, consistent with the teachers' expectations. Third, as a result of expectations and treatment, students respond differentially according to the sex role stereotype.

Because many of the sex-related differences in mathematics have been attributed to environmental differences, increased efforts have been made to encourage females' participation in mathematics at an earlier age so that they are not "filtered" (Sells, 1980) out of fields that require the mathematics preparation which they have not received. Intervention strategies have been used relatively successfully to encourage females' greater participation in mathematics courses. For example, one strategy used, which increased girls' persistence in an accelerated mathematics class, was to teach an all girls' class using a female instructor. Cooperation rather than competition was stressed and potential occupations using these skills included social as well as theoretical applications. This strategy increased the girls' chance of persistence (Fox & Cohn, 1980).

At the college level, a similar strategy was used (MacDonald, 1980) to help women acquire basic mathematics skills. A special section in the Fundamentals of Mathematics was taught to an all female class in an attempt to reduce feelings of intimidation and encourage student participation. The course was taught by a woman and was supplemented by personal assistance and group tutoring. Participants in the special section of the course received higher grades than students in the regular section. More importantly, only three percent of the participants in the special section withdrew as compared with 22% of the women in the standard section. Participants also reported a much greater increase in their performance and understanding of mathematics (76% of participants versus 40% of nonparticipating females and 47% of nonparticipating males) (MacDonald, 1980).

A third strategy used a mixed group of male and female students as well as mathematics teachers and counselors (Fennema, Wolleat, Pedro &

Becker (1981). The assumption was that if females' knowledge about sex-related differences increased and certain attitudes towards mathematics improved, females would be more willing to take mathematics courses. Further, since it is hypothesized that the social environment influences female attitudes, attitudes of others regarding females as learners of mathematics would also have to change. Each group was shown videotapes with vignettes depicting sex-related differences in mathematics, the relevance of mathematics to careers and suggestions for activities to facilitate change. There was also a control group which received no intervention. Females in the experimental group reported they were going to study more math, both during and after high school. These results were substantiated by an increase in enrollment in mathematics courses for the females in the experimental group in grades 11 and 12. In contrast, enrollment for the control group decreased during the same period. Females in the experimental group also perceived mathematics as being more useful in the future. With respect to the male students and male teachers, knowledge about sex-related differences in mathematics were significant. Male teachers also perceived mathematics to be significantly more useful to both male and female students (Fennema et al., 1981).

Summary

Thus far, many of the findings in the computer literature are tentative. They tend to suggest that males, particularly students in junior high school and beyond, demonstrate a greater interest in computers, have had more experience with computers, receive more encouragement to use a computer, and have different computer activity preferences than females. Some of the explanations for these differences suggest that 1) the existing computer software has a greater appeal to boys' interests, 2) advertising and marketing strategies are directed at males, 3) girls prefer computer games or activities that tend to be less violent or aggressive, and 4) girls are less aggressive than boys and therefore less apt to compete for the few computers that typically exist in most schools.

Similarly, differences between males and females have been documented with respect to attitudes towards mathematics and mathematics achievement, primarily in the secondary grades. Reasons for these differences in achievement have been attributed to 1) increased interest and involvement in mathematics for males but decreased interest for females; 2) differential involvement and encouragement to take mathematics courses by teachers, parents and other significant individuals and 3) other affective variables such as the perception of males of mathematics as a "male domain" and girls' perception that mathematics is less useful. Some of these differences could be secondary to biological differences.

Several strategies have been proposed to increase female access to computers. The success or failure of these strategies has not been documented. In contrast, efforts have been made to encourage females to take more mathematics courses, to feel less intimidated by the subject and to realize the importance of mathematics in the job market. These strategies, at least on the short-term, have been relatively successful.

If, in fact, as suggested, there is a parallel between mathematics and computers, the findings in the mathematics literature can provide a theoretical basis for research on sex differences in the area of computers.

Path Analysis

Path analysis is a method for studying the causal relationships among a set of variables (Pedhazur, 1982) and was developed by Sewall Wright, the geneticist, for use in population genetics (Duncan, 1966). One advantage of this method is that it presents a pictorial representation of the proposed model. Another advantage is that the researcher must conceptualize the study and identify the theoretical model prior to implementation (Duncan, 1975; Pedhazur, 1982; Wolfle, 1980). Finally, unlike a correlational study where there is no assignment of cause and effect, causal assumptions are made explicit in path analysis (Warren, Fear & Klonglan, 1980). This method is not, however, intended to discover causes:

> . . .the method of path coefficients is not intended to accomplish the impossible task of deducing causal relations from the value of the correlation coefficients. It is intended to combine the quantitative information given by the correlations with such qualitative information as may be at hand on causal relations to give a quantitative interpretation (Wright, 1934, p. 193).

The starting point, therefore, is the theoretical model, not the statistical technique (Duncan, 1975).

As a statistical method, path analysis is similar to multiple regression analysis. In the case of a recursive model, path coefficients can be estimated using ordinary least squares regression. However, rather than dealing with one equation, the researcher deals with a system of equations (Duncan, 1975).

The path diagram is used to graphically display the causal relationships among the variables in the proposed model. There are two kinds of variables in a path model, exogenous and endogenous. Endogenous variables are those variables that are explained by other variables that precede it in the model and are ordered causally in the model. Endogenous variables may be treated as an independent variable with respect to one set of variables and as a dependent variable with respect to others. In the case of recursive models, paths in the form of unidirectional arrows (----->) are drawn from the variables hypothesized as causes to those variables hypothesized as effects. In contrast, exogenous variables appear prior to the dependent variables in the model and their causes are not explained by the model. They are connected by a curved double headed arrow (↔), indicating a correlation that cannot be analyzed causally (Duncan, 1975).

There are five basic assumptions of a recursive model:

1. The relations among the variables in the model are linear, additive and causal.
2. Each residual is not correlated with the variables that precede it in the model.
3. There is a one-way causal flow in the system. That is, reciprocal causation is ruled out.
4. The variables are measured on an interval scale.
5. The variables are measured without error (Pedhazur, 1982, p. 582).

A path coefficient represents the direct effect of an independent variable (the cause) on the dependent variable (the effect). When expressed in standard form, it is the same as the partial regression coefficient, or in the case of only two variables, the same as the correlation coefficient (Duncan, 1975). In algebraic terms, the path equation is expressed as, $Y = b_{yx}X + u$, where Y is the dependent variable or effect, X is the independent variable or cause, b is the number of units change in Y produced by a one unit change in X, and u represents the error term or all other causes of variation in Y that are not identified in the model (Duncan, 1975). Path notation is somewhat different. A path coefficient is represented by a "p" with two subscripts; the first indicates the dependent variable and the second indicates the effect. The equations for the path model or recursive system depicted in Figure 2 would be the following:

$r_{12} = p_{21}$

$r_{13} = p_{31} + p_{32}r_{12}$

$r_{23} = p_{31}r_{12} + p_{32}$

$r_{14} = p_{41} + p_{42}r_{12} + p_{43}r_{13}$

$r_{24} = p_{41}r_{12} + p_{42} + p_{43}r_{23}$

$r_{34} = p_{41}r_{13} + p_{42}r_{23} + p_{43}$

Variable 1 is exogenous. Variable 2 is dependent on Variable 1 and e_2, which represents all other causes of variation in the dependent variable that are not explained in the model (Duncan, 1975). Similarly, Variable 3 is dependent on variables 1, 2 and the residual e_3, and Variable 4 is dependent on variables 1, 2, 3 and the residual e_4. Each path coefficient is equal to the standardized regression coefficient associated with the

the same variable. In the case of two variables and a residual, the path or regression coefficient is the same as the zero-order correlation coefficient. The path coefficient from the residual to an endogenous variable, j, is equal to $\sqrt{1-R^2_{j.12...i}}$, where $R^2_{j.12...i}$ is the squared multiple correlation of the endogenous variable j with variables 1,2,...,i that affect it (Pedhazur, 1982).

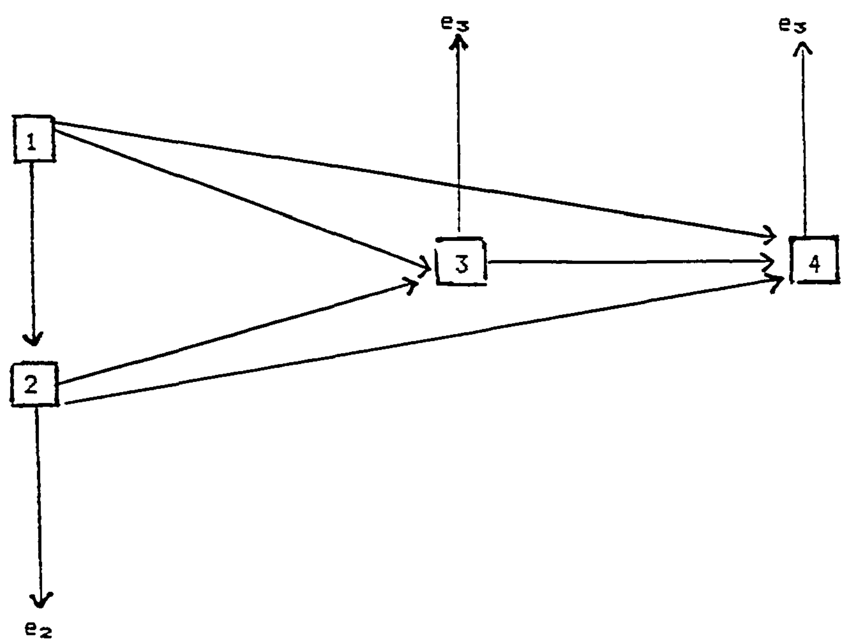


Figure 2. Example of a recursive model with four variables

A common practice in path analysis is to decompose the correlation, or total asssociation, between variables. The total effect is that portion of the correlation that is given a causal interpretation by the model. The total effect is further decomposed into direct and indirect effects.

A direct effect implies that that part of the total effect is not mediated by intervening variables; an indirect effect is mediated by an intervening variable (Alwin & Hauser, 1981). Thus, while Variable 1 exerts only a direct effect on Variable 2, the total association between Variables 1 and 3 includes direct effects of Variables 1 and 2 and an indirect effect of Variable 1 which is mediated by Variable 2 (Figure 2). The remainder is the part of the total association due to common causes, correlation among causes or unanalyzed correlation (Alwin & Hauser, 1981). If Variables 1 and 2 (Figure 2) are both exogenous variables and therefore no causal linkage was implied, r_{13} would consist of the direct effect of 1 on 3 and that part of r_{13} due to correlation of Variable 1 and 2 which would be left unanalyzed.

While it is convenient to express path coefficients with standardized regression coefficients, there have been arguments for and against this procedure. Advantages of standardization include the ease of comparing the effects of different independent variables and the ease of interpreting the coefficients because of their equivalence to the correlation coefficient (Kim & Ferree, 1981). The major disadvantage of standardization is that the coefficients are specific to a given population and cannot be generalized across populations (Duncan, 1975; Kim & Ferree, 1981). One solution proposed is to report both standardized and non-standardized coefficients (Kim & Ferree, 1981).

There has been much discussion concerning how concepts, particularly abstract ones, are to be represented in a path model. Jacobson and Lalu (1974) discussed three types of measurement procedures used in path analysis, the single indicator, index and multiple indicator approaches.

The single indicator method is the simplest and most "vulnerable," especially when dealing with abstract concepts. As implied, one variable is used to represent the underlying concept. The analysis must assume that the variable is a good indicator of the abstract concept and that there is no specification error. Generally, it is not possible to summarize an abstract concept with only one variable (Jacobson and Lalu, 1974).

The second method of measurement combines several indicators to construct a summary score, or index, to represent a single underlying concept. The number of items in the index can vary, weights can be assigned to variables and the items can be combined in a variety of ways. While some of the problems inherent with the single indicator are overcome, the use of an index can also be a source of specification error. Additionally, a well-formulated theory to interpret the index is often absent and substituted by many items (Jacobson & Lalu, 1974).

The third method uses multiple indicators. Like the index approach, several variables are used. However, the "separate identity" (Jacobson & Lalu, 1974) of each of the variables is retained rather than being combined as an index or factor and each indicator is used in solving for the unknowns in the path model. Jacobson and Lalu (1974) concluded that the greater the number of indicators used to measure one concept, "the greater is one's ability to reject alternative auxiliary theories linking the measured variables with unmeasured ones" (p. 219). Duncan (1975), however, warned against the abuse of multiple indicators. "Sometimes multiple indicator models merely complicate if not obscure what is surely the more fundamental problem: proper specification of our model in substantive terms" (p. 47).

One method of testing the model using the multiple indicator approach is to use a hierarchical regression procedure and divide the independent variables into blocks. A set of indicators from each block is added in each step of the statistical procedure. This method enables the researcher to examine the total variance explained by all the indicators, as well as the proportion of variance explained by each of the respective blocks (Warren, Fear & Klonglan, 1980).

One of the questions that arises in path analysis is how to treat hypothesized paths that yield path coefficients that are not statistically significant. Duncan (1975) suggested that a "theory trimming" approach could be used in path analysis by deleting those paths that were not statistically significant or meaningful. He also warned against acceptance of the null hypothesis purely on the basis of statistical evidence. In situations where there is no statistical evidence to support failure to reject the null hypothesis, the null hypothesis should not be accepted "unless there is sufficient a priori reason to do so" (p. 49). At exploratory stages of research, however, theory trimming may be acceptable as long as it is not a substitute for a priori hypothesis testing (Pedhazur, 1982).

Path analysis is widely recognized in sociology and has appeared frequently in the sociology literature since 1966 (Duncan, 1975). The introduction of path analysis in the educational literature appeared much later with limited application (Wolfle, 1980). Although causes and effects of educational attainment have been examined (e.g., Duncan, Featherman & Duncan, 1972), this has been from a sociological perspective. During the five-year period from 1979 to 1983, the method of path analysis was found in only three percent of the articles published in the American Educational Research Journals (Goodwin & Goodwin, 1985).

The predominant application of path analysis in education has been to examine student achievement and those variables that mediate it. Munck (1979) used data collected by the International Association for the Evaluation of Educational Achievement in a cross-national study of educational achievement in three countries. Others used path analysis to examine the effect of cognitive and affective measures on high school and college performance (Burke, 1982; DeBoer, 1981). Champagne and Klopfer (1982) employed a path analytic model to explain student achievement in the mechanics portion of a college physics course. Path analysis was also used to examine the effects of time spent on homework on grades of high school seniors (Keith, 1982). Aside from testing models of scholastic achievement, path analysis has also been used to predict voluntary persistence or withdrawal from college in the freshman year (Pascarella & Terenzini, 1983) and to test a model of teaching which evaluated student teaching skills (Denton & Mabry, 1981). Although not explicitly stated or tested as a path model, Dunkin and Biddle (1974) proposed a model with teacher and student properties to organize the findings of research on teaching. As diagrammed, arrows appeared in the model which indicated causative relationships. While most of the variables were ordered temporally, some were contemporaneous.

Path analysis is a method of statistical analysis that has become popular in the social sciences. Although its application in educational research has increased, its use is less widespread than in areas such as sociology. Path analysis is an attractive method because the theoretical model is graphically displayed, there is assignment of cause and effect in the model and multiple equations, rather than one equation can be tested simultaneously. One of the consequences of the popularity of this method is that it has been abused. Path analysis has been employed in situations where it has been used to generate the theory rather than employing the method to test the theory. The successful application of path analysis is contingent on the soundness of the theory being tested (Pedhazur, 1982).

CHAPTER III - METHODS

Subjects

Students in grades four, five and six at three elementary schools were participants in this computer literacy project. School 1 had 25, 38 and 35 fourth, fifth and sixth graders, respectively. There were 44 fourth graders, 66 fifth graders and 61 sixth graders at School 2. Lastly, there were 40 fourth graders, 45 fifth graders and 46 sixth graders at School 3. Thus, there was a total of 400 participants or 98, 171 and 131 students at Schools 1, 2 and 3, respectively. Two fourth grade students, one from School 1 and the other from School 3, were subsequently eliminated from the study because they failed to follow instructions due to their lack of proficiency with the English language.

Students participating in the computer literacy project were administered three attitudinal questionnaires and one objective test (Appendix A-D.) over the course of the project. Only those students who were in school on the day the evaluation instruments were administered were asked to complete a particular instrument. All instruments were administered to students at Schools 1 and 2, while students at School 3 completed the two final instruments. Two hundred forty-eight students completed the initial questionnaire, 251 completed the Attitudes Towards Mathematics Inventory, and 377 and 379 students completed the Post-Logo Attitudinal Questionnaire and objective test, respectively.

Procedures

During Spring semester 1983, a computer curriclum was implemented in grades four through six using the computer language, Logo. The goals of the computer literacy project were to:

1. develop an inservice training program for teachers in the Logo language,
2. cooperatively develop realistic, integrated strategies for using Logo in the classroom using a sequential approach for grades 4-6,
3. implement these strategies in the classroom initially using Iowa State students and faculty as aides, and
4. collect data from the above experiences; these data will be used in the development of similar programs for both inservice and preservice teachers (Thompson and Thomas, 1982).

In the second phase of the project, Logo was implemented in the classroom. Teachers, with the assistance of project directors, eight Iowa State University undergraduate teacher education students and the investigator, introduced Logo to approximately 400 students at the three schools using Apple II Plus computers. In general, a minimum of formal instruction was advised. Rather, the role of the instructor was to provide assistance to students on an as needed basis. Aside from the first session where the primitive Logo commands were discussed, students were encouraged to develop their own projects. It was anticipated that questions regarding more complex Logo commands would evolve as a result of the children's experiences, that students would work at their own pace and that the instruction would be relatively unstructured.

Implementation and amount of time spent on the computer varied from school to school. On the average, students used the computer for two to three 20 minute sessions per week from mid-February to mid-May. In School 1, computers were rotated from classroom to classroom; in School 2, computers were kept in a central location, and in School 3, teachers had the option of using the computer in the classroom or in a central computer facility. The amount of assistance received from project personnel varied as well. In one school, instruction and implementation were carried out almost exclusively by Iowa State personnel. The amount of assistance received from the University varied in the other two settings; it was based on the teachers' desire for assistance and availability of aides.

The program was formally evaluated through the use of three questionnaires and an objective test administered to students at various phases of the project. Scores on the Iowa Tests of Basic Skills (ITBS) were also obtained for a subset of the students at Schools 1 and 2 (n = 157). This battery of achievement tests was administered in the fall of the academic year. Prior to introducing Logo in the classroom, students were administered the first questionnaire, which examined attitudes and experiences with computers. The Attitudes Towards Mathematics Inventory was administered during the first few weeks of the project. The last two instruments were administered at the conclusion of the project. An attitudinal questionnaire was administered first followed by an objective test. The objective test was given last so as not to bias student responses on the attitudinal questionnaire.

The evaluation instruments were administered by teachers to their respective classes. Because of scheduling constraints it was deemed more appropriate that teachers rather than the investigator administer the instruments. They were also advised to clarify items that students did not understand or found ambiguous, with the exception of items on the objective test. Teachers were asked to impress upon students that they would not be graded on the objective test. Teachers were instructed that student participation was voluntary; however, all students who were in attendance when the instruments were administered completed them. Informal feedback from teachers suggested that students had little difficulty completing the instruments.

Materials

Four instruments were used in this study. The first assessed student interest and experience with computers prior to learning Logo and the second examined students' attitudes towards mathematics. Student attitudes and assessments of the Logo experience were measured in the third questionnaire, and the final instrument measured their performance on an objective test whose subject was Logo.

Because of the specificity of the subject matter and lack of suitable instruments, the pre-Logo and post-Logo affective measures and post-cognitive measure were developed by the researcher. The first questionnaire was pretested using a small group of fifth graders who attended another school in the district. Item content, difficulty and clarity were examined and modified based on students' responses and comments. Suggestions from project investigators were also incorporated in the questionnaire. The two final instruments were circulated among teachers participating in the project to ensure that the instruments were comprehensible and, in the case of the cognitive measure, representative of material covered in their respective classrooms. Suggestions from teachers and investigators were incorporated in the final version of the questionnaire and test.

These instruments were used as a framework in the development of the model, particularly in the identification of variables and composites that represented the constructs in the theoretical model. Therefore, the purposes and content of each instrument as well as results will be discussed. Additionally, the ITBS will be described. Descriptive statistics will be used to describe the participants at various phases of the project. Frequency distributions or measures of central tendency will be reported. These were obtained using the SPSSX Frequencies procedure (SPSS, Inc., 1983) and are reported in Appendix A through Appendix D.

Iowa Tests of Basic Skills (ITBS)

The ITBS is a standardized multilevel battery of achievement tests with overlapping items across levels. The skills measured by the Multilevel Battery are classified into five major areas: vocabulary, reading, language, work-study, and mathematics.

There were three mathematics subtests: mathematics concepts, problem solving and computation. The mathematics concepts subtest emphasized understanding, discovery and quantitative thinking. The problem solving test stressed problem solving strategies and introduced problems that were realistic and typical of ones students might encounter in everyday situations. The mathematics computation test covered the major skills arithmetic operations. Total mathematics score, as implied, was the sum of the scores on the three subtests. The composite score was a total of performance in mathematics as well as other areas including vocabulary, reading, language, and work-study (Hieronymus, Lindquist & Hoover, 1982).

Based on data from a 1977 standardization sample, internal consistency reliabilities for the total mathematics score were .93, .94, and .94 for the fourth, fifth and sixth grades, respectively. Stability coefficients were relatively high for these tests and were .89, .94 and .95 for the composite for 4th-5th, 5th-6th and 6th-7th grades, respectively (Hieronymus, Lindquist & Hoover, 1982).

Although the ITBS were not designed as aptitude tests nor as predictors of future academic success, the relationship between performance on tests of basic skills and subsequent high school and/or college success has been demonstrated (Hieronymus, Lindquist & Hoover, 1982). Here, the ITBS were used in a more specific application, as a predictor of success with Logo. Because of the overlap between computer science, mathematics and science, it was speculated that there might be some relationship between academic achievement in mathematics and science and subsequent performance using Logo.

The ITBS were administered in the fall of the academic year to approximately two-thirds of the classrooms. Six scores were obtained: a composite or overall score on the test, three mathematics subscores and a total score for mathematics and a score for science. Because of the high intercorrelations of the subscores on the three mathematics subtests, mathematics total, composite score and supplementary science score, only one score, the total mathematics score, was selected for use in the model.

Scores were obtained for 52 fourth graders, 54 fifth graders and 51 sixth graders at Schools 1 and 2. Percentile ranks within the school district were the only scores available. Since percentile ranks are not linear transformations of raw scores, they will be interpreted with caution.

Fourth grade students achieved the highest mean percentile rank (65) followed by fifth grade students (55), and lastly sixth grade students (53). It appears that with respect to other fourth graders in the district, the fourth grade students participating in the Logo project received higher mathematics scores. Therefore, with respect to ITBS scores, the fourth graders in particular may not necessarily be representative of other students in the district.

Pre-Logo assessment

The first instrument was administered prior to the introduction of Logo in the schools (Appendix A). The objectives were to determine prior in-school and out-of-school experiences with computers, the nature of these experiences, and preferences of computer activities over a variety of in-school and out-of-school activities. The data are based on students' self-reports of their activities and preferences. Students at Schools 1 and 2 completed the first instrument.

Two hundred forty-eight students completed the initial questionnaire. This included 61 fourth graders, 99 fifth graders and 89 sixth graders. Boys outnumbered girls (53%) and there was a greater representation from School 2 (62%).

With the exception of one, all of the students indicated they had used a computer before, either in school or out of school. Over half (53%) had access to a computer at home. Of those who had a computer at home, 81% owned computers like an Atari or Intellivision whose capabilities were limited to videogames. The remainder (19%) had a computer like an Apple, Pet or Radio Shack that had wider applications which included programming capabilities. The majority (61%) reported that they usually worked by themselves on the computer. On the average, they used the computer for 11 sessions per week for approximately 40 minutes per session. Since time spent is based on student perceptions, the accuracy of these data may be questionable.

In school, Pet computers were the predominant brand used by 95% of the children; over two-thirds (69%) of the students had used an Apple computer. Children were also asked to indicate in which grades they had used the computer in school. In general, they had relatively little exposure to computers prior to grade 3. By fourth grade, almost two-thirds (64%) of the students had been exposed to the computer while fifth and sixth graders received the most exposure (92% and 83%, respectively). During the academic year, computer work had been assigned to 61% of the students. On the average, they used the computer twice a week for a twenty minute period.

Students were provided a checklist of computer activities and asked to indicate if they had used the computer for that purpose before. General categories included educational activities, programming, simulations and games. Games were the most popular, especially Pac Man (86%) and Space

Invaders (80%). These games were available for home computers as well as in video arcades. With respect to educational activities, using the computer for math was the most common application (73%) followed by spelling (56%). Almost one fourth (23%) indicated they had done some computer programming which in most cases was BASIC. The extent of programming was not known. Only six percent had been exposed to Logo prior to the project.

Students were asked to list their two favorite computer activities, the two they disliked the most and the two activities they would like to try. Games were the most favored, especially Pac Man (37%) and Frogger (30%). The non-game activity receiving the highest rating was computer programming, however, only nine percent of the respondents selected this activity. Based on the previous checklist, a limited number of students had experience with computer programming (23%). Only seven percent of the students selected one of the academic applications such as mathematics or spelling, although the majority had used the computer for that purpose.

When asked which activities they disliked the most, one half of the responses related to computer games. Here, respondents were apt to specify a particular game they disliked. The second general category most frequently cited was school activities. Over one fourth of the students (27%) mentioned using the computer for math as one of their most disliked activities. The response rate on this item ($\underline{n}$ = 173) tended to be lower than the ones where students were asked to list their favorite activities ($\underline{n}$ = 236) or the activities they would like to try ($\underline{n}$ = 214). For over one fourth of the students, their exposure to computers had been limited to six or fewer activities. It is possible that these students did not have a strong dislike of the activities they had tried thus far or had not had enough experience to judge them.

Logo was the single activity named most frequently by students (34%) as one of the computer activities they would like to try. This is to be expected since the Logo project had received publicity in the schools and in the community. This was followed by computer programming (17%). However, as a general category, games were listed most frequently and comprised over two fifths of the responses (44%).

In general, games received the most votes for the three items relating to favorite activities, least favorite activities and activities students wanted to try. This may be attributed to the fact that, with the exception of two respondents, all students had tried at least one computer game. Less than 10% of the responses referred to an academic subject.

Children were asked to compare how much they liked using the computer to a variety of school activities using a five-point scale (1=like school activity a lot more, 2=like school activity some more, 3=like both the same, 4=like computer activity some more, 5=like computer activity a lot more). Activities receiving the highest mean ratings, indicating a strong preference for the computer were, learn a new social studies lesson (4.3) and work on a class assignment (4.0). Go to the gym (2.7), talk to my friends (2.7) and conduct a science experiment (2.9) were most preferred over the computer. The latter three activities tended to be less structured and involved more active student participation than the former. For all but three activities the mean ratings were above 3.0 (like both the same). This seemed to indicate that students viewed the computer positively.

In a similar question, students were asked to compare how much they like using the computer to out of school activities using a 5-point rating scale (1=like activity a lot more, 2=like activity some more, 3=like both the same, 4=like computer activity some more, 5=like computer activity a lot more). Children expressed the strongest preference for the computer over doing their homework (4.3) and taking a music lesson (4.0). They preferred going to a movie (2.3), playing an outdoor sport (2.3), playing with their friends (2.6) and going to a football, baseball or basketball game (2.6), recreational types of activities, over the computer. Again, using the computer received mean ratings above 3.0 in most of the cases (67%).

In general, students appeared to be enthusiastic about using a computer, both in-school and out-of-school. This was corroborated by their responses to an item asking them to rate how interested they were in using a computer. Based on a five-point scale (5=very interested, 4=interested, 3=neutral, 2=not interested, 1=very uninterested), the mean rating was 4.4. Only three of the respondents indicated they were not interested in using the computer. The initial impression was that students were beginning the Logo project with a high degree of enthusiasm about computers.

Finally, students were asked to indicate their favorite and least favorite school subjects. Science and mathematics were clear favorites (31% and 25%, respectively), whereas social studies stood out as being the least favorite (44%).

<u>Summary</u> Computers were not novel to most of these fourth, fifth and sixth graders. Many had computers at home or had used one in school or at a friend's house. Almost all the students had used a computer in school, especially in the upper elementary grades. During the academic year computer applications had been incorporated in the curriculum for some of the students. While the predominant application was games, several had used other educational software and a few had learned a programming language such as BASIC. Students demonstrated an interest in and positive attitude towards computers and generally preferred them over other in-school and out-of-school activities.

<u>Attitudes Toward Mathematics Inventory</u>

Students at Schools 1 and 2 also completed a questionnaire intended to elicit responses regarding their attitudes towards mathematics, self-perceptions of performance in that area as well as preferred learning styles (Appendix B). The original instrument developed by Ebmeier (1978) was used with the following modifications: Repetitive items were removed and the scaling was changed from a true-false format to a five-point Likert type scale to allow for greater variability in responses. Results of this questionnaire will be highlighted briefly.

Two hundred fifty-one students completed this instrument. Although similar, this population was not identical to the first group owing to school absences. Sixty-two fourth, 97 fifth and 92 sixth graders completed the inventory. Again, boys were in the majority (52%) and there was a greater representation from School 2.

Using a five-point scale, students were asked to indicate their agreement with 40 statements (5=strongly agree, 4=agree, 3=neither agree nor disagree, 2=disagree, 1=strongly disagree). In a similar manner, they were asked to respond to nine statements about their mathematics class using a five-point scale (5=always, 4=most of the time, 3=some of the time, 2-seldom, 1=never).

Items receiving the highest and lowest mean ratings will be discussed. Results of the questionnaire (means and standard deviations) appear in Appendix B. Items with the strongest positive mean ratings, all above 4.0, included the following: My teacher really wants me to do well in math (4.4), Getting my math problems correct is really important to me (4.4), Does the teacher help you enough? (4.4), Do you learn a lot in math class? (4.3), Do you always do your best in math class? (4.2), I usually finish my math assignments (4.2), I like my teacher to work a few problems before I have to do a new problem by myself (4.2), Before I start working new math problems I like to make sure I can do them (4.2), Are most of the students in math class friendly to you? (4.1), and I will do well in math this year (4.0). Items receiving the lowest mean ratings (2.0 and below) were: It is not that important to know math (1.3), I want to do well in math just to show my friends (1.8), My math teacher last year yelled at me a lot (1.8), I get into trouble in school about once every week (2.0), and If I know my math problems will not be checked, I do not work on them very much (2.0). Items whose mean ratings reflected neither agreement nor disagreement included the following: I always like to choose what math problems to do (3.0), I can always remember what I am told to do (3.1), I do not like to check my math problems (2.9) and I like to be able to choose what our class does in math (2.9).

Summary Based on students' responses to items on the Attitudes Towards Mathematics Inventory, it appears that, on the average, the students enjoyed mathematics and were motivated to do well in mathematics class. In addition, they were conscientious and did not perceive themselves as behavior problems. They were generally neutral regarding choice of mathematics activities.

Post-Logo Attitudinal Questionnaire

At the termination of the project, a questionnaire was administered to all fourth, fifth and sixth graders who participated in the project and who were present the day the instrument was administered. The purposes of this instrument were to assess students' reactions to the Logo project including positive and negative aspects of Logo. Additionally, children were queried about their facility with the Logo language and preference of Logo over other activities. A copy of the questionnaire and summary of the results are presented in Appendix C.

Three hundred seventy-nine students completed the questionnaire with School 2 having the largest representation (41%). As was the case previously, there were more fifth and sixth graders (38% and 36%, respectively) than fourth graders (27%).

Because of the limited number of computers available to each school, children frequently had to work in pairs. About two-fifths (39%) preferred working by themselves while an equal number (40%) had no preference.

On the average, students used the computer for Logo 2.3 times a week for approximately a 20 minute period. Seven percent of the participants thought that Logo was hard to learn and half (50%) thought it was easy or very easy to learn.

The majority of the students worked on Logo consistently for the duration of the project. Others either stopped working on Logo on a temporary or permanent basis. Of this group, the majority (35%) checked that they had too much other school work to do. Approximately one fifth of these students (22%) thought Logo was boring, but only two students indicated that Logo was too hard to learn.

When students were asked what they liked most about Logo, they exhibited general agreement. Over two-thirds mentioned the drawing aspect of Logo. Often times they mentioned a specific shape or design they enjoyed drawing. Other comments included learning specific Logo commands or computer knowledge (12%), working with the editor (10%) which included writing, changing and debugging procedures, and writing programs (9%).

In response to a question asking them what they liked least, the comments were more varied. Interestingly, the most frequent response was "nothing" (18%). The second most common comment was "not enough time" (8%). Others cited difficulty in learning or remembering the correct Logo commands (8%) as well as other mechanics of Logo such as using the editor (4%) and making or discovering errors (4%). In summary, many of their negative comments suggested their like of Logo. Several comments were related to the frustration of learning a language like Logo. Only a small percentage of the comments (6%) demonstrated a general dislike of Logo (e.g., Logo was boring).

Similar to the initial questionnaire, students were asked to name their two favorite computer activities, the two computer activities they liked the least and the two they wanted to try. A list of general activities had been provided in the previous question.

Predictably, Logo or a specific Logo activity was mentioned by over half of the students (57%). However, games were still the most preferred activity (83%) and adventure games were the top choice in this category (32%).

Games were also disliked most as well. Here, students were more apt to name a specific game. Within the games category, word games were the least favorite. Word processing was also mentioned by over one fourth of the respondents, however, based on their previous computer experience, it is unlikely that that number of students had first hand experience with word processing. A more likely interpretation is that the item was an ambiguous one.

Again, games were the overwhelming favorite (88%) choice of activity that students wanted to try. Only 16% mentioned using the computer for school work while 13% mentioned computer programming other than Logo. This was a lower percentage than in the first questionnaire (17%) but the populations were not identical.

Students were provided a checklist and asked to indicate which two aspects of Logo they liked and disliked the most. Drawing designs that changed colors and/or blinked (50%) and drawing designs with lots of repeats (45%) were the favorites. Drawing pictures of objects or figures such as a house, car, person, an animal, etc. drawing right on the screen (48%), drawing designs with lots of big numbers (40%) and drawing designs that fill up the screen (40%) were disliked most.

Students were asked to indicate their general approach to Logo. The majority (60%) preferred to work in the editor over the draw mode. In the editor they entered the program first and then were able to view the picture. It was also possible to save and modify the program in this mode. The draw mode allowed them to watch the picture being drawn as the commands were entered but it was not possible to alter or save the program. The most frequent explanation was that the editor was easier, more fun or faster (34%). The same explanation was also the most common for those preferring the draw mode (45%). The ability to save programs was also mentioned as an attractive feature of the editor (21%), while being able to see what one is doing (30%) was a plus for the draw mode.

Children were asked to rate a variety of statements regarding their experience with Logo using a five-point scale (5=strongly agree, 4=agree, 3=neither agree nor disagree, 2=disagree, 1=strongly disagree). The statements receiving the highest mean rating were, My teacher wants me to learn Logo (3.9), I learned a lot using Logo (3.8) and When I come to the computer I usually know what I want to do (3.7). They tended to disagree most with, When I come to the computer I like to have the teacher or aide suggest something for me to do (2.0) and I need to learn Logo (2.5). Their disagreement with the latter two items tended to be consistent with their indication that they learned a lot using Logo and they knew what they wanted to do when they came to the computer. They were about neutral on the following statements: My parents want me to learn Logo (3.1), I am good at writing Logo programs (3.1), When I have a problem with Logo, I ask the teacher or aide what is wrong right away (2.9) and It is very important to know Logo (2.9).

Students' self-confidence with Logo was reflected in their evaluation of their performance in several specific areas. Using a five-point scale (5=very well, 4=well, 3=average, 2=a little bit, 1=not at all) to rate their performance, none of the ratings fell below 3.0 and two items received ratings above 4.0. Based on their performance on the objective test, it appears that some of the ratings may have been unrealistic. On the average, children felt they were most proficient at driving the turtle around (use of primitives) (4.5) and using the repeat command (4.1). All students received some form of instruction in these areas. Finding mistakes in programs (3.4) and writing procedures that use variables (3.1) tended to produce the most difficulty. In many cases the exposure to variables was cursory. For students in the lower grades, an introduction to variables did not always occur. The use of variables was generally a topic that was introduced on an individual basis to the more advanced students.

Students were asked to compare how much they liked using the computer for Logo to a number of school activities. This was similar to a question asked in the Pre-Logo questionnaire which compared computer activities in general to school activities. A rating of 1 indicated that they liked the school activity a lot more whereas a 5 indicated they liked Logo a lot more. Learn a new social studies lesson (4.1) and work on a class assignment (3.7) received the highest ratings indicating a stronger preference for Logo. Going to the gym (2.2), going to recess (2.3) and talk to my friends (2.5) were clear preferences over Logo. Do computer work other than Logo received a mean rating of 3.0 suggesting that students liked Logo at least as much as other computer work. Five of the items received ratings below 3.0, five above 3.0 and two were in the neutral (3.0) range. Although the ranking of items on this question was similar to an item on the first questionnaire, the ratings themselves were generally lower. Perhaps, after a prolonged exposure to computers in school, their judgments regarding computers became more realistic. This is speculative at most because the two populations in question, although overlapping, were different.

Finally, students were asked to comment on the two most important things they learned from Logo. Working in the editor (21%) and Logo primitives (19%) (basic commands) were the most frequent responses. Several mentioned familiarization with the keyboard or typing and learning about computers. Many mentioned general knowledge or skills (22%) which included perseverance, precision and the importance of planning things out, all important skills for computer programming.

<u>Summary</u> Overall, students viewed their experience with Logo positively. They perceived Logo as a relatively easy computer language to learn. This was reflected in their assessment of their proficiency with Logo in general as well as specific areas. They preferred the drawing aspects of Logo, the ability to draw a variety of shapes and designs. Few became bored or developed a dislike of Logo, however, several experienced

the frustration of remembering the correct commands. Most preferred to work in the editor which allowed them to save or modify a program. In general, students indicated they learned a lot using Logo and rated their accomplishments the highest with respect to knowledge of primitives and using the repeat command. They felt less proficient at finding mistakes in programs and writing procedures that use variables. They also perceived Logo as a high priority for their teachers. Although popular, Logo was not always a top choice activity. Games still surpassed Logo but Logo often took precedence over a variety of in-school activities. Students were also able to generalize beyond the Logo language. This was suggested by their responses regarding the important things they learned with Logo. Skills named generalized to computers as well as other programming activities.

Objective Test

It was anticipated that, by the end of the Logo project all students would have acquired a general knowledge of Logo and be able to operate a computer. More specifically, they would have learned the following, 1) basic Logo commands and the syntax of the Logo language, 2) how to write and save a simple Logo program and 3) how to identify and correct 'bugs' in programs. A multiple choice objective test was constructed to test these competencies. Under ideal circumstances the test would have involved writing Logo programs, but due to the number of participants and time constraints, a relatively short multiple-choice instrument was the most appropriate.

Students were administered a 22-item pencil and paper multiple choice test (Appendix D). One item was subsequently eliminated because there was no correct answer. Questions covered basic Logo commands, Logo vocabulary, repeat command, disk management, and the use of procedures. Items were constructed at varying degrees of difficulty. The number of correct responses for a particular item ranged from a high of 94% to a low of 22% (Appendix D). The KR-20 reliability estimate was .73.

Three hundred seventy students, representing the three schools and grades, completed the final test. The scores ranged from 4 to 21 (all items correct) with an average score of 13 or 61%. Almost one fifth scored 17 and above and four attained a perfect score. Test items were divided into categories, and performance in each of seven subareas was scored. The number of items in each of these categories ranged from one item (circle - #7) to seven items (disk management - #13-18, 20). Performance was best on vocabulary (#8&9) (90%), simple drawing (#1-3) (75%), and the circle command (69%), while students had the most difficulty with the two questions which used procedures (#15,16). Almost one fourth got at least one item correct. The latter two items were designed to be the most difficult ones on the test. It was anticipated that performance would be better on the former areas because presumably, all of the students had been exposed to these topics. Although some disk management items were common to all students, many did not choose to save their programs and consequently had used the commands infrequently, if at all. Performance on the three reasoning items (#10-12) was one of the lowest. Here, students were required to integrate what they'd learned about angles in order to respond correctly. Over one third of the students had at least one out of three correct answers.

Analysis

Data preparation

A codebook was developed by the investigator which specified the location and number of columns for each item. A code was developed for the open-ended questions with the assistance of the principal investigator. A sample of items was coded by both to ensure intercoder agreement.

Data reduction

Two methods were used to reduce the data to a discrete number of factors which were used in subsequent analyses. In some instances, factors were identified based on logical grouping of variables. In the majority of cases, however, factor analysis was used on selected items as a data reduction technique to examine the relationship among variables. The SPSSX factor procedure (SPSS Inc., 1983) using the principal factoring with iteration method and varimax rotation was used. Results are presented in Tables 1 through 5 (Appendix E).

Factor analysis was employed for each of the questions relating to activity preferences on the pre-Logo assessment. For the mathematics inventory, all items were subjected to a factor analysis and restricted to five factors. On the post-Logo assessment, three questions were factor-analyzed; the first dealt with general attitudes towards Logo, the second examined specific competencies and the third related to activity preferences.

Initially, factors and couplets were formed by automatically including items with loadings of .50 or greater. Items falling between .40 and .50 were generally not included unless they seemed to fit with other items in that factor and their loadings were unique. In the case of similar items on pre- and post-tests, an attempt was made to include the same items in a factor if loadings were a minimum of .40 and reliabilities were relatively high.

Inclusion of an item in a particular factor was determined by the conceptual fit of the items and the reliability estimates obtained using a measure of internal consistency (Cronbach's alpha) (Tables 5-9, Appendix F). Given the exploratory nature of this study and in accordance with Nunnally's (1978) recommended reliabilities for research purposes, alpha figures above .60 were considered highly reliable and figures between .50 and .60 suggested moderate reliabilty. Factors with reliabilities below .45 were dropped from the analysis, and in some cases, single items were selected. Reliability estimates ranged from a low of .50 to a high of .85. Only three reliability coefficients were .55 or below. In at least one instance, one of the factors was split into one couplet and two individual items because the four items did not belong together based on the theoretical model proposed. These procedures yielded 13 usable factors, five from the pre-Logo assessment, four from the mathematics inventory and four from the post-Logo instrument. Items included in each factor will be discussed in more detail in the next section.

<u>Identification of indicators in the model</u>

The model under development is an exploratory one. The theoretical model was operationalized almost entirely with indicators derived from self-report data collected from student participants in the project. Results of a standardized battery of achievement tests (ITBS) were also used for a subset of the population. Within each of the conceptual areas identified in the theoretical model, indicators were selected that corresponded to each construct. There was a tendency to include factors obtained through factor analysis procedures or logical clustering of variables. Single items considered pertinent to the theoretical model were also included.

Consistent with the terminology used by Evers (1979) in developing his causal model, the term _indicator_ will be used to refer to an observed or measured variable. Single item indicators will be identified as _variables_ and indicators with more than one variable will be called _composites_.

Because only post-Logo indicators were available from School 3, two separate models were developed and tested. The first included students from Schools 1 and 2 who completed all four instruments. This will be referred to as the _Matched Model_ (_n_=188). A subset of these students (_n_=121) had taken the Iowa Test of Basic Skills and a portion of the model was again tested on this group. The second model included students from all three schools who had completed the post-Logo instruments, the final attitudinal measure and the objective test (_n_ =338). This will be referred to as the _Post-Logo Model_. Although overlapping, the two models are not necessarily comparable. The preliminary models are illustrated in Figure 3.

According to the convention adopted by Duncan (1966), unidirectional

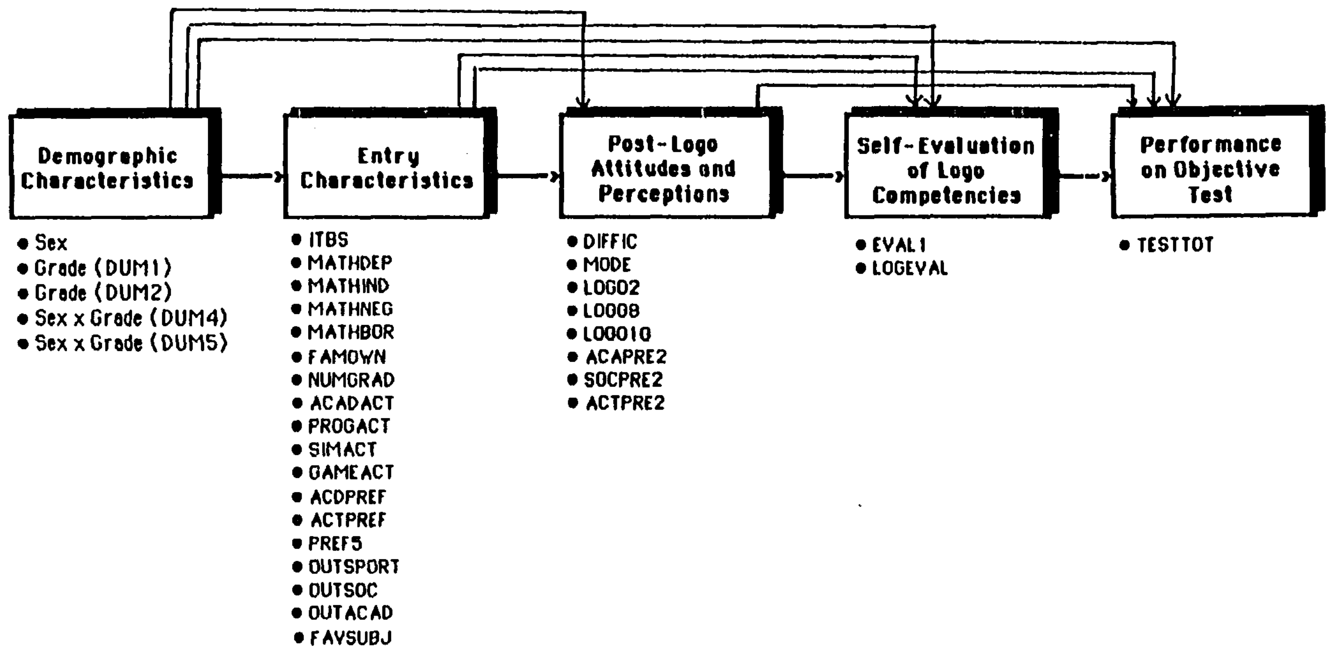


Figure 3. Empirical causal model of measures influencing attitudes and performance of students using Logo

arrows are drawn from a particular indicator to all indicators with which a causal relationship is hypothesized. Although curved arrows are not drawn between those indicators for which no attempt is being made to explain the relationship, the assumption is the same.

The following indicators were selected for inclusion in the basic path model and are displayed in Appendix G. Other variables of interest that could not be quantified were discussed in the descriptive analysis. Indicators will be identified beginning with the exogenous variables and followed by the endogenous ones.

There were two exogenous or independent variables in the basic model, gender and grade in school. As depicted in the model and consistent with the definition of an exogenous variable, no attempt was made to explain the variability of these indicators or their relationship with each other. With respect to gender, females were assigned the value of 1 and males were assigned a value of 2. Since grade in school was not a continuous variable, dummy variables were created to test for school differences. Grade was added to the basic revised model and dummy variables were also formed to test for an interaction between grade and school. A more thorough analysis of gender and grade differences and the interaction of the two was conducted using a t-test, oneway analysis of variance and ANOVA procedures using selected indicators proposed in the path model as the dependent variables. Results of this analysis will be reported for both models, but examined more thoroughly for the Matched Group.

Endogenous indicators were those indicators for which it was hypothesized that the variability could be explained by both endogenous and exogenous indicators (Pedhazur, 1982). These indicators were further divided into four sub-classifications or blocks. Block 1 indicators were entry characteristics prior to Logo; the remaining blocks included indicators which examined post-Logo attitudes and behaviors. Block 2 indicators were Post-Logo attitudes and preferences and Block 3 indicators encompassed students' self-evaluation of their competency with Logo. Block 4, score on an objective test on the Logo language, was the dependent variable.

Entry characteristics (Block 1 Indicators) Entry characteristics consisted of achievement measures (available for a limited number of students), attitudes towards and experience with computers, and general attitudes towards mathematics and mathematics classes. With the exception of the achievement measures, these were all self-report items and derived from the first two questionnaires. Entry behaviors consisted of 17 indicators.

Score on the Iowa Tests of Basic Skills (ITBS) The ITBS were administered in the fall of the academic year to approximately two-thirds of the classrooms. Scores were obtained for students in Schools 1 and 2 who took the test and were reported in percentile ranks for the school district. Only one score, the total mathematics score, was selected for use in the model.

Computer experience prior to Logo This construct consisted of seven indicators and included computer experiences in a variety of settings. The nature of these experiences was also examined. Based on the theoretical model, prior experience with computers was hypothesized to influence subsequent attitudes towards Logo as well as performance. Specific experiences will be described by the following indicators:

1. Presence or absence of a computer at home (FAMOWN). Specifically, students were asked, "Does your family own a computer?" A value of 1 was assigned if a student indicated that a computer was present; otherwise a 0 was assigned.

2. In-school experience with computers prior to grade 4 (NUMGRAD). Students were asked to indicate the grades in which they had used a computer in school. They received a point for each grade they had used a computer in school. A maximum of 3 points was possible. Experience beyond grade 3 was not examined so as to equate the fourth, fifth and sixth graders.

3. The number of computer activities students had experienced based on a checklist provided. Whereas all of the computer activities required familiarity with controls or a keyboard, activities like programming required a greater amount of expertise. Four composites were formed to represent these activities:

a. Educational activities. Computer applications for academic activities (ACADACT). They included using the computer for math, science, social studies and/or spelling. A maximum of 4 points was possible, one for each application. The majority of the educational software used for these purposes consisted of drill and practice exercises or tutorials. These activities tend to be computer-directed and to stress informing and reinforcing applications. They require relatively little computer experience on the part of the teacher as well as the student (Thomas &

Boysen, 1982).

Computer programming (PROGACT). This category included two options, computer programming and Logo. The former included all programming languages except Logo. This was verified in a subsequent question where students were asked to indicate the programming languages they had used. A maximum of two points was possible.

c. Simulations (SIMACT). Simulations utilize more of a student-centered approach and permit higher levels of learning than traditional drill and practice activities (Thomas & Boysen, 1982). Two popular simulations that were available for the microcomputer were noted, Oregon Trail and Lemonade Stand. Oregon Trail simulates the westward experience of a family in a covered wagon. The student is required to make decisions about matters such as food, supplies, traveling and hunting at various points along the way. Lemonade Stand allows the user to make business decisions about running a lemonade stand. One point was assigned for each option checked.

d. Games (GAMEACT). This category encompassed the greatest number of activities. It included specific computer games that were popular at the time such as Space Invaders, Frogger and Pac Man. It also included general categories of games such as sports games, word games, and space games. There were eight such activities named for a maximum score of eight points.

Activity preferences These indicators examined the students' preferences of a variety of activities. They included favorite school subject and preference of using the computer over a variety of

It was hypothesized that preference of computer activities over non-computer activities would be related to subsequent attitudes towards Logo as well as performance. There were two questions that examined the latter priorities; one compared using the computer to in-school activities while the second compared using the computer to out-of-school activities. Children were asked to rate each activity on a five-point Likert type scale. A score of 5 indicated they liked using the computer a lot more while a score of 1 indicated they liked the named activity a lot more. A rating of 3 indicated no preference. There were six indicators that examined activity preferences.

1. Favorite school subject (FAVSUBJ). Students were asked to write down their favorite school subject. Those who selected mathematics, science or computer science were assigned a value of 1 while the remaining subject areas received a value of 0. Because of the relationship of computer science to quantitative subjects such as mathematics and science, it was hypothesized that there might be a positive relationship between students who preferred mathematics and/or science and attitudes towards Logo as well as competence with the Logo language.

2. In-school activities. This question examined students' preferences of specific intramural activities in contrast to using the computer. Two composites and one variable comprised the three indicators derived. In the case of the two composites, the mean score on each factor was used.

a. Traditional school activities (ACDPREF). This indicator included the more traditional or typical school activities. Four items comprised this factor: "Go to the media center," "Work on a class assignment," "Work with my teacher" and "Learn a new social studies lesson."

b. Other school activities (ACTPREF). This indicator included three items, "Watch a movie or filmstrip," "Conduct a science experiment" and "Go to the gym." These tended to be activities which involved greater student participation and/or activities that did not occur on a regular basis.

c. Talk to my friends (PREF5). This single item was selected in lieu of a factor which included social activities. The reliability on the factor did not meet the criteria for inclusion in the model. A similar factor was included, however, as one of the post-Logo measures.

2. Out-of-school activities. Children were asked to compare how much they liked using the computer to several extramural activities. Three factors were formed which focused on sports activities, recreational activities, and activities of an intellectual nature.

a. Sports activities (OUTSPORT). This indicator included two items, "Go to a football, baseball or basketball game" and "Play an outdoor sport such as soccer, baseball, football or basketball."

b. Recreational activities (OUTSOC). There were four items in this factor: "Play with my friends," "Ride my bicycle," "Go to a movie" and "Make cookies." They were all leisure activities.

c. Intellectual activities (OUTACAD). The third factor included solitary activities that were more intellectual in nature. There were three items in this factor, "Do my homework," "Take a music lesson" and "Read a book."

4. Interest in Mathematics and Learner Characteristics. Students were

administered an inventory designed to measure their interest in mathematics and preferred learning styles with respect to mathematics (Ebmeier, 1978). Because of the relationship of quantitative skills to Logo, it was hypothesized that these attitudes, self-perceptions and preferences might be related to subsequent attitudes towards Logo as well as Logo achievement. These items were factor analyzed and four factors were derived. Mean scores were used for each indicator.

a. Dependence on mathematics teacher/importance of doing well in mathematics (MATHDEP). This factor comprised five items, "I like my teacher to work a few example problems before I have to do a new problem by myself," "I like to learn math best by listening to my teacher," "My teacher really wants me to do well in math," "Getting my math problems correct is really important to me" and "Do you learn a lot in math class?". These items tended to stress reliance on the teacher for guidance and approval as well as the importance of doing well in mathematics. In the Logo environment, self-reliance was stressed versus reliance on the teacher. The child rather than the teacher was in charge of her/his own learning.

b. Conscientiousness/Behavior in mathematics class (MATHNEG). This indicator comprised seven items. They tended to focus on behavioral problems as well as students' assuming responsibility for completing their work. With the exception of one item, the questions were phrased negatively. The one item was recoded to agree with the others. Variables included in this factor were the following: "I need to be reminded often to get my math assignments done," "I sometimes forget to do my math assignments," "I usually finish the easy math problems but not the hard ones," "I usually finish my math assignments" (recoded), "I sometimes lose my books and papers," "I get into trouble in school about once every week," and "My math teacher last year yelled at me a lot." The Logo curriculum was such that students were responsible for structuring their own activities. Therefore, it was anticipated that students who perceived themselves as being less responsible and conscientious would react less favorably to the Logo program. Their performance, also, would be lower.

c. Achievement/Learning styles (MATHIND). The third indicator in this group emphasized performance as well as learning styles. There were four items in this factor: "I will do well in math this year," "I am good at working math problems in my head," "I like to work math problems by myself," and "I like to work math problems in my head." Again, it was expected that students who anticipated that they would do well and demonstrated a general interest in mathematics and desire to work independently would be more apt to react positively to Logo and perform well in this area.

d. Choice/Like Mathematics (MATHBOR). The final indicator combined two themes, that of having some input into the selection of topic and/or problems as well as an evaluation of the class. Two of these items were recoded to correspond to the responses to the remaining items in the factor. The five items were the following: "I always like to choose what math problems to do," "I like to be able to choose what our class does in math," "Do you like being in math class?" (recoded), "Do you have much fun in math class?" (recoded), and "Do you ever feel like staying away from math class?" Thus, students who preferred an element of choice in mathematics tended to have a lower evaluation of their mathematics class. Because decisions regarding Logo projects were for the most part left up to the student, students who preferred some degree of choice were expected to excel with Logo.

Post-Logo indicators The remaining data were collected at the completion of the computer literacy project at the three participating schools. Two instruments were administered, a questionnaire that was a subjective measure of students' perceptions of the Logo experience and their facility with Logo, and a multiple-choice test that was an objective measure of their performance. There were 12 indicators derived from these instruments and were distributed among Blocks 2, 3 and 4.

Post-Logo attitudes and perceptions (Block 2 indicators

Block 2 indicators examined students' general reactions to the Logo project. Children were asked several questions which were intended to elicit how difficult they perceived Logo to be, their preferred learning styles, general ratings of Logo, the importance they placed on learning Logo, and comparisons of Logo to other computer activities. There were seven indicators in this block.

1. Difficulty in learning the Logo language (DIFFIC). Students were asked to rate how hard it was to learn Logo. A rating of 5 indicated Logo was very hard to learn, a 3 meant is was neither hard nor easy to learn and a 1 indicated it was very easy to learn. Difficulty rating was expected to be negatively related to self-assessment of performance as well as an objective rating of performance.

2. Learning preference (LOGO2). Children were asked to indicate their agreement with the following item, "I like to work on Logo by myself." A score of 5 indicated strong agreement while a 1 indicated strong disagreement. Because of the limited number of computers in each school, students were sometimes assigned to work in pairs. When possible, students worked on the computer by themselves.

3. Preference of draw or edit mode (MODE). There were two methods in which Logo could be used. The first, the draw mode was the simpler and allowed students to enter commands and watch the picture being drawn concurrently. A major drawback, however, was that the program could not be saved. The second mode was the edit mode. Working in this mode allowed the students to save the picture, but the program had to be saved before the image could be viewed. The advantages of the edit mode included being able to save programs, modify them and use them in larger programs. Working in the edit mode allowed them to write more sophisticated programs. Additionally, the edit mode was more similar to other computer languages.

Students were asked to indicate the mode they preferred, draw or edit. Children who selected the edit mode were assigned a score of 1 and those who selected the draw mode were assigned a 0. It was hypothesized that students who preferred the edit mode would be more proficient with Logo.

4. Importance of learning Logo (LOGIMP). There were two variables that comprised this indicator: "I need to learn Logo" and "It is very important to learn Logo." Students were asked to rate these statements using a 5-point scale. A rating of 5 indicated they strongly agreed with the

statement and a rating of 1 indicated they strongly disagreed with the statement. It was hypothesized that students' perceptions of importance would be positively related to their self-evaluations and subsequent performance on the objective test. The mean of the two items was used.

5. Expectation of others. Two separate variables examined the students' perceptions that others placed on learning Logo. First, students were asked to indicate their agreement with the statement, "My parents want me to learn Logo." (LOGO8) using a five-point scale. Similarly, they were asked to rate the statement, "My teacher wants me to learn Logo." (LOGO10) using the same rating scale. With respect to the two indicators, it was hypothesized that attitudes of others would positively influence one's self-evaluation as well as performance.

6. Activity preferences. Similar to the Pre-Logo questionnaire, students were presented a checklist of activities and asked to indicate whether they preferred a particular school activity or whether they preferred Logo (1=Like school activity a lot more, 2=Like school activity some more, 3=Like both the same, 4=Like Logo some more, 5=Like Logo a lot more). Three factors were derived from these items, of which two corresponded to two of the Pre-Logo indicators. It was hypothesized that a preference of Logo would be positively related to self-evaluation as well as performance on the objective measure. The mean score was used for each factor.

a. Traditional school activities (ACAPRE2). The four items in this factor corresponded to a Pre-Logo indicator. The items were: "Go to the media center," "Work on a class assignment," "Work with my teacher by myself," and "Learn a new social studies lesson."

b. Other school activities (ACTPRE2). The items comprising this indicator were the same as its pre-Logo counterpart, "Watch a movie or filmstrip," "Conduct a science experiment," and "Go to the gym."

c. Social/solitary school activities (SOCPRE2). The final indicator in this group contained four items that were either more social in nature or involved an activity that was performed alone: "Draw or paint a picture," "Go to recess," "Read a book," and "Talk to my friends."

Self-evaluation (Block 3 indicators) Block 3 indicators examined students' self-perceptions of their accomplishments with respect to Logo. General as well as specific Logo competencies were examined. There were two indicators in this block, one variable and one composite. Based on the theoretical model, it was hypothesized that students' self-evaluation of performance in general and specific areas would be positively related to performance on the objective measure.

1. Knowledge of primitives (EVAL1). Students were asked to rate how well they were able to drive the turtle around. As explained in the question, this implied being able to use the basic Logo commands such as FORWARD, BACK, RIGHT and LEFT. A value of 5 indicated they were able to do it very well and a 1 indicated they were not able to do it at all.

2. Evaluation of general and specific Logo skills (LOGEVAL). The final indicator in this block examined specific Logo competencies as well as an overall evaluation of one's ability with respect to Logo. There were eight items in this factor for which a mean score was used. Although all employed a 5-point rating scale the ratings were slightly different for the last two items. For the former items a value of 5 indicated that

students were able to perform the named activity very well and a 1 indicated they were not able to do it at all. For the latter two items, a 5 indicated strong agreement and a 1 indicated strong disagreement with the particular statement. The eight items were as follows: "Working in the editor or writing procedures," "Changing procedures which you have written," Finding mistakes in programs," "Correcting mistakes in programs," "Saving a procedure on a disk," "Getting a procedure back that was saved on a disk," "I am good at writing Logo programs," and "I learned a lot using Logo."

Objective test (Block 4) Score on the objective test (TESTTOT), was the dependent variable. The 22-item paper and pencil multiple-choice test was administered at the conclusion of the project.

Additional variables Although not part of the initial project design, implementation of the Logo curriculum did vary across schools. Therefore, an additional analysis was performed on the Matched Model to determine if prediction of key indicators could be improved with the addition of school as a variable. Whereas hypothesis testing was emphasized thus far, this analysis was in a predictive mode. Dummy variables were introduced to represent school differences. Additionally, dummy variables were also formed to examine the influence of school as well as sex and grade on each of the indicators in the path models that were significant in the explanation of score on the objective test (TESTTOT). Slope as well as intercept differences were tested.

Statistical Analysis

There were two major analyses in this dissertation. The first major analysis involved the testing of the causal model. A preliminary analysis was conducted using a Pearson correlation procedure (SPSS, Inc., 1983) which examined the bivariate relationships between the indicators in the hypothesized path model. This included indicators within- as well as between-blocks. It was hypothesized that significant correlations would occur between indicators with direct causal arrows, although correlations between indicators that were conceptually similar and within the same block were also anticipated.

Multiple regression was used to develop and test the path model using an ordinary least squares regression procedure. The forward entry method was selected; the order of entry of blocks was fixed but indicators within blocks were entered as long as they satisfied tolerance tests. At each step, the indicator with the lowest F-probability was entered (SPSS, Inc., 1983). An indicator was eliminated from the model if it was not significant in the regression with an indicator that entered the model in an earlier stage of the analysis. For example, if a Block 2 indicator were not significant in the regression with either a Block 3 or 4 indicator, it was removed.

The model was tested on three samples. The first included all students at the three schools who had completed the post-Logo affective and cognitive measures (Post-Logo Model). The second included those students at Schools 1 and 2 who completed all of the evaluation instruments (Matched Model). The third was a subset of the Matched Model for whom scores on the Iowa Tests of Basic Skills were available. Here, only two of the structural equations were examined. Self-evaluation of general and specific Logo skills and score on the objective test were the two effects tested.

Finally, an additional analysis was done based on the revised path models that were developed. A stepwise multiple regression procedure was run for the Matched Model to determine if the prediction of key indicators could be improved by using a different model for each sub-population. For the Matched Model, 12 sub-groups were involved because there were only two schools. Dummy variables were formed for school, grade and the interaction of school, grade and sex with the significant indicators in the revised path models.

In the second major analysis, gender and age differences were examined to determine if there were any parallels between the findings cited in the mathematics literature and this research. A t-test was used initially to determine if gender differences existed. In those instances where there were significant sex differences, an analysis of variance procedure (SPSS, Inc. 1983) was used to examine the main effects and interaction of grade and sex with selected variables in the causal model. When the main effect of grade was significant, one-way analysis of variance using a Scheffe a posteriori test was used to examine significant differences among grades.

CHAPTER IV - RESULTS

Zero-order Correlations for Matched Model

Introduction

A preliminary analysis of the data was conducted by examining the zero-order correlations of the variables proposed in the path model (Tables 10 and 11). There were two models proposed, the Matched Model and the Post-Logo Model. The Post-Logo Model differed from the Matched Model in the following ways: 1) Student attitudes and experiences prior to learning Logo were not available for this group of students and 2) School 3 was added to this analysis resulting in an increase of subjects from 193 to 338. Because of the deficits in the Post-Logo Model and despite the smaller sample size of the Matched Group, this section will focus on results for the Matched Group. Differences between the two models with respect to common indicators will be noted.

Because of the reduced number of subjects in the Matched Model, the magnitude of the correlation coefficients had to be higher than in the Post-Logo Model (.140 versus .107) to attain statistical significance. Thus, when compared with the Post-Logo Group, there were fewer significant correlations.

There were 34 indicators in the Matched Model, including four dummy variables, two representing grade and school, and two representing the interaction of grade and gender. They were divided into four blocks of variables, 1) Pre-Logo or entry characteristics, 2) Attitudes and perceptions of Logo, 3) Self-evaluation of performance and 4) Score on the objective test. Statistically significant correlations were at the $p < .05$ level or below.

Score on the objective test

Thirteen indicators exhibited significant correlations with the dependent variable, or test score (TESTTOT)(Table 10). Of these, six were Block 1 or pre-Logo indicators whose range of values was from .15 to .33. The weakest significant correlations were with Dependence on Mathematics Teacher/Importance of Doing Well (-.17) and Other School Activities (versus Logo) such as conducting a science experiment (.15), while the strongest relationships were exhibited by Preferred Programming Mode (.33) and Self-evaluation of Logo Competencies (.32).

With respect to the pre-Logo indicators, the highest correlation with score on the objective test was prior experience with a computer programming language (PROGACT) (.28). There was also a moderate correlation (.23) between Test Score and Other School Activities, suggesting a positive relationship between Test Score and preference of the computer over activities such as conducting a science experiment. There were no significant effects of the exogenous variables, sex, grade and the interaction of sex and grade.

Correlations between test score and the Post-Logo indicators revealed positive correlations for six of the 11 possible comparisons. Preference of the edit mode (MODE) and positive self-evaluations (LOGEVAL) had the highest correlation with test score for the set of Post-Logo indicators (.33 and .32, respectively). The latter two indicators had also displayed the strongest relationship with test score in the Post-Logo

Model (Table 11). Additionally, there were generally stronger correlation coefficients and a greater number of statistically significant coefficients for the Post-Logo Model when compared with the Matched Model for this set of indicators.

Self-Evaluation indicators

Examination of correlations with the self-evaluation indicators (Block 3), Evaluation of General and Specific Logo Skills (LOGEVAL) and "Driving the turtle around" (EVAL1) revealed several moderate correlations, primarily with the self-evaluation composite. Thirteen of the 33 possible comparisons with the self-evaluation composite were significant. The strongest relationship was exhibited by Preference of the Edit Mode (.49) followed by Difficulty Rating assigned to learning Logo (DIFFIC) (-.38), all Block 2 indicators. The negative correlation with difficulty suggests a positive relationship between ease of learning Logo and the student's assessment of general Logo ability. These results were similar to those obtained for the Post-Logo Model although correlation coefficients for the latter two variables were higher for the Matched Model.

Seven of the Pre-Logo indicators correlated significantly with the self-evaluation composite. Of interest were the four indicators which measured prior computer experience. The strongest of these were, using the computer for school activities such as social studies or spelling (ACADACT) (.36) and prior experience with computer programming activities (.28). Again, there were no significant correlations with the exogenous variables.

Other indicators displaying medium correlations with the self-evaluation composite included preference of Logo over Social/Solitary School Activities (.31) such as talking to friends or reading a book (SOCPRE2) and agreement with the statement, "My parents want me to learn Logo" (LOGO8) (.27). Again, the Post-Logo and Matched Models shared common significant variables, but there was a tendency for a greater number of significant correlation coefficients to be obtained in the Post-Logo Model (Table 11).

Correlations with the student's rating of her/his ability to "drive the turtle around" (EVAL1) were generally weaker and fewer than they were for the other self-evaluation indicator. This was also characteristic of the Post-Logo Model. The pre-Logo indicators that correlated significantly with one's reported ability to "drive the turtle around" were generally different from those that correlated with the Evaluation of General and Specific Logo Skills factor. Two of the mathematics indicators, Choice/Like Mathematics (MATHIND) (.21) and Dependence on Teacher/Importance of Doing Well (MATHDEP) (.20) exhibited the highest correlations for the set of entry characteristics.

Three of the four significant correlation coefficients in the Post-Logo Model were present in the Matched Model. The strongest for both was difficulty rating assigned to Logo (-.23).

Pre-Logo indicators and post-Logo attitudes and behaviors

The strongest correlations between pre-Logo indicators and post-Logo attitudes and behaviors were for those pre- and post-Logo indicators that were measuring similar constructs. For example, the correlation between the pre-Logo indicator, Other School Activities (ACTPREF) and the post-Logo indicator Other School Activities (ACTPRE2) was .35. In both instances, the indicators were comprised of identical items. The only difference was that on the pre-Logo indicator, the nature of the computer activity was not specified; with respect to the post-Logo indicator, the computer activity was Logo. Similarly, the pre- and post-Logo indicators Academic Activities (ACAPRE2 and ACDPREF) displayed a correlation coefficient of .37.

Within the set of Post-Logo indicators which examined attitudes toward Logo, difficulty rating assigned exhibited the greatest number of significant correlations with other indicators; four of the correlation coefficients were above .20. Two of the computer activities, Programming Activities and Academic Activities were negatively correlated with Difficulty Rating. That is, students who had more exposure to these activities tended to assign a lower difficulty rating to learning the Logo language. Likewise, students who had a computer at home (FAMOWN) found Logo less difficult to learn (r=-.22). Of interest also is the correlation of mode preference with programming activities. Preference for the edit mode was positively related to experience with computer programming languages prior to Logo (r=.24).

In general, gender was not significantly related to the Post-Logo attitudes and behaviors. Of the three indicators that were statistically significant, Preference of Logo over Other School Activities was the strongest and exhibited a moderate negative correlation (-.27), suggesting that males had a greater preference for Logo than females over school activities such as conducting a science experiment. A similar relationship existed in the Post-Logo Model.

Dummy variables representing grade and the interaction of grade and sex were generally non-significant. Two exceptions were, "My teacher wants me to learn Logo" (LOGO10) and "I like to work on Logo by myself" (LOGO2). With respect to the former, all the dummy variables were significant indicating sex differences, grade differences and interactions between gender and grade. The contrast between grades 4 and 6 tended to yield the higher coefficients (DUM4), indicating that the fifth graders rated the item higher than the fourth graders. For the item "I like to work on Logo by myself," two of the dummies were significant, DUM2 and DUM5; the former contrasted fifth graders with sixth graders and the latter was the interaction of sex with grade (5 versus 6). Based on the grade comparison, students in grade 6 indicated a greater preference for working on Logo by themselves.

Correlations of pre-Logo indicators with exogenous variables

The relationship between the 17 pre-Logo indicators (Block 1) and the five exogenous variables revealed some interesting patterns. With respect to gender, almost half of the possible relationships were statistically significant although generally in the weak range. Significant correlation coefficients were generally related to activity preferences and kinds of computer activities experienced prior to Logo. The strongest of these relationships was preference of Sports Activities versus Logo (-.34), indicating that boys had a stronger preference for sports activities over Logo than girls. This finding was not surprising and consistent with male-female stereotypes. Additionally, boys were apt to have more experience with simulation activities (SIMACT) (.21), have a computer at home (.16), and prefer using the computer over Recreational (OUTSOC) (.20) and Intellectual Activities (OUTACAD) (.24). These findings were generally consistent with the preliminary findings in the computer literature and the more established body of findings in the mathematics literature. Sex differences will be discussed in more detail in the "Gender Differences" section of this chapter.

In contrast, there were fewer grade differences. The strongest grade difference was related to in-school computer experience prior to grade 4 (NUMGRAD). Significant correlation coefficients were obtained for both of the grade comparisons (DUM1 and DUM2). The former was one of the highest correlations (.41). Fourth graders had used the computer significantly more in the early elementary grades than the sixth grade students. However, the sixth grade students had used the computer more than the fifth graders (r=-.25). Knowledge of programming languages varied in a similar fashion across grades. Two of the mathematics indicators also exhibited grade differences. The relationship with Dependence on Teacher/Importance of Doing Well (MATHDEP) was significant for grade (DUM1) indicating higher scores for the fourth grade when compared to the sixth grade. For Conscientiousness/Behavior (MATHNEG), both grade contrasts were significant, -.21 and .18, respectively. The correlation was negative for the grade 4 and 6 comparison and positive for the grade 5 versus 6 contrast.

Sex-grade interactions occurred less frequently than sex or grade differences, however, in one instance the correlation coefficient was above .40. In school experience with computers prior to grade 4 (NUMGRAD) exhibited a correlation coefficient of .43 with DUM4 (Sex x Grade 4 versus 6) and a lower but significant correlation (-.21) with DUM5 (Sex x Grade 5 versus 6). Thus, differences in experience with computers prior to grade 4 were related to the combined effect of sex and grade. Fourth grade students had significantly more computer experience than sixth grade students and, for these students, males reported more experience. Significant interactions were also obtained for three of the mathematics indicators, Dependence on Teacher/Importance of Doing Well (MATHDEP), Mathematics Conscientiousness/Behavior (MATHNEG) and Achievement/Learning Styles (MATHIND), suggesting different attitudes with respect to mathematics varied by gender and grade.

Zero-order correlations within blocks

Several significant zero-order correlation coefficients were also obtained within blocks. In general, they were between indicators that were conceptually similar. For example, all correlations between the four pre-Logo computer activities were significant and ranged from a low of .16 between programming and simulation activities to a high of .36 between computer games and educational computer activities. Additionally, as one would expect, ownership of a computer was significantly related to the four computer activity indicators which measured the amount of experience with specific computer applications. Significant but generally weak correlation coefficients were exhibited between the four mathematics indicators which comprised some of the items on the Attitudes towards Mathematics instrument.

Moderate relationships were also obtained for the pre-Logo variables between the activity preference indicators, particularly Other School Activities (ACTPREF) and Traditional School Activities (ACDPREF) (.37), both of which were in-school activities and generally of an academic nature. For the post-Logo variables, similar results were obtained between the three activity preference indicators, Traditional School Activities, Other School Activities and Social/Participative School Activities. In all cases, these were factors derived from a common set of items and measuring a similar construct. Therefore one would expect that the correlation between these factors would be significant. The correlations between these factors were generally lower than between indicators that were causally linked.

Summary

Several significant correlation coefficients were noted in this analysis. Self-evaluation of Logo Skills (LOGEVAL), score on the objective test (TESTTOT), Difficulty in Learning Logo (DIFFIC), and prior experience with computer programming (PROGACT) exhibited the greatest number and strongest correlation coefficients between blocks. The strongest bivariate correlations were between Out-of-School Intellectual Activities (OUTACAD) and Traditional School Activities (ACDPREF), and Self-evaluation of Logo Skills (LOGEVAL) and preference of the Draw or Edit Mode (MODE). In the case of the former, both activities were of an academic nature. One related to out-of-school while the other related to in-school activities. Since these indicators were of the same general concept, no causal linkage was proposed in the model.

Although correlations with the exogenous variables were not among the strongest, they were significant in a number of instances, particularly for sex. The greatest number of gender differences tended to occur with respect to activity preferences. Grade differences as well as sex-grade interactions were strongest for *In-School Computer Experience Prior to Logo* (NUMGRAD). Typically, the relationship was stronger for the contrast between grades 4 and 6 for the correlations which involved grade and sex-grade interactions. Moderate correlations were typical of pre- and post-Logo indicators that were conceptually similar and/or subjected to a factor analysis. When applicable, significant correlations for the Matched Model tended to to correspond to those of the Post-Logo Model (Table 11).

Path Model 1 - Matched Group

Introduction

The Matched Model was comprised of 34 indicators. Means and standard deviations are found in Table 12. Path analysis was used to test the causal model proposed in Figure 3. In this section, a revised path model will be constructed. The order of entry of the indicators in the regression equation was dictated by their position in the model. Block 3 indicators were allowed to enter the regression equation first, followed by Block 2 indicators, Block 1 indicators and finally, the exogenous variables representing sex, grade and the interaction of sex and grade (SEX, DUM1-DUM4). Causal arrows were deleted for those path coefficients whose t-values were not statistically significant at the .05 level (t=1.96). This procedure resulted in a modification of the initial statistical model, and the revised model is depicted in Figure 4. Regression analysis, based on the revised model, was computed, and the t-value for each partial regression coefficient was significant at the .05 level when it entered the model. In some instances, t-values were not significant after other variables entered the model, but in these cases the variables remained. Both standard and nonstandard path coefficients were computed.

Consistent with the correlation analysis, results of the analysis for the Post-Logo group will not be presented in detail. When applicable, the two models will be compared with respect to two of the effects, test total and self-evaluation. Results of the analysis appear in Appendix J (Tables 22-24).

Score on the objective test (TESTTOT)

Thirty-three indicators were hypothesized to have a direct link with the dependent variable (TESTTOT), but only seven were empirically supported, and six were in the hypothesized direction. They are listed in their order of entry:

1. LOGEVAL - Evaluation of General and Specific Logo Skills;
2. MODE - Programming Style - preference for draw or edit mode;
3. ACTPRE2 - Other School Activities;
4. MATHIND - Mathematics Achievement/Learning Styles;
5. MATHDEP - Choice/Like Mathematics;
6. PROGACT - Experience with Computer Programming Languages Prior to

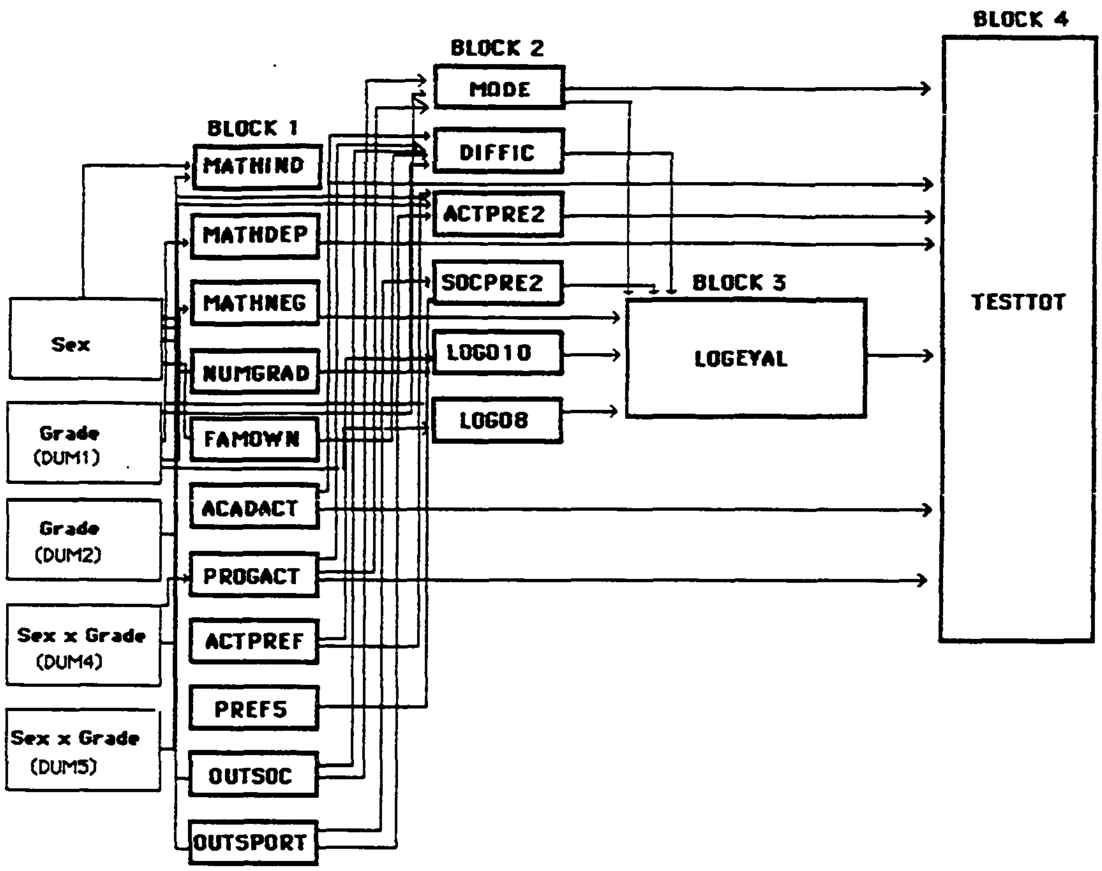


Figure 4. Reduced causal model of measures influencing attitudes and performance of students using Logo

Logo; and

7. ACADACT - Using the computer for mathematics, science, social studies and/or spelling.

The signs of the partial regression coefficients corresponded to the signs of the bivariate correlation coefficients and, with the exception of Experience with Computer Software Programs Related to Academic Subject Areas, were significant on the bivariate level.

Combined, the seven indicators explained 28 percent of the variance of test score (Table 13, Appendix I). Evaluation of General and Specific Logo Skills (LOGEVAL) had the strongest relationship with the final test score and explained ten percent of the variance. It also suggests that students were relatively realistic in their appraisal of their performance and general abilities with respect to Logo.

Block 2 indicators examined student attitudes and preferences toward the Logo experience and were next to enter the model. The two Block 2 indicators, Programming style (MODE) and Other School Activities (ACTPRE2), conducting a science experiment, for example, explained an additional six percent of the variance; the added contribution of Programming Style was larger than that of Other School Activities. There was a positive relationship between preference for the edit mode and performance on the final test. Typically, familiarity with the edit mode demonstrates a more in-depth knowledge of Logo than does the draw mode. Generally, students who preferred working with Logo compared with school activities such as, watching a movie or filmstrip, conducting a science experiment or going to the gym, scored higher on the final test.

The percent variance explained was incremented by 12 percent with the addition of the four Block 1 indicators that examined student characteristics at the onset of the Logo project. Of these, the composite Mathematics Achievement/Learning Styles (MATHIND) entered first followed by Experience with Computer Programming Activities Prior to Logo (PROGACT). Contrary to expectation, the sign of the partial regression coefficient was negative for prior experience with Educational Computing Activities.

Summary One fourth of the indicators with hypothesized direct links to score on the Logo test were supported empirically. Based on the significant paths, students who performed well on the objective test could be profiled as having a high self-evaluation, preferring to work in the edit mode and to work with Logo over Other School Activities such as going to the gym. Regarding mathematics, they rated themselves high on achievement and expressed an interest in working independently. Reliance on the mathematics teacher and doing well were less important. With respect to prior computer experience, familiarity with other computer programming languages was positively related to performance, while exposure to computer software used for academic subjects was negatively related.

A comparison of Block 2 and 3 indicators in this model with those in the Post-Logo Model resulted in some interesting findings (Table 13 and Table 23): 1) The contribution of the self-evaluation indicator (LOGEVAL) was reduced by four percent in the Matched Model; 2) Preferred Programming Mode (MODE) and Other School Activities (ACTPRE2) were similar with respect to the order they entered the regression equation and the resultant changes in explained variance; 3) the two items, "I like to work on Logo by myself" and "My teacher wants me to learn Logo," (LOGO2 and LOGO10) were significant in the Post-Logo Model only, but they explained less than two percent of the variance of the test score; 4) for both models, the effects of gender were not significant, however, grade effects were displayed in the Post-Logo Model; 5) despite the addition of 17 pre-Logo variables to the matched model, the R^2 values for the models were the same, 28 percent; and 6) the four significant pre-Logo indicators contributed an additional 11 percent of the variance.

Self-evaluation (LOGEVAL)

Eight indicators with significant partial regression coefficients explained almost half the variance of the self-evaluation indicator (Table 14). They entered the model in the following order:

1. MODE - Programming Style (preference for edit or draw mode);
2. DIFFIC - Difficulty Rating assigned to learning Logo;
3. SOCPRE2 - Social/Solitary Activities;
4. LOGO10 - "My teacher wants me to learn Logo";
5. LOGO8 - "My parents want me to learn Logo";
6. ACTPRE2 - Other School Activities;
7. ACADACT - Using the computer for mathematics, science, social studies and/or spelling;
8. MATHNEG -Mathematics Conscientiousness/Behavior

Six Block 2 indicators and two Block 1 indicators were causally linked to self-evaluation. Programming mode was the first variable to enter the equation and explained 24% of the variance, the largest amount for a single indicator in this analysis. Difficulty rating assigned to learning Logo (DIFFIC), the second Block 2 indicator to enter the model, explained an additional nine percent of the variance and was negatively related to self-evaluation. Combined, the six Block 2 indicators explained 40% of the variation of the dependent variable. The item "My parents want me to learn Logo," (LOGO8) was significant at the .05 level when it entered the model, but significant at only the .10 level after the addition of other indicators.

The Block 1 indicators explained an additional eight percent of the variance. Using the Computer for Mathematics, Science, Social Studies and/or Spelling (ACADACT) preceded Mathematics Conscientiousness/Behavior (MATHNEG), and explained six percent of the variance. The path coefficient for educational computing applications (ACADACT) was one of the largest in the structural equation.

With the exception of Other School Activities, the path coefficients were in the hypothesized direction. Of the eight indicators, only Programming Style, Other School Activities and Educational Computing Activities (MODE, ACTPRE2 and ACADACT) had direct effects on test score. Other School Activities, such as going to the gym, was positively related to score on the Logo test but negatively related to self-evaluation; Using the computer for mathematics, science, social studies and/or spelling was negatively related to test score but positively related to self-evaluation. The remaining indicators operated through the intervening variable, self-evaluation (LOGEVAL).

Summary The following causes were directly related to a positive self-evaluation of Logo competencies: 1) preference for the edit mode, 2) assignment of a low difficulty rating to learning Logo, 3) preference for Logo over school activities such as reading a book or talking to friends, 4&5) perceptions that both teachers and parents had a desire for the students to learn Logo, 6) preference for other school activities such as going to the gym, watching a movie or filmstrip or conducting a science experiment over using the computer, and 7) the self-perception that s/he was a conscientious and well-behaved mathematics student.

In contrast to the Post-Logo Model (Table 21), a greater proportion of the variance of Self-evaluation was explained in the Matched Model (Table 14). However, Block 2 and 3 indicators explained equal amounts of the variance in both models, 40%. The remaining eight percent of explained variance in the Matched Model was contributed by two Block 1 indicators, Using the Computer for Mathematics, Science, Social Studies and/or Spelling and Mathematics Conscientiousness/Behavior. For both the Matched and Post-Logo models, although not identical, the same number of Block 2 indicators were directly related to self-evaluation. Programming mode and difficulty rating explained the greatest proportion of the variance for the two models. The order of entry of the remaining indicators was similar, but not identical. For both, the exogenous variables were not significant.

Post-Logo Attitudes and Behaviors

The third stage of this analysis involved the computation of partial regression coefficients for the six Block 2 indicators that were significant in the regression with test score and/or Self-evaluation. For this group of indicators, the amount of explained variance ranged from a high of 23% for Other School Activities to a low of two percent for "My parents want me to learn Logo." The indicators, along with their significant regression coefficients are listed in Table 15. The three indicators with explained variation exceeding 10 percent, Other School Activities, Difficulty Rating and Preferred Programming Mode will be discussed.

Other School Activities Three indicators significantly contributed to the explained variance of this indicator. The identical pre-Logo indicator (ACTPREF) was the first to enter the regression equation. The only difference between the two was that for the pre-Logo indicator, the school activities (i.e., conducting a science experiment, going to the gym and watching a movie or filmstrip) were contrasted with computer activities in general and not Logo. Preference of the computer versus out-of-school Sports Activities, sex, and a sex grade interaction were also significant. Holding other things equal, there was a general trend for girls to exhibit a greater preference for the computer over Other School Activities. However, the gender-grade interaction revealed that, in descending order, the scores on preference for Logo versus Other School Activities were the following: fifth grade girls, fifth grade males, all other females and all other males.

Difficulty Rating The combined contribution of five indicators, Prior Experience with Programming Languages, Out-of-School Recreational Activities, Experience with Educational Computing Activities, In-School

Computer Experience Prior to Logo and home ownership of a computer explained 17% of the variation in Difficulty Rating. Preference for Out-of-School Recreational Activities such as playing with friends versus using the computer exhibited the highest path coefficient in the structural equation. Knowledge of a programming language, preference for using a computer over recreational activities, experience with educational software, and presence of a computer at home were negatively related to difficulty rating. Only In-School Computer Experience (NUMGRAD) was positively related to the dependent variable. This suggests that the students with the greatest amount of exposure to computers prior to grade 4 perceived that Logo was more difficult to learn.

Preferred Programming Mode   Three indicators were directly related to mode. Experiences with computer programming activities, preference of the Logo over Out-of-School Recreational Activities and grade in school explained 11 percent of the variance. This was one of the few Block 2 indicators where fourth grade students were significantly different from the rest. Membership in fourth grade was negatively related to mode, suggesting a tendency for this group to select the draw mode. The remaining indicators were positively related.

Summary   Although the R^2 values were typically lower for the Block 2 indicators in the third stage of the analysis, half of the indicators yielded regression equations that explained at least 18% of the variance. The largest amount of variance was explained for Other School Activities (23%), while the least amount (2%) was explained for

"My parents want me to learn Logo." The first occurrences of significant sex, grade and sex-grade differences appeared in this stage of the analysis. Grade differences were present for the items, "My parents want me to learn Logo" and "My teacher wants me to learn Logo." A sex difference and a sex-grade interaction was present for the post-Logo indicator Other School Activities.

Pre-Logo Attitudes and Experiences

The final stage of this analysis examined the effect of the exogenous variables, sex, grade and the interaction of sex and grade on those pre-Logo indicators that were significant in an earlier stage of the analysis. Table 16 (Appendix I) lists the indicators, and the significant variables in the multiple regression analysis.

In general, the amount of variance explained by the exogenous variables was minimal and in only one case did it exceed 10 percent. The indicators with the highest amount of explained variation were In-school Computer Experience (NUMGRAD), Out-of-School Sports Activities (OUTSPORT), and experience with Computer Programming Languages prior to Logo (PROGACT) with 18, nine and seven percent, respectively.

Gender related differences were found for Out-of-School Sports Activities and suggest that boys had a greater preference for watching or participating in sports versus using the computer than girls. The dummy variable representing the sex-grade interaction was significantly related to In-School Computer Experience and it explained 18% of the variance. There was a tendency for fourth grade boys to have had the most computer experience prior to grade 4, followed by fourth grade girls, and lastly all other students. A sex-grade interaction was also found for experience with Computer Programming Languages prior to Logo. Fourth grade males tended to have the most programming experience, followed by fourth grade females and finally, all other students.

Summary

Results of the multiple regression analysis of the Matched Model can be summarized as follows. Seven indicators had direct effects on the final test score and explained 28% of the variance. Self-evaluation of Logo Skills had the largest standardized regression coefficient followed by Experience with Computer Programming, Mathematics Achievement/Learning Styles, Dependence on Mathematics Teacher/Importance of Doing Well, preference for Other School Activities versus Logo, Preferred Programming Mode, and Experience with Educational Computing Activities prior to Logo.

In contrast, almost half of the variation of Self-evaluation of Logo Skills (LOGEVAL) was explained, lending the most empirical support to this portion of the model. Eight indicators significantly contributed to the explanation of this indicator, Preferred Programming Mode, Experience with Educational Computing Activities, Preference of Logo over Social/Solitary Activities, and Difficult Rating displayed the highest regression coefficients.

With respect to the indicators in Blocks 1 and 2, the explained variance was considerably lower. Indicators with the highest R^2 values were preference of Logo over Other School Activities such as conducting a science experiment (20%), In-School Computer Experience prior to Logo (19%) and Preferred Programming Mode (18%). The majority of the indicators were retained in the revised model, but only a few Block 1 and 2 indicators had more than one direct link with other indicators in the model. Preferred Programming Mode, Preference of Logo over Other School Activities, and prior experience with Educational Computing Activities had direct effects on Self-Evaluation and final test score. Prior use of the computer for math, social studies, science or spelling was also related to difficulty rating assigned. Prior Experience with Computer Programming Languages was directly related to final test score, programming mode as well as difficulty rating, but affected Self-evaluation only indirectly.

The effect of the demographic variables appeared only in the later stages of the analysis. Of note were the sex-grade interactions that affected prior In-School Computer Experience, Experience with Programming Activities and preference of Logo over Other School Activities, conducting a science experiment, for example. Gender differences were also supported for Out-of-school Sports Activities.

Thus, the 34 indicator model was reduced to 24 indicators (Figure 4). The ten indicators that were eliminated were the following:

1. SIMACT - Prior Experience with Computer Simulations;
2. GAMEACT - Prior Experience with Computer Games;
3. FAVSUBJ - Preference of Science, Mathematics or Computer Science over Other School Subjects;
4. ACDPREF - Academic/traditional Activities (versus the computer)
5. OUTACAD - Out-of-school Intellectual Activities (versus the computer)
6. MATHBOR - Choice/Like Mathematics;

7. LOGO2 - "I like to work on Logo by myself";

8. LOGIMP-Importance of Learning Logo;

9. ACAPRE2 - Academic/traditional activities (versus Logo); and

10. EVAL1 - Knowledge of primitives of the Logo language.

Slightly over one third of the Pre-Logo indicators were dropped from the model. In contrast, a slightly smaller percentage (30%) of the Block 2 indicators which examined post-Logo attitudes and perceptions were eliminated. Several of the indicators that were eliminated did not have unique contributions to the model. Some tended to have moderate correlations with other indicators that were conceptually similar. For example, Prior Experience with Computer Simulations and with Computer Games (SIMACT and GAMEACT) were related to Prior Experience with a Programming Language and Using the Computer for Math, Spelling, Social Studies or Science (PROGACT and ACADACT), other computer activities. This was also characteristic of the pre- and post-Logo activity preference indicators. The remaining indicators tended to have low or non-significant bivariate correlations with other indicators in the model.

Path Model 2 - Matched Group with Addition of School Variables

<u>Introduction</u>

Twenty-eight percent of the variance of Final Test Score was explained in the revised Matched Model. The hypothesis that school differences might increase the amount of variance explained was tested next. Using a framework identical to that of the Post-Logo model, school differences, school-grade, school-sex, and interactions between school or grade and significant Blocks 1, 2 and 3 indicators were tested in a predictive mode to examine their contribution to the model. An additional 25 dummy variables were created to represent these differences in means and partial regression slopes for school and grade and are listed in Table 17. Only the special features of this model will be highlighted.

Zero-order correlations

First, bivariate correlations were examined (Table 17). There were only four significiant correlation coefficients. They involved school-sex interactions with Preferred Programming Mode (DUM28) (.30), Prior Experience with a Computer Programming Language (DUM54) (.28) and Self-Evaluation (DUM16) (.17) and an interaction between Prior Experience with Programming Languages and Grade (DUM53) (.18). Though there were few significant differences on the bivariate level, a school-sex interaction with key indicators predominated.

Path analysis

The multiple regression analysis involved only one structural equation with Test Score as the dependent variable. The additional dummy variables entered the model in four stages: 1) Dummy variables representing school, 2) Dummies representing the interaction of school with grade and school with sex, and 3) the remaining dummy variables representing the interaction of grade and school, respectively, with those indicators that were significant in the Matched Model.

On the bivariate level, there were three comparisons with significant school effects, Prior Experience with Programming Activities, Preferred Programming Mode and Self-Evaluation. However, they were not upheld in the multiple regression analysis. On the multivariate level, only one of 25 possible direct effects, the interaction of Preferred Programming Mode and grade, was significant (Table 18). On the bivariate level, this indicator did not exhibit a significant Pearson correlation with the dependent variable. Holding other things equal, fourth grade students who expressed a preference for the edit mode tended to score lower than the other students; their scores were generally higher than their fourth grade counterparts who preferred the draw mode. This may be attributed to the fact that, in general, fourth grade students' exposure to the edit mode may have been shorter than the fifth or sixth grade students. Fourth graders spent most of their time working in the immediate or draw mode and, although interested, may have had less time to experiment with the editor. This effect operated through mode in the previous model.

The dummy variable representing Programming Mode and grade contributed an additional two percent to the explained variation of Final Test Score. Given the number of dummy variables tested, it is also possible that a significant interaction was a chance occurrence. Coupled with the fact that there were no school differences, which was the main thrust of the analysis, it was concluded that examination of separate means and slopes did not sufficiently improve the explanatory power of the model and, in the interest of parsimony, this analysis was not pursued.

Path Model 3 - Matched Group with Inclusion of Mathematics Achievement Measure

Introduction

The final analysis examined the contribution of a mathematics achievement measure, total mathematics score on the Iowa Tests of Basic Skills (ITBS), to the explanation of two indicators, score on the objective test (TESTTOT) and self-evaluation (LOGEVAL). Means and standard deviations for the indicators in this model are reported in Table 19. The analysis was not carried back any further because of the reduced sample size (n=126). Therefore, only the Pearson correlations for Final Test Score, Self-evaluation and ITBS score with the other indicators in the model will be reported. Multiple regression analysis will be used to develop the two structural equations for Final Test Score and Self-evaluation, respectively.

Zero-order correlations

In general, the correlations with test score and Self-evaluation were similar in strength and direction as they were in the Matched Model with a larger sample size (n=193) (Table 20). ITBS score exhibited the strongest correlation with test score (r=.39) than with the remaining indicators. Prior Experience with a Computer Programming Language (PROGACT) was second to ITBS with a correlation of .31. In contrast, the correlation between Self-evaluation and ITBS score was low (-.10). Consistent with the analysis of the Matched Model, Difficulty Rating and Preferred Programming Mode exhibited the strongest relationships with Self-evaluation.

Path analysis

Multiple regression analysis was performed using the same criteria for entry as for the Matched Model. The ITBS Mathematics Score entered the model with the other pre-Logo indicators in Block 1. The regression with test score produced six indicators with significant partial regression coefficients (Table 21):

1. LOGEVAL - Evaluation of general and specific Logo skills;
2. MODE - Programming style - preference for draw or edit mode;
3. LOGO2 - "I like to work on Logo by myself";
4. ITBS - Total mathematics achievement test score;
5. ACTPREF - Other School Activities (pre-Logo);
6. MATHDEP - Choice/Like mathematics.

Self-evaluation explained nine percent of the variance, programming style and "I like to work on Logo by myself" explained an additional seven percent of the variance and ITBS score contributed 14% to the explained variation of Test Score. The remaining indicators explained an additional six percent of the variance; 39% of the variance of Test Score was explained. Given that only 28% of the variance was explained in the initial Matched Model, this was a considerable increase. Comparable amounts of variance were explained by the Post-Logo indicators (16%). The ordering of the path coefficients was also different in this analysis. Previously, Self-evaluation displayed the highest standardized regression coefficient. Here, ITBS score was the highest followed by Other School Activities, "I like to work on Logo by myself" and Self-evaluation. Unlike the basic Matched Model, Prior Experience with a

Computer Programming Language (PROGACT) and Mathematics Achievement/Learning Styles (MATHIND) were not significant in this analysis. Both had medium correlations with ITBS score.

Similar to previous analyses, half of the variation of Self-evaluation was explained by the independent variables (Table 21). The indicators with significant path coefficients are identified according to the order in which they entered the regression equation:

1. MODE - Programming style - preference of draw or edit mode;
2. DIFFIC - Difficulty rating assigned to learning Logo;
3. LOGO2 - "I like to work on Logo by myself";
4. LOGO10 - "My teacher wants me to learn Logo";
5. ACADACT - Using the computer for mathematics, science, social studies and/or spelling; and
6. PREF5 - "Talk to my friends"

The largest single contributor to the explained variation of Self-Evaluation was Preference for Draw or Edit Mode. Difficulty Rating contributed an additional 12% of the variance. Combined, the Post-Logo indicators contributed 41 percent of the variation while the Pre-Logo indicators contributed an additional eight percent. Consistent with the Pearson correlation coefficient, ITBS score did not significantly contribute to the explanation of Self-evaluation.

Summary

Although the sample size was limited, it appears that the addition of the mathematics achievement test score made a considerable contribution to the explanation of score on the objective test. The bivariate correlation was .38 and explained 15% of the variation of the test score. The actual increase in variance explained was 14% which suggests that there was almost no relationship between ITBS score and the indicators that preceded it in the model. However, ITBS did not directly affect self-evaluation of general and specific Logo skills. The indicators with significant partial regression coefficients in the equation with Self-Evaluation as the dependent variable were similar to those in the Matched Model with a larger sample size. The amount of explained variance was comparable in each as well.

The inclusion of ITBS Total Mathematics Score in the model was supported with a reduced sample size. If the data were available, the analysis should be pursued with a larger sample. Additionally, the complete model should be analyzed so that the effect of ITBS on other indicators as well as the impact of the demographic variables on ITBS could be examined.

Sex Differences

To test the hypothesis of sex differences, t-tests were performed. It was anticipated that if statistically significant differences occurred, males would demonstrate higher achievement and/or more positive attitudes and perceptions with respect to 1) mathematics achievement and attitudes towards mathematics and learner characteristics, 2) pre-Logo computer experience, 3) attitudes toward computers prior to Logo, 4) attitudes and perceptions of the Logo experience, 5) self-evaluation of performance and 6) performance on an objective test. Further, it was anticipated that differences on the affective measures as opposed to the achievement measures would be more apt to occur. To test the hypothesis that, when present, these sex differences would be more likely to occur in higher grades, an ANOVA was performed on those indicators where statistically significant sex differences resulted to examine effects of sex, grade and a sex-grade interaction. A one-way analysis of variance with a Scheffé a posteriori test was subsequently performed if there was a significant grade effect.

A list of indicators used in the model and the items comprising them can be found in Appendix G. Although both the Matched and Post-Logo Groups were tested, only the results for the Matched Group will be discussed. Generally, results were comparable for the two groups for those indicators which they shared in common. Entry data were not available for the Post-Logo Group. Results of the analysis for the Post-Logo group will be reported in Appendix L (Tables 28-30). t-values with $p < .05$ were considered to be statistically significant.

Results for the Matched Group appear in Table 25 through Table 27 (Appendix K). Table 25 examines the means for males and females and significant differences between them on the indicators in the path model. Table 26 provides mean scores by grade for each of the indicators where sex differences were significant. Table 27 presents the results of the ANOVA which examines sex, grade and sex-grade interactions for these indicators.

Entry characteristics

Mathematics achievement and interest in mathematics and learner characteristics There were no differences between males and females on the score on the total mathematics score on the Iowa Tests of Basic Skills. Of the four factors derived from the mathematics inventory, two, Achievement/Learning Styles and Choice/Like Mathematics, yielded significant gender differences. Consistent with the hypothesis, achievement and a greater tendency to work autonomously were valued significantly more by males. The main effect of grade was significant as well. Results of the Scheffe indicated that the sixth grade mean rating was significantly higher than the fifth grade (3.6 versus 3.3). There was also a significant interaction effect for the Choice/Like Mathematics factor. Of all the indicators tested, this was the only statistically significant interaction effect for this sample. Mean scores for females were lower in the fourth and fifth grades and highest in the sixth grade (2.4, 2.4 and 2.9, respectively), while males' mean ratings were highest in the fourth grade (2.9) and approximately the same in the fifth and sixth grades (2.7). Thus, the greatest differences between males and females were in the lower grades. By grade six, ratings were more similar. Lower ratings suggest that students have a relatively high evaluation of their mathematics class yet prefer that others select their activities.

Computer experience prior to Logo There were only two statistically significant differences noted with respect to computer experience prior to Logo. When these differences occurred, they suggested, as hypothesized, that males had more computer experience than females. Based on self-report, a significantly greater number of boys (58% versus 44%) had computers at home (Table 25). Additionally, boys had used a greater number of computer simulations. There were also significant differences in the number of simulation activities used according to grade level. Sixth graders had the most experience with the two simulations, Oregon Trail and Lemonade Stand (Table 27).

Activity preferences There were significant gender differences for four of the six indicators which examined preferences of in-school and out-of-school activities versus using the computer. Grade differences were significant in only one instance, however, and there were no interaction effects. Both sexes demonstrated a greater interest in talking to their friends than using the computer (overall mean=2.7), however, females indicated a significantly greater interest in talking to their friends than did males, and scored approximately one-half point higher on this variable (2.5 versus 3.0) (Table 25). Significant differences were exhibited between grades four and six as well. Grade 4 demonstrated a greater preference for the computer (3.0), but by grade 6, there was a stronger preference for talking to friends (2.4).

In contrast to in-school activities which exhibited few differences, significant differences were found for all three indicators dealing with out-of-school activity preferences. Boys demonstrated a greater preference for using the computer over Recreational Activities, playing with friends, for example. This was also true with respect to Intellectual Activities which included doing homework, reading a book or taking a music lesson. Despite the sex differences, both boys and girls clearly favored recreational activities such as playing with friends or going to a movie over using the computer (2.7 for females versus 2.9 for males). In contrast, there was a stated preference for computer activities versus intellectual activities such as doing homework, reading a book or taking a music lesson; the mean rating for females was 3.7 versus 4.0 for males, a statistically significant difference. With respect to Sports Activities, however, girls expressed a significantly greater interest in using the computer than playing or watching sports. Means for girls and boys were 2.9 and 2.1, respectively (Table 25).

Summary When student entry characteristics were examined, several differences between males and females emerged. While there were no differences with respect to mathematics achievement, there were differences with two of the indicators examining attitudes toward mathematics. Males scored higher on the Achievement/Learning Styles composite, suggesting that achievement in mathematics and the ability to work autonomously were more important for them. Rating on Choice/Like Mathematics varied depending on the sex and grade of the child. Whereas ratings for males were highest in the fourth grade, they were highest for females in the sixth grade. The difference between the sexes was greatest in fourth grade and by sixth grade, ratings for males and females were more similar. It was predicted that the opposite would occur, and that girls' ratings would go down as grade level increased. Other results indicate that males were more apt to have a computer at home and had worked with a greater number of computer simulations. There was one grade difference as well. Sixth graders had signficantly more experience than the other students with the two simulations, Oregon Trail and Lemonade Stand.

With respect to student preferences of computer activities there were several differences, primarily for the out-of-school activities. With the exception of Sports Activities, where females demonstrated a greater interest in the computer, males tended to prefer using the computer more than females for a variety of academic, social and recreational activities. Most notable were the item, "talk to my friends" and the composite, Sports Activities, the former preferred by girls and the latter by boys. There was also a signficant grade difference for the item "talk to my friends." The sixth grade students had a higher priority for socializing than did their fifth grade counterparts.

Post-Logo attitudes and behaviors

Subjective and objective measures of attitudes and behaviors were collected at the termination of the Logo project. Students evaluated the Logo project, assessed their own competencies and were administered an objective test.

Attitudes toward Logo   There were seven indicators that examined students' attitudes and perceptions of the Logo language. Students were asked to rate how hard it was to learn Logo. On a five-point scale where 5 represented "very hard to learn" and 1 represented "very easy to learn," the difficulty rating assigned by the boys was significantly lower than that of the girls (2.3 versus 2.6) (Table 25). Boys also exhibited a significant preference for the edit mode compared with girls who tended to prefer the draw mode (.4 vs. .6). The former mode was more dificult to learn but had the advantage of greater flexibility and allowance for more sophisticated programming. There were no significant sex differences on the two items which rated the parents' and teachers' desires for the child to learn Logo.

With respect to the three indicators relating to student preferences of Logo over other school activities, only one, Other School Activities, was significant. Girls tended to prefer Logo to the three activities that comprised this factor, "Watch a movie or filmstrip," "Conduct a science experiment," and "Go to the gym."

Subjective and objective measures of achievement Only one of the assessment indicators yielded statistically significant results. Females rated themselves significantly lower than males (3.1 versus 3.3) on specific and general abilities which included competencies like working in the editor, finding and correcting bugs, disk management as well as a general ability to write Logo programs. Although significant at only the .10 level, there was a tendency for males to rate their ability to "drive the turtle around" higher (4.4 versus 4.2). Finally, on the average, males scored one point higher than females on the objective test (12.7 versus 11.9). Again, these results were significant at only the .10 level (Table 25).

Summary Only a small proportion of the indicators that examined students' perceptions and preferences of Logo resulted in significant gender differences. In two instances, boys expressed more positive attitudes toward Logo. Based on self-report, it was easier for them to learn Logo and they preferred working in the edit mode. Contrary to expectation, boys preferred school activities such as going to the gym, conducting a science experiment and watching a movie or filmstrip over Logo. With respect to the achievement measures, only one which assessed a variety of Logo competencies, was statistically significant. As hypothesized, boys rated their ability higher than girls. Performance on the objective test was not statistically significant.

Summary

The hypothesis of sex differences was supported in some instances. Although the majority of the comparisons were not statistically significant, evidence suggests that when differences occurred, males' generally demonstrated more positive attitudes toward mathematics, computers prior to Logo, and the Logo experience. Further, they rated their performance with Logo higher than did the females. While there were a few instances of grade differences, only "talk to my friends" suggested a greater preference for girls, and particularly sixth grade girls for this activity. The sixth grade boys also had the strongest preference for talking to friends relative to the fourth and fifth grade males. Contrary to expectation, girls expressed a preference for Logo in two instances. They preferred Logo to Other School Activities (e.g., going to the gym) and Sports Activities which included observing and participating in competitive sports. Both indicators included items that were stereotyped as male activities.

Results for the Post-Logo Group (Appendix L) tended to parallel those of the Matched Group, however, a greater number of indicators were significant for the Post-Logo Group. Of particular note were evaluation of one's ability to "drive the turtle around" and score on the objective test. Generally, a trend was evidenced in those instances for the Matched Group and significance at the .10 level was attained. Additionally, higher levels of significance were generally obtained for the Post-Logo group which had the advantage of a larger sample size.

CHAPTER V - DISCUSSION

Summary

One of the purposes of this study was to evaluate a Logo computer curriculum that was implemented in a typical elementary school classroom without the advantage of a large number of computers nor the benefit of teachers who had received extensive computer training. The feasibility of such an effort was supported based on students' reactions to the program.

A questionnaire was administered to students at the conclusion of the project. Responses suggested that the student viewed the experience positively. While Logo was a popular activity and often took precedence over other school activities, interest in computer games still surpassed interest in Logo. Students indicated that Logo was not very difficult to learn, and that they learned a lot using Logo; this was consistent with their own assessment of their proficiency with specific Logo skills. Students rated their accomplishments the highest with respect to knowledge of Logo primitives and using the repeat command while they felt less proficient at finding mistakes in programs and writing procedures with variables. Although few became bored or developed a dislike of Logo, several experienced the frustration of remembering correct commands. Most preferred to work in the editor which allowed them to save or modify a program. Although students' ability to generalize beyond the Logo language was suggested by their responses regarding the important skills they had learned with Logo, this was not tested empirically. Those skills named ranged from computer programming to geometry. This study was a preliminary analysis, and results from this questionnaire, a Pre-Logo questionnaire, an assessment of attitudes toward mathematics, as well as an objective test of the Logo language were used to operationalize a theoretical model, a main focus of this dissertation.

Because of the need to identify factors that influence attitudes and performance with a computer language such as Logo, a theoretical model was proposed that attempted to identify and subsequently test these factors. Variables identified included student entry characteristics, attitudes toward the computer experience, and subjective and objective measures of achievement. The causal model was tested using the method of path analysis.

Because all instruments were not administered to the students at all three participating schools, two models were tested. The first, the Matched Model, tested all of the indicators in the model, but included students from only two of the schools. The second, the Post-Logo Model, included students from the three schools, but examined only the Post-Logo indicators. While results were presented for both models, only the Matched Model was discussed in detail because results for the two groups were generally comparable.

On the bivariate level, many of the proposed causal links appeared to be upheld. Some of the strongest correlations were between score on the objective test, Self-Evaluation of Logo Competencies, Preference of the Draw or Edit Mode, Difficulty Rating and Prior Experience with a Computer

Programming Language and other indicators in the model.

Several of the correlations with the exogenous variables in the model, sex, grade and an interaction between sex and grade, were significant, although they were not among the strongest. The greatest number of gender differences tended to occur with respect to activity preferences. In the majority of instances, males preferred either a computer activity or Logo to other in-school or out-of-school activities. There were fewer grade differences and sex-grade interactions than there were sex differences. When they occurred, the differences between grades 4 and 6 were generally greater.

Moderate correlations were also evidenced between indicators that examined activity preferences. In some instances preference of the computer over other activities was examined at the onset of the study and preference of Logo over the same activities was examined at the termination of the study. In other instances, the indicators were conceptually similar.

The causal model was then tested using a multivariate approach, the method of path analysis. The proposed Matched Model contained 34 indicators. Based on the multiple regression analysis, it was reduced to 24 indicators. Seven of the indicators in the model were empirically linked with Final Test Score and explained 28% of its variance. In combination, a high Self-evaluation, Preference of the Edit Mode, selection of Logo over Other School Activities (e.g., conducting a science experiment), Experience with a Computer Programming Language, an expressed interest in working independently and doing well in mathematics and self-identification as a high achiever in mathematics and working problems alone were positively and directly related to a high Test Score. In contrast, Experience with Educational Software was negatively related to test score. On the basis of these results, the following conclusions were drawn. First, knowledge of a programming language, typically BASIC, may have facilitated learning Logo. Second, use of the computer for mathematics, science, spelling, or social studies, presumably drill and practice applications, apparently had a negative impact on performance. This may be attributed to the fact that drill and practice activities are generally passive in nature and do not require knowledge or expertise about a computer language. Perhaps, students had the expectation that they had to respond to questions posed by the computer rather than telling the computer what to do. Third, interest in mathematics was positively related to performance, suggesting evidence of a relationship between mathematics and computer science, at least on the affective level. Fourth, preference of the edit mode, which was more difficult to use than the draw mode but allowed the student to save programs and to use more sophisicated programming methods, was positively related to performance. Fifth, preference of Logo over Other School Activities (e.g., conducting a science experiment), which were generally appealing to students, suggests an interest in Logo. Finally, students were relatively accurate in evaluating their own Logo competencies.

In comparison, a larger proportion of the variance of Self-Evaluation of Logo Competencies (50%) was explained by eight indicators which had direct effects on Self-evaluation. In combination, Preference of the

Edit Mode, assignment of a low Difficulty Rating, preference of Logo over Social/Solitary School Activities (e.g., reading a book or talking to friends), Preference of Other School Activities (e.g., going to the gym), perceptions that both teachers and parents had a desire for the student to learn Logo, prior experience with Educational Software, and the self-perception that s/he was a conscientious and well-behaved mathematics student explained almost half of the variance of Self-Evaluation. Students who evaluated themselves highly tended to balance their preferences of Logo versus in-school and out-of school activities, sometimes preferring Logo and sometimes preferring another activity. Further, these students perceived that their parents and teacher felt it was important for them to learn Logo. Students who rated their ability high assigned a low difficulty rating and indicated a preference to work in the edit mode which suggests that their behavior was consistent with their evaluations.

In the first two stages of the analysis, gender and grade did not exert a direct effect on either Test Score or Self-evaluation. Therefore any sex or grade differences that occurred were mediated through other indicators in the model.

In the third stage of the analysis, the causes of the significant indicators related to attitudes and perceptions of the Logo experience were examined. Typically, the explained variance was lower for these indicators than those that followed them in the model. The highest amount reached only 23% and was the explained variance for Preference of Logo over Other School Activities. Significant indicators were the identical pre-Logo composite, preference of the computer versus out-of-school Sports Activities, sex and a sex-grade interaction. Girls, unlike boys, demonstrated a preference for using Logo over Other School Activities. A similar relationship existed for the two pre-Logo indicators, Other School Activities and Sports Activities. These tended to be activities that are stereotyped as male activities, particularly competitive sports. Additionally, the relationship between the pre- and post-Logo indicator (Other School Activities) suggests that students were consistent in their choices at the onset and termination of the Logo project.

Almost 18% of the variance of Difficulty Rating was explained by five indicators. All of the significant indicators suggested some kind of previous experience with computers with the exception of one, preference of a computer activity versus out-of-school Recreational Activities (e.g., going to a movie). Others included experience with computer programming languages and educational software, access to a computer at home and prior experience with a computer in grades one through three. Contrary to expectation, the latter experience was negatively related to difficulty rating.

Explanation of Block 1 indicators, sex, grade and sex-grade interactions, were evidenced in several cases. The first occurrence was in the later stages of the analysis, and although a significant contribution was made, sex and grade did not explain a large portion of the variance.

The addition of 25 dummy variables representing school, and the interaction of school and/or grade with those indicators that were significant in earlier analyses, was examined in a predictive mode. This generally resulted in non-significant findings at the bivariate as well as the multivariate level; the addition of these variables increased the explained variation of Test Score only slightly. Therefore, this model was rejected in favor of a more parsimonious model. With respect to final test score, no school differences occurred, which suggests that some variation in implementation had no direct effect on subsequent performance for the two schools. Whether this was the case on the classroom level was not ascertained.

The final test of the causal model introduced a mathematics achievement measure, the total score on the mathematics section of the Iowa Tests of Basic Skills. As hypothesized, mathematics achievement exerted a direct and positive effect on performance and increased explained variation from 28% to 39%, despite a reduced sample size. However, ITBS score had no direct impact on students' Self-evaluation of performance. The influence of mathematics achievement needs to be examined with a larger sample size and in the context of the complete model.

Another purpose of this study was to examine the effect of gender on indicators in the model to determine if they supported the primarily anecdotal findings in the computer literature and the empirically grounded findings in the mathematics literature that indicated differences on the affective level. The pattern that emerged for those indicators that were significant lent some support to the hypothesis of sex differences. No significant differences were observed with respect to the two achievement measures, mathematics achievement as measured by the Iowa Tests of Basic Skills and performance on the final test. However, attitudinal differences were identified with respect to mathematics. Consistent with the hypothesis, mathematics achievement and a greater tendency to work autonomously were valued significantly more by males. Males and females entered the Logo program with some differences. The males had more computer experience than females prior to Logo in two instances. They were more apt to have a computer at home and reported more experience with the two simulation activities, Oregon Trail and Lemonade Stand. When given their choice of using a computer or a specific activity, males tended to prefer using the computer more than females for a variety of academic, social and recreational activities. These differences were more apt to occur for out-of-school activities. Girls, however, expressed a preference for the computer over Sports Activities. Although this finding was not anticipated, it is not surprising since boys have been stereotyped as preferring more aggressive activities such as competitive sports.

Some differences between the sexes persisted through the Logo program. Boys rated Logo less difficult to learn, and they preferred to work in the edit mode. They also rated themselves higher on a variety of Logo competencies. While they perceived themselves to be better at Logo than girls, this was not upheld by performance on the objective test. Males performed slightly better than females, but the differences were not statistically significant. Contrary to expectation, boys preferred school activities such as going to the gym, conducting a science experiment and watching a movie or filmstrip over Logo. However, it is purported that boys have a greater preference for science and a greater interest in sports activities than girls.

There were few grade differences that occurred in combination with gender differences. With the exception of the item "talk with my friends," there was no pattern suggesting decreased interest in computers or lower achievement for girls in the higher grades. Both boys and girls exhibited a greater preference for talking with their friends in the sixth grade. However, girls rated it higher than boys.

Conclusions

Several questions were posed in this study. An overriding concern was the feasibility of implementing a Logo curriculum with a limited number of computers and relatively little teacher training. Based on student and teacher (Thompson & Blaustein, 1985) reactions to Logo, it was concluded that it was possible to successfully implement a Logo curriculum under the above conditions. Both students and teachers evaluated the program positively and generally indicated high levels of accomplishment. Scores on the 22-item objective test suggested that the majority of students had a general understanding of the primitive commands of the Logo language. However, based on performance on this test, generalization of Logo to geometric concepts was tenuous. Students' responses to open-ended questions suggested generalization to other areas which included geometry or problem solving, but there was no mechanism for testing this effect. Despite the relatively short exposure to Logo, these findings lend support to the assertion that children of differing backgrounds and ability levels can become proficient at programming with Logo in a relatively unstructured setting (Papert, 1980a, Watt, 1982a).

Results of this study also lend empirical support to several of the hypothesized causal linkages in the path model. Performance on the objective test was directly affected by the combined influence of entry characteristics, post-Logo attitudes and perceptions and self-evaluation of performance. The contribution of demographic variables (i.e., sex and grade) was not supported. Explanation of Test Score was weaker than that of Self-evaluation of Logo Competencies which preceded Test Score in the model (28% vs. 50%). It is possible that a more comprehensive test would have been a more accurate measure of performance.

One of the best predictors of performance on the bivariate as well as multivariate level was total mathematics score on the Iowa Tests of Basic Skills. Two affective measures which examined attitudes toward mathematics (Dependence on Mathematics Teacher/Importance of Doing Well and Achievement/Learning Styles) were also significant predictors of performance. These findings support the anecdotal findings in the computer literature that characterize successful computer programmers as having a strong interest in mathematics (Turkle, 1984) and as doing well in mathematics (Loop & Christensen, 1980). Whereas Milner (1973) found no differences in the number of correct Logo programs written based on student ability, many of the studies of computer programming achievement conducted at the college level found some sort of intellective measure that was the best predictor of computer programming performance, usually college or high school achievement (as measured by grade point average; Hostetler, 1983; Peterson, 1976; Stephens et al., 1981) or mathematics background (Alspaugh, 1972). In this study, Total Mathematics Score on the Iowa Tests of Basic Skills was used in lieu of overall score because of the high intercorrelations between the two. Therefore, one could tentatively state that achievement in elementary school was the best predictor of performance.

Programming style has also been linked with programming proficiency. Turkle (1984) identified the top down programmer as the more serious computer user, and Cheney (1980) found that students who used a structured approach to programming performed better. Others (Rampy & Swensson, 1983; Solomon, 1982; Watt, 1979) have identified different programming styles but have not linked them with performance. The only differences in programming style measured in this study were of a more general nature, the preference of the draw versus the edit mode. Performance on the final test was typically higher for those students who expressed a preference for the edit mode. Working in this mode also required a higher level of understanding of the Logo language. Based on this dichotomy, it is not possible to draw any conclusions about cognitive style without further study.

An interesting finding was the negative effect of Experience with Educational Computing Applications (e.g., spelling or mathematics), presumably drill and practice activities, on subsequent performance on the final test. Whereas students who had been exposed to a programming language generally performed better on the test, experience with drill and practice activities tended to lower test scores. While there is some evidence that drill and practice activities resulted in increases in student performance (e.g., Chambers & Sprecher, 1980), it appears that an activity of this nature does not generalize to Logo. Drill and practice has been characterized as a passive learning mode and has been criticized for using a new technology to substitute for traditional methods of instruction (Becker, 1982; Ellis, 1974; Luehrmann, 1980; Papert, 1980a). Frequently, the only form of input to drill and practice programs is in response to a particular question. In contrast, Logo requires the student to formulate programs or tell the computer what to do. It appears that drill and practice activities may be counterintuitive to programming with Logo.

Based on the causal model, a second hypothesis was that self-evaluation of performance was influenced by demographic variables, entry characteristics and post-Logo attitudes and perceptions. Self-evaluation was directly affected by entry characteristics and post-Logo attitudes and perceptions, but not by gender and grade. Empirical evidence lent the most support to the self-evaluation indicator that was retained in the model, Self-evaluation of Logo competencies. Unfortunately, few previous studies have examined affective measures of achievement. The present study suggests that self-evaluation was influenced by a variety of factors. With respect to entry characteristics, Educational Computing Applications such as drill and practice were positively related to self-evaluation as well as the student's perception that s/he was a responsible mathematics student. Students who rated their ability high indicated that Logo was relatively easy to learn and preferred working in the edit mode. These students were not totally committed to Logo and in at least one instance expressed a preference for selected school activities over Logo.

These students also identified a desire on the part of parents and teachers for them to learn Logo. A similar but not identical finding in the mathematics literature was the positive relationship between the influence or support of significant others, such as parents, peers (Sells, 1980), and teachers (Ernest, 1976; Sells, 1980) and mathematics achievement.

A third hypothesis in the causal model was that post-Logo attitudes and perceptions were influenced by demographic variables and entry characteristics. Two-thirds of the initial nine Post-Logo indicators remained in the model. Prediction was generally lower for this set of indicators which was one of the weaker portions of the model. The first occurrence of gender and/or grade differences appeared in this stage of the model as well. Greater amounts of variance were explained for Difficulty Rating and Mode Preference. Experience with Computer Programming Activities and preference of using the computer over Out-of-school Recreational Activities (e.g., playing with friends) were positively related to the two. Family ownership of a computer was related to Difficulty Rating, suggesting evidence of differential access to computers. This has been identified as an area of concern with respect to females (Fisher, 1984; Kreinberg & Stage, 1983; Lockheed & Frakt, 1984) as well as students at large (Sheingold, 1981).

A final hypothesis related to the causal model was that entry characteristics are influenced by demographic variables. While there were some gender and grade influences, the exogenous variable did not adequately explain these entry characteristics. Only 10 of 17 of these indicators remained in the reduced model.

One of the concerns in this study was the existence of differences between schools because of differences in implementations. An exploratory analysis indicated that the addition of school variables did not adequately improve the prediction of test score. However, the differences were not tested at the classroom level. It may be advisable to explore differences on the classroom level to determine whether individual teaching styles affect performance.

Sex differences were examined in the final analysis. Based on the mathematics and computer science literature, it was hypothesized that if significant differences occurred between males and females, they would favor males with respect to computer experience prior to Logo, attitudes toward computers prior to Logo, attitudes and perceptions of the Logo experience, self-evaluation of performance and actual performance on an objective test. No differences were found between males and females on either of the performance measures, Total Mathematics Score on the ITBS and score on the objective test, confirming Loop & Christensen's (1980) observation that males and females are equally knowledgeable. It also supports the findings of no differences in mathematics achievement for preadolescent students (Fennema & Sherman, 1977; 1978; Maccoby & Jacklin, 1974). While not supported in all instances, this study lent some support to the hypothesis of sex differences in several areas. Consistent with the report of Revelle et al. (1984), this study found that males entered the study with significantly more computer experience. They were more apt to have a computer at home and had more experience with the Simulation Activities. Although not true in all cases, males were more apt to prefer using the computer or Logo over a variety of in-school and out-of-school activities. This parallels findings in the mathematics literature that attributed differences in achievement to differences in interest in the subject matter (Fennema & Sherman, 1977; Hilton & Berglund, 1974). Paralleling Fennema and Sherman's findings (1977) that few cognitive differences existed between males and females but males tended to score higher on mathematics confidence, in this study boys evaluated themselves higher than girls on Logo competencies while performance for the two groups was not significantly different.

Recommendations

This study is a first attempt to identify and test factors that influence attitudes toward and performance with the Logo language. There are several recommendations that address areas for future study which include methodological changes to the present study.

A follow-up study of this group of fourth, fifth and sixth grade students could provide valuable information in several areas. One research question is whether working with the Logo language facilitates learning other computer languages or activities such as word processing or working with electronic spread sheets. A second question is whether working with Logo generalizes to other curricular areas such as mathematics or science, and whether it affects academic achievement in general. A third question is whether the Logo experience influences attitudes toward and performance using computers in these same students at adolescence and beyond. More specifically, are male-female differences exhibited for this group of students, and if so, are they as great for this group compared with other students who did not work with Logo at the elementary school level? Ideally, an experimental design would be used in studies of this nature.

A logical progression from this study is to test the reduced causal model using a variety of populations. First, it is important to determine if the model is upheld with students of similar backgrounds and grade levels. Second, the model should be tested using a group of adolescents to determine if it it generalizes to older students, and in particular, if a greater number of gender differences occur. Third, a logical extension of the model would be to examine teacher characteristics and the effects they have on various outcomes.

A final area that requires further study is whether Logo fosters problem solving and critical thinking. Based on the relatively short exposure to Logo in this study as well as the difficulty in testing these skills, problem solving was not examined. Because the educational benefits of Logo are controversial (Moursund, 1983-84; Tetenbaum & Mulkeen, 1984), it is especially important to explore this area. A first step could be to develop a more comprehensive test of Logo that would examine acquisition of geometric and algebraic concepts.

This study suffered from several methodological problems. The evaluation instruments were designed expressly for this study because of a lack of suitable instruments. First, there is a need to cross-validate these instruments using a similar group of students. Second, because many of the indicators were derived using factor analysis, they were not always discrete variables. Those indicators that were ambiguous or difficult to interpret should be reexamined and substituted with indicators that are more comprehensible. This problem was most evident for the mathematics inventory. Substitution of or development of another instrument, the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1977), which has gained more widespread use, is recommended. This could also be adapted to examine computer attitudes. Finally, it is recommended that the objective test be more comprehensive in nature to enable examination of more specific skills. If possible, it is recommended that the test be administered with a computer rather than paper and pencil.

The method of path analysis using multiple regression analysis was used to test the causal model and placed certain constraints on this study. In social and behavioral research, it is unrealistic to assume that the assumptions of path analysis using a recursive system are met (Pedhazur, 1982). A more viable approach would be to use LISREL which is less restrictive. First, LISREL accommodates multiple indicators easily, using latent variables to represent the construct and manifest variables to represent the observed variables. Second, recursive models may oversimplify a theoretical model (Pedhazur, 1982). LISREL allows for reciprocal causation, which may have been operating in this study. It is possible that student attitudes affected achievement which in turn affected attitudes. Finally, the multiple regression approach assumes that variables are measured without error, another unrealistic assumption (Pedhazur, 1982). This may result in an understatement or overstatement of the causal impact of an independent variable on a dependent variable. This method allows for errors-in-variables or unobserved measurement error and errors in equations or unobserved disturbance terms.

Computers in the schools, particularly at the elementary school level, are a relatively new innovation. Consequently, there are little data that support or reject specific computer curricula. This study is a first attempt to identify and test factors that influence attitudes toward and performance with the Logo language. Because computer use in the schools has become more widespread and will continue to grow, it becomes increasingly important to further explore the model proposed in this study. Future research on integrating computers into the curriculum will need to examine alternative computer approaches as well as noncomputer approaches in a comparative framework. These alternative approaches will need to be evaluated with respect to both effectiveness and efficiency in a range of school settings. Further, the theoretical and empirical basis for various computer applications needs to be considered as educators continue to use computers in the classroom.

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ACKNOWLEDGEMENTS

This study was reviewed and approved by the Iowa State Committee on the Use of Human Subjects in Research. There are a number of people who have greatly contributed to the completion of this dissertation. I would like to thank all the members of my committee for making this a challenging and rewarding experience. I especially want to thank Richard Warren for his patience and expert advice, and Rex Thomas and Ann Thompson who were instrumental in my involvement in the computer literacy project. Rex Thomas sparked my interest in educational computing and Ann Thompson provided helpful suggestions in the development of the evaluation instruments and support and encouragement throughout the project. I also want to thank Mary Huba for her prompt and probing critiques.

I am grateful to the Research Institute for Studies in Education for providing support for the Logo Project. The members of the RISE staff also provided valuable assistance with various aspects of the project.

Special thanks is due the Ames Community School District who allowed me to conduct this study. Without the cooperation of the fourth, fifth and sixth grade students who took the time to complete the evaluation instruments, this study would not have been possible.

Finally, I would like to thank my family for their support, love and encouragement. My husband Jeff's critical review of my work was invaluable. The added responsibilities he took on to enable me to spend more time on my dissertation are appreciated. And, last but not least, my son Jeremy's urging to "go work on your dissertation" spurred me on to completion.

APPENDIX A - PRE-LOGO QUESTIONNAIRE AND RESULTS

	N	Percent
Females	116	47.0
Males	131	53.0
School 1	94	37.9
School 2	154	62.1

NAME ______________________________

GRADE ______ Grade 4 N=61 Grade 5 N=99 Grade 6 N=89

SCHOOL ____________________

We would like to ask you some questions about computers. Some of the things we would like to know are: if you've used computers before, the kinds of things you've done with them and how much you like using them. If you don't understand a question, please feel free to ask.

Number / Percent

1. Have you ever used a computer?
(Please place a check mark next to your answer)

1 No ---> Skip to question 21. 0.4

247 Yes 99.6 N=248

If you have used a computer before, please answer the following questions.

2. Does your family have a computer at home?

116 No ----> Skip to question 7. 47.2

130 Yes 52.8 N=246

3. If your family has a computer at home, what is the name of it?

16 Apple 12.5

2 Pet 1.6

6 TRS80 (Radio Shack) 4.7

67 Atari ---> What kind? 52.3

15 Intellivision 11.7

0 IBM 0.0

22 Other ---> What kind is it? 17.2 N=111

4. When you use the computer at home, do you usually . . .

68 Work by yourself 61.3

34 Work with others 30.6

9 Both 8.1 N=111

5. How many times a week do you use the computer at home?

_____ times. Mean=10.7 S.D.=12.25 N=111

6. For each time you use the computer at home, how many minutes do you usually use it?

_____ minutes. Mean=39.9 S.D.=24.3 N=113

Number Percent

7. Have you used a computer in school?

2 No ---> Skip to question 15. 0.8
246 Yes 99.2 N=248

8. If you have used a computer in school, what is the name of the computer(s) that you used?

166 Apple 69.2 N=240

230 Pet 94.7 N=243

231 Other ----> What was the name of the computer?________________
98.3 N=235

9. In what grades have you used the computer? Check all that apply.

Number	Grade	Percent	N
9	first grade	3.7	N=244
37	second grade	15.2	N=244
120	third grade	49.2	N=244
163	fourth grade	64.4	N=243
170	fifth grade	91.9	N=185
77	sixth grade	82.8	N= 93

10. During this year, has computer work been assigned by your teacher?

148 Yes 60.9
95 No 39.1 N=243

11. This year, at what times do you use a computer in school? Check all that apply.

Number	Time	Percent	N
25	Before school	10.6	N=235
220	During school	92.8	N=237
59	After school	25.1	N=235

12. When you use the computer at school, do you usually . . .

40 Work by yourself 16.8

191 Work with others 80.3
7 Both 2.9 N=238

13. This year, how many times a week do you use the computer at school?

_____ times. Mean=1.8 S.D.=1.3 N=212

14. This year, for each time you have used the computer at school, how many minutes have you usually spent?
Mean=20.5 S.D.=9.1 N=233

____ minutes

15. Are there any places other than your home or school where you've used a computer?

52 No 21.1

195 Yes--->If you checked yes, where have you used the computer(s)?
78.9 N=247

____

16. The following is a list of things that can be done with a computer.

Circle SCH if you have used the computer for that purpose in SCHOOL.

Circle HOME if you have used the computer for that purpose at HOME.

Circle OTHER if you have used the computer for that purpose at a place other than home or school.

Circle NO if you have not used the computer for that purpose.

EXAMPLE:

Other space games SCH (HOME) (OTHER) NO

Since I play space games at home and my friend's house, I I circled HOME and OTHER.

					Number	Percent	N
Using the computer for math problems	SCH	HOME	OTHER	NO	183	73.4	248
Using the computer for social studies	SCH	HOME	OTHER	NO	99	39.9	248
Using the computer for science	SCH	HOME	OTHER	NO	92	37.1	248
Using the computer for spelling	SCH	HOME	OTHER	NO	139	56.0	248
Word processing or writing	SCH	HOME	OTHER	NO	82	33.1	248
Computer programming	SCH	HOME	OTHER	NO	58	23.4	248
LOGO	SCH	HOME	OTHER	NO	16	6.5	248
Oregon Trail	SCH	HOME	OTHER	NO	77	31.0	248
Lemonade Stand	SCH	HOME	OTHER	NO	147	59.3	248
Space Invaders	SCH	HOME	OTHER	NO	198	79.8	248
Other space games	SCH	HOME	OTHER	NO	209	84.3	248
Hangman	SCH	HOME	OTHER	NO	144	58.1	248
Other word games	SCH	HOME	OTHER	NO	130	52.4	248
Pac Man or Snack Attack	SCH	HOME	OTHER	NO	214	86.3	248
Frogger	SCH	HOME	OTHER	NO	161	64.9	248
Eamon Dragons	SCH	HOME	OTHER	NO	47	19.0	248
Sports games	SCH	HOME	OTHER	NO	171	68.9	248
Other games	SCH	HOME	OTHER	NO	202	81.4	248
Other--->________________	SCH	HOME	OTHER	NO	3	1.2	248
Other--->________________	SCH	HOME	OTHER	NO			

Note. Number and percent are based on students who circled either HOME, SCHOOL, or OTHER.

17. From the list of computer activities in question 16:

A. Name your two favorite activities.

Favorite Activity	Number	% Responses	% Cases
PacMan or Snack Attack	87	19.6	36.9
Frogger	72	16.2	30.5
Space games	29	6.5	12.3
Space invaders	26	5.9	11.1
Sports games	23	5.2	9.7
Computer programming	22	5.0	9.3
Donkey Kong	21	4.7	8.9
Oregon Trail	20	4.5	8.5
Lemonade Stand	17	3.8	7.2
Academic subjects	17	3.8	7.2
Other games	97	21.8	41.1
Other	13	2.9	5.5
	444		(N=236)

B. Name the two computer activities you dislike the most.

Least Liked Activity	Number	% Responses	% Cases
Math problems	47	16.4	26.6
Hangman	24	8.5	13.9
Space Invaders	20	7.1	11.6
Sports games	20	7.1	11.6
Lemonade Stand	19	6.8	11.0
Spelling	18	6.4	10.4
None	11	3.9	6.4
Social Studies	10	3.6	5.8
Science	9	3.2	5.2
Other Games	75	26.7	43.4
Other	29	10.3	16.8
	281		(N=173)

C. Name the two activities you would like to do with the computer but have not done.

Like to Try	Number	% Responses	% Cases
Logo	72	18.7	33.6
Computer Programming	37	9.6	17.3
Frogger	32	8.3	15.0
Eamon Dragons	29	7.5	13.6
Oregon Trail	23	6.0	10.7
Lemonade Stand	20	5.2	9.3
Hangman	20	5.2	9.3
Pacman	18	4.7	8.4
Academic subjects	36	9.3	16.8
Other games	70	18.0	32.7
Other	28	7.3	13.1
	385		(N=214)

18. Please compare how much you like using the computer to the following school activities.

Please use the following rating scale:

LIKE SCHOOL ACTIVITY		LIKE BOTH	LIKE COMPUTER ACTIVITY	
A Lot More	Some More	the Same	Some More	A Lot More
1	2	3	4	5

Circle the number which matches your response.

EXAMPLE:

eating lunch 1 2 (3) 4 5

Since I LIKE BOTH THE SAME, I circled the 3.

		N	Mean	Standard Deviation
draw or paint a picture	1 2 3 4 5	244	3.5	1.3
go to recess	1 2 3 4 5	244	3.2	1.2
read a book	1 2 3 4 5	243	3.2	1.4
go to the media center	1 2 3 4 5	243	3.7	1.3
talk to my friends	1 2 3 4 5	243	2.7	1.3
work on a class assignment	1 2 3 4 5	243	4.0	1.1
watch a movie or filmstrip	1 2 3 4 5	243	3.2	1.2
work with my teacher	1 2 3 4 5	243	3.6	1.2
learn a new social studies lesson	1 2 3 4 5	243	4.3	1.0
conduct a science experiment	1 2 3 4 5	242	2.9	1.3
go to the gym	1 2 3 4 5	243	2.7	1.3
work on a project in a small group	1 2 3 4 5	244	3.5	1.2

19. How much do you like using the computer compared to the following out of school activities?

Use the following rating scale:

LIKE ACTIVITY		LIKE BOTH	LIKE COMPUTER ACTIVITY	
A Lot More	Some More	the Same	Some More	A Lot More
1	2	3	4	5

Circle the number which matches your response.

EXAMPLE:

go to sleep 1 2 3 (4) 5

Since I like using the computer SOME MORE than going to sleep, I circled the 4.

		N	Mean	Standard Deviation
play with my friends	1 2 3 4 5	245	2.6	1.1
watch television	1 2 3 4 5	244	3.1	1.2
play a board game	1 2 3 4 5	244	3.7	1.2
ride my bicycle	1 2 3 4 5	242	3.1	1.3
go to a movie	1 2 3 4 5	245	2.3	1.2
do my homework	1 2 3 4 5	244	4.3	1.1
take a music lesson	1 2 3 4 5	245	4.0	1.2
go to a football, baseball or basketball game	1 2 3 4 5	244	2.6	1.5
play an outdoor sport such as soccer, baseball, football, or basketball	1 2 3 4 5	244	2.3	1.3
read a book	1 2 3 4 5	243	3.3	1.3
put together a model	1 2 3 4 5	244	3.8	1.4
make cookies	1 2 3 4 5	244	3.2	1.3

Number | Percent

20. Have you ever written your own computer program(s)?

190 No — 79.2

50 Yes---->If you checked yes, what computer language(s) did you use? — 20.8 — N=240

21. How interested are you in using a computer?

Number	Response	Percent			
129	Very interested	53.5	N=241	Mean=4.4	S.D.=.80
76	Interested	31.5			
33	Neutral	13.7			
1	Not interested	0.4			
2	Very uninterested	0.8			

22. Name your favorite school subject.

(See below)

23. Name your least favorite school subject.

(See below)

Subject	Favorite N	Favorite %	Least Favorite N	Least Favorite %
Art	31	12.9	—	—
Computers	3	1.2	—	—
Language Arts	8	3.2	38	15.9
Math	63	24.9	32	13.4
Music	1	0.4	5	2.1
Physical Ed.	16	6.3	—	—
Reading	12	4.7	5	2.1
Science	78	30.8	18	7.5
Social Studies	6	2.4	106	44.4
Spelling	11	4.3	25	10.5
Other	9	3.6	—	—
All (None)	2	0.8	10	4.2
	240	100.0	239	100.0

APPENDIX B - MATHEMATICS INVENTORY AND RESULTS

NAME ______________________

BOY _____ GIRL _____

MATH TEACHER'S NAME ______________

SCHOOL ______________________

	N	Percent
Grade 4	62	24.7
Grade 5	97	38.6
Grade 6	92	36.7
School 1	91	36.3
School 2	160	63.7
Females	121	48.2
Males	130	51.8

$N = 251$

DIRECTIONS

Read each statement and decide if you usually agree or disagree with that statement.

Answer the following questions by circling . . .

5 if you STRONGLY AGREE with the statement
4 if you AGREE with the statement
3 if you NEITHER AGREE NOR DISAGREE with the statement
2 if you DISAGREE with the statement
1 if you STRONGLY DISAGREE with the statement

	Statement	Scale	N	Mean	Standard Deviation
1.	I like to work my math problems with several other students.	5 4 3 2 1	251	3.2	1.0
2.	I always like to choose what math problems to do.	5 4 3 2 1	250	3.0	1.2
3.	I like to have my parents help me with my math problems.	5 4 3 2 1	251	3.3	1.2
4.	I do not like to work alone	5 4 3 2 1	250	2.7	1.2
5.	I work harder on math problems that I know will be checked.	5 4 3 2 1	251	3.3	1.3
6.	I need to learn math.	5 4 3 2 1	250	3.4	1.5
7.	I need to be reminded often to get my math assignment done.	5 4 3 2 1	251	2.2	1.3
8.	I want to do well in math just to show my friends.	5 4 3 2 1	251	1.8	1.1
9.	I sometimes forget to do my assignments.	5 4 3 2 1	251	2.3	1.2
10.	I do not need any practice work before I start work on new math problems.	5 4 3 2 1	249	2.5	1.2
11.	I can always remember what I am told to do.	5 4 3 2 1	250	3.1	1.0
12.	I usually finish the easy math problems but not the hard ones.	5 4 3 2 1	250	2.1	1.1
13.	I like my teacher to work a few example problems before I have to do a new problem by myself.	5 4 3 2 1	251	4.2	1.1

CIRCLE. . .
5 if you STRONGLY AGREE with the statement
4 if you AGREE with the statement
3 if you NEITHER AGREE NOR DISAGREE with the statement
2 if you DISAGREE with the statement
1 if you STRONGLY DISAGREE with the statement

							N	Mean	Standard Deviation
14.	I like to learn about math best by listening to my teacher.	5	4	3	2	1	250	3.7	1.0
15.	I will do well in math this year.	5	4	3	2	1	250	4.0	0.9
16.	I am not good at math games.	5	4	3	2	1	251	2.5	1.1
17.	I usually finish my math assignments.	5	4	3	2	1	251	4.2	1.0
18.	I am good at working math problems in my head.	5	4	3	2	1	251	3.3	1.0
19.	I like to do math problems in my own way.	5	4	3	2	1	249	3.2	1.2
20.	My teacher really wants me to do well in math.	5	4	3	2	1	251	4.4	0.8
21.	Getting my math problems correct is really important to me.	5	4	3	2	1	250	4.4	0.8
22.	I sometimes lose my books and papers.	5	4	3	2	1	250	2.2	1.2
23.	I get into trouble in school about once every week.	5	4	3	2	1	249	2.0	1.3
24.	I like to work math problems by myself.	5	4	3	2	1	251	3.5	1.1
25.	I learn about math best by reading my math book.	5	4	3	2	1	251	2.4	1.1
26.	I like to figure out how to work new math problems without my teacher's help.	5	4	3	2	1	251	2.6	1.2
27.	Before I start working new math problems, I like to make sure I can do them.	5	4	3	2	1	249	4.2	0.9
28.	I do not like to check my math problems.	5	4	3	2	1	249	2.9	1.3
29.	I like to know if a math assignment will be checked.	5	4	3	2	1	249	3.7	1.2
30.	It is not that important to know math.	5	4	3	2	1	250	1.3	0.7
31.	If I have a question in my math class, I ask the teacher right away.	5	4	3	2	1	247	3.5	1.0
32.	Other subjects are more important than math.	5	4	3	2	1	249	2.6	1.0
33.	My math teacher last year yelled at me a lot.	5	4	3	2	1	251	1.8	1.2

CIRCLE. . .

5 if you STRONGLY AGREE with the statement
4 if you AGREE with the statement
3 if you NEITHER AGREE NOR DISAGREE with the statement
2 if you DISAGREE with the statement
1 if you STRONGLY DISAGREE with the statement

			N	Mean	Standard Deviation
34.	I want to do well in math just for myself.	5 4 3 2 1	250	3.6	1.25
35.	If I find out why I made a mistake on a math problem, I usually do not miss that kind of problem again.	5 4 3 2 1	251	3.6	1.0
36.	I like to be able to choose what our class does in math.	5 4 3 2 1	249	2.9	1.2
37.	Getting all my math problems correct is really important to me.	5 4 3 2 1	250	4.4	0.8
38.	If I know my math problems will not be checked, I do not work on them very much.	5 4 3 2 1	249	2.0	1.1
39.	I like to check my math problems to see which problems I missed.	5 4 3 2 1	249	3.7	1.1
40.	I like to work math problems in my head.	5 4 3 2 1	251	3.1	1.2

Answer the following questions about your math class by circling . . .

5 if you want to answer ALWAYS
4 if you want to answer MOST OF THE TIME
3 if you want to answer SOME OF THE TIME
2 if you want to answer SELDOM
1 if you want to answer NEVER

			N	Mean	Standard Deviation
41.	Do you like being in math class?	5 4 3 2 1	250	3.7	0.9
42.	Do you have much fun in math class?	5 4 3 2 1	251	3.4	1.0
43.	Does the teacher help you enough?	5 4 3 2 1	251	4.4	0.8
44.	Do you learn a lot in math class?	5 4 3 2 1	249	4.3	0.8
45.	Do you ever feel like staying away from math class?	5 4 3 2 1	251	2.6	1.3
46.	Are you proud to be in math class?	5 4 3 2 1	250	3.8	1.1
47.	Do you always do your best in math class	5 4 3 2 1	247	4.2	0.8
48.	Do you talk in class discussions in math class?	5 4 3 2 1	250	3.5	1.2
49.	Are most of the student in math class friendly to you?	5 4 3 2 1	250	4.1	0.9

APPENDIX C - POST-LOGO QUESTIONNAIRE AND RESULTS

	Number	Percent
School 1	92	24.3
School 2	156	41.2
School 3	131	34.6

NAME ________________

GRADE ____ Grade 4 N=101 Grade 5 N=142 Grade 6 N=136

TEACHER ________________

Number Percent

1. When you used the computer for LOGO at school, did you like to

   144 work by yourself 39.0

   78 work with others 21.1

   147 liked both the same amount 39.9

2. How many times a week have you usually used the computer for LOGO at school?

   ____ times Mean=2.3 S.D.=1.1 N=364

3. Are there any places other than school where you've used the computer for LOGO?

   283 No 76.7

   86 Yes ---> If you checked yes... 23.3

   a. Where have you used the computer?

   ____

   b. How often have you used it? ________________

4. Would you say that LOGO was . . . (check one)

   0 very hard to learn? 0.0

   25 hard to learn? 6.8

   158 neither hard nor easy to learn? 42.8

   133 easy to learn? 36.0

   53 very easy to learn? 14.4 N=362

5. What did you like the <u>most</u> about LOGO?

   See attached

6. What did you like the <u>least</u> about LOGO?

   See attached

	Number	Percent
5. What did you like the most about LOGO?		
Drawing shapes, pictures or designs	155	42.8
Working in editor/writing, changing debugging procedures	38	10.5
Writing programs	33	9.1
Selecting own project	27	7.5
Fun, easy, liked everything	31	8.6
Other general Logo or computer knowledge	43	11.9
General learning skills	12	3.3
Other comments	23	6.0
	362	100.0
6. What did you like the least about LOGO?		
Nothing	62	17.8
Difficulty in learning/remembering commands	29	8.3
Not enough time	29	8.3
Being told what to make/too much structure	18	5.2
Specific shape or design	17	4.9
Using the editor	14	4.0
Making/discovering errors	13	3.7
Logo was boring	11	3.2
Interference with other activities	11	3.2
Speed of turtle too slow	11	3.2
Typing, finding correct keys	10	2.9
Logo in general	11	3.2
Other categories with less than 10 responses	102	29.3
	348	100.0

2.

7. If you stopped working with LOGO, what made you stop?

Number		Percent
56	I had too much other school work to do	34.6
2	LOGO was too hard to learn	1.2
36	LOGO was boring	22.2
26	I enjoyed working on other subjects more than LOGO	16.0
1	Other ---> Please explain ______	
207	Not Applicable	

8. When you had a problem with a program you were working on, were you more likely to . . . (check one)

103	work on it until you found the error	28.0
18	work on it for a short time and go on to something else	4.9
233	ask the teacher or aide for help after you tried a few things yourself	63.3
14	forget about it and go on to a new project	3.8

9. The following is a list of a few things that can be done with a computer.

a. Using the computer for school work (science, math, social studies, language arts, etc.)
b. Computer programming other than LOGO (BASIC, for example)
c. LOGO
d. Space games
e. Word games
f. Sports games
g. Adventure games
h. Learning how to type
i. Computer graphics or drawing
j. Word processing

Choose from the list above or add other things you have done with the computer to answer parts a, b and c.

a. Name your two favorite activities that you have done with the computer.

1. See attached

2. ______

b. Name the two computer activities you have tried but dislike the <u>most</u>.

1. See attached

2. ______

c. Name two computer activities you have not tried but would like to try.

1. See attached

2. ______

	Number	% of Responses	% of Cases
9a. Name your two favorite activities you have done with the computer.	(N=362)		
Logo	168	23.8	46.4
Adventure games	117	16.6	32.3
Space games	105	14.9	29.0
Computer graphics or drawing	85	12.0	23.5
Specific Logo activities	37	5.2	10.2
Computer programming	32	4.5	8.8
Sports games	31	4.4	8.6
Typing	30	4.2	8.3
Word games	29	4.1	8.0
School work	29	4.1	8.0
Other games	18	2.5	5.0
Other	25	3.5	6.9
	706	100.0	
9b. Name the two computer activities you have tried but dislike the most.	(N=253)		
Word games	96	20.9	37.9
Word processing	67	14.6	26.5
Learning to type	49	10.7	19.4
School work	47	10.2	18.6
Sports games	38	8.3	15.0
Programming	30	6.5	11.9
Specific Logo activities	32	7.0	12.6
Logo	29	6.3	11.5
Computer graphics	24	5.2	9.5
Space games	19	4.1	7.5
Adventure games	15	3.3	5.9
Other	14	3.0	5.5
	460	100.0	
9c. Name the two computer activities you have not tried but would like to try.	(N=329)		
Sports games	91	14.7	27.7
Word processing	81	13.1	24.6
Adventure games	81	13.1	24.6
Learning to type	73	11.8	22.2
Space games	71	11.5	21.6
Academic activities	54	8.8	16.4
Graphics or drawing	44	7.1	13.4
Computer programming other than Logo	42	6.8	12.8
Word games	35	5.7	10.6
Logo activities	18	2.9	5.5
Other	27	4.4	8.2

3.

10. Answer the following questions by circling . . .

5 if you STRONGLY AGREE with the statement
4 if you AGREE with the statement
3 if you NEITHER AGREE NOR DISAGREE with the statement
2 if you DISAGREE with the statement
1 if you STRONGLY DISAGREE with the statement

						Number	Mean	Standard Deviation
When I come to the computer I usually know what I want to do	5	4	3	2	1	368	3.7	1.0
I like to work on LOGO by myself	5	4	3	2	1	367	3.5	1.2
When I come to the computer I like to have the teacher or aide suggest something for me to do	5	4	3	2	1	368	2.0	1.0
I need to learn LOGO	5	4	3	2	1	363	2.4	1.2
When I have a problem with LOGO, I ask the teacher or aide what is wrong right away	5	4	3	2	1	365	2.9	1.2
It is very important to know LOGO	5	4	3	2	1	365	2.9	1.1
I am good at writing LOGO programs	5	4	3	2	1	365	3.1	1.2
My parents want me to learn LOGO	5	4	3	2	1	364	3.1	1.1
I learned a lot using LOGO	5	4	3	2	1	366	3.8	1.1
My teacher wants me to learn LOGO	5	4	3	2	1	366	3.9	1.1

11. Presently, how long do you usually spend on a project or picture?

Number		Percent
73	Less than one session	20.0
157	One session	43.0
87	Two sessions	23.8
48	Three or more sessions	13.2

N=365

12. How much time do you usually spend in one session?

30	Less than 15 minutes	8.2
28	15 minutes	7.7
128	20 minutes	35.1
174	30 minutes	47.7
3	more than 30 minutes	.8
1	Other ----> How much time?	.3

N=365

4.

13. Name and draw a sketch of your favorite LOGO project you have done.

14. Please check the two things you like to do the most?

Number		Percent Responses
166	Draw designs with lots of repeats	23.6
75	Draw designs with lots of big numbers	10.7
95	Draw pictures of objects or figures such as a house, a car, a person, an animal etc. drawing right on the screen	13.5
117	Draw pictures of objects or figures such as a house, car, person, etc. working in the editor (writing procedures)	16.6
66	Draw designs that fill up the screen	9.4
185	Draw designs that change colors and/or blinked	26.3
704	N=367	

15. Please check the two things you like to do the least?

85	Draw designs with lots of repeats	12.2
145	Draw designs with lots of big numbers	20.8
171	Draw pictures of objects or figures such as a house, a car, a person, an animal etc. drawing right on the screen	24.5
109	Draw pictures of objects or figures such as a house, car, person, etc. working in the editor (writing procedures)	15.6
145	Draw designs that fill up the screen	20.8
42	Draw designs that change colors and/or blinked	6.0
704	N=367	

16. Which of the following ways do you like working with LOGO?

		Percent
140	Drawing right on the screen	38.8
216	Working in the editor (writing procedures)	59.8
5	Both N=361	1.4

Why? ______________________________

17. Do you usually . . .

105	plan out what you want to do before you go to the computer?	28.8
247	plan your project as you go along?	67.7
13	both N=365	3.6

18. How well were you able to do each of the following?

Circle. . .

5 if you were able to do it VERY WELL
4 if you were able to do it WELL
3 if you were able to do it about AVERAGE
2 if you were able to do it A LITTLE BIT
1 if you were able to do it NOT AT ALL
D if you don't know what the question means

						Number	Mean	S.D.
Driving the turtle around (using commands such as FD, BK, RT and LT)	5	4	3	2	1	362	4.5	0.8
Working in the editor or writing procedures	5	4	3	2	1	353	3.7	1.2
Changing procedures which you have written	5	4	3	2	1	338	3.4	1.2
Using the repeat command (for example REPEAT 4 FD 20 RT 90)	5	4	3	2	1	356	4.1	1.1
Finding mistakes in programs	5	4	3	2	1	353	3.1	1.2
Correcting mistakes in programs	5	4	3	2	1	353	3.3	1.2
Saving a procedure on a disk	5	4	3	2	1	335	3.4	1.4
Getting a procedure back that was saved on a disk	5	4	3	2	1	326	3.4	1.4
Writing procedures that use variables (SQUARE :SIDE, for example)	5	4	3	2	1	270	3.1	1.3

GO ON TO THE NEXT PAGE

19. What were the two most important things you learned by learning to program in LOGO?

1. See attached

2.

20. Please compare how much you like using the computer for LOGO to the following school activities. Please use the following rating scale:

LIKE SCHOOL ACTIVITY		LIKE BOTH	LIKE LOGO	
A Lot More	Some More	the Same	Some More	A Lot More
1	2	3	4	5

Circle the number which matches your response.

EXAMPLES:

eating lunch	1	(2)	3	4	5
taking a test	1	2	3	4	(5)

Since I like eating lunch SOME MORE than LOGO, I circled the 2.

Since I like using LOGO a lot more than taking a test, I circled the 5.

						Number	Mean	S.D.
draw or paint a picture	1	2	3	4	5	366	3.2	1.3
go to recess	1	2	3	4	5	366	2.3	1.2
read a book	1	2	3	4	5	365	3.0	1.4
go to the media center	1	2	3	4	5	365	3.6	1.3
talk to my friends	1	2	3	4	5	366	2.5	1.2
work on a class assignment	1	2	3	4	5	366	3.7	1.3
watch a movie or filmstrip	1	2	3	4	5	362	2.8	1.3
work with my teacher by myself	1	2	3	4	5	363	3.5	1.3
learn a new social studies lesson	1	2	3	4	5	365	4.1	1.2
conduct a science experiment	1	2	3	4	5	366	2.6	1.4
go to the gym	1	2	3	4	5	364	2.2	1.3
work on a project in a small group	1	2	3	4	5	363	3.1	1.3
do computer work other than LOGO	1	2	3	4	5	363	3.0	1.3

19. What were the two most important things you learned by learning to program in LOGO?

	Number	% of Responses	% of Cases
Edit/editor	67	11.5	20.6
Logo primitives	62	10.7	19.1
Using or learning about computers	52	9.0	16.0
Knowledge of keyboard/typing	51	8.8	15.7
Drawing	46	7.9	14.2
Disk management skills	28	4.8	8.6
General computer or programming skills	43	7.4	13.2
Angles/degrees	26	4.5	8.0
Logo in general	26	4.5	8.0
Making specific shapes or designs	20	3.4	6.2
General skills or knowledge	72	12.4	22.2
Other Logo and computer skills	71	12.2	21.8
Other comments	17	2.9	5.2
	325	100.0	

APPENDIX D - OBJECTIVE TEST AND RESULTS

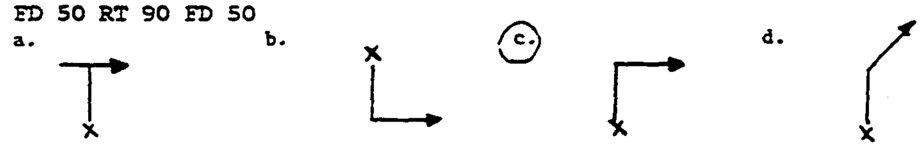
Please mark all of your answers in pencil on the answer sheet provided.
Fill out your name, school and teacher's name on the answer sheet.
If you have any questions, please ask your teacher.

For the following questions, an X will show where the turtle started and the turtle will be shown where it ends up.

N=370 | Percent Correct

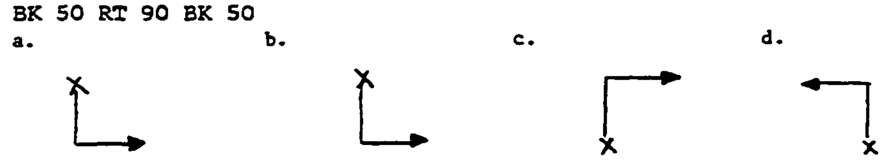
1. What do you get when you give the command?

a. FD 50 RT 90 FD 50



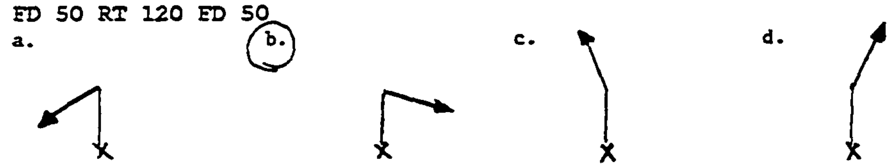
84

b. BK 50 RT 90 BK 50



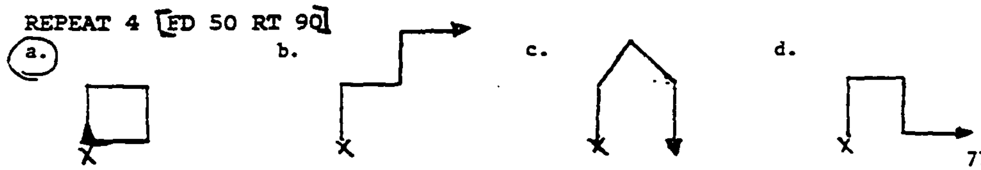
omitted

c. FD 50 RT 120 FD 50



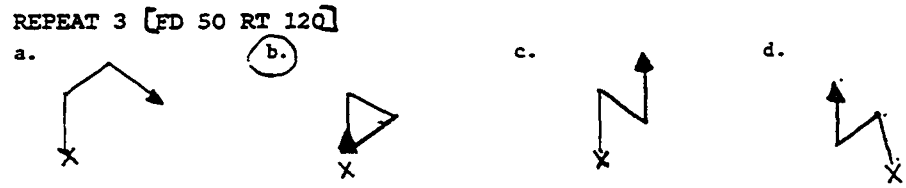
67

d. REPEAT 4 [FD 50 RT 90]



77

e. REPEAT 3 [FD 50 RT 120]



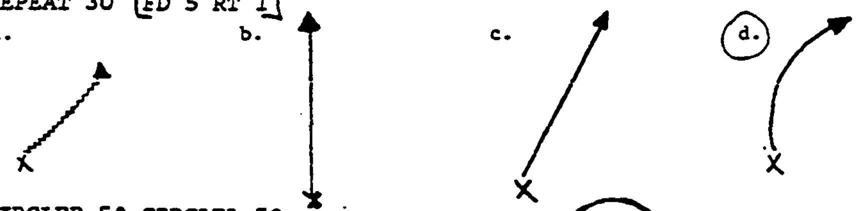
71

2.
Percent Correct

1. (continued)

f. REPEAT 30 [FD 5 RT 1]

a. b. c. (d.)



30

g. CIRCLER 50 CIRCLEL 50

(a.) b. c. d.

69

2. What command would you use if you wanted to move the turtle forward 50, but didn't want to leave any marks?

a. PENERASE FD 50
(b) PU FD 50
c. PD FD 50
d. HT FD 50

83

3. If I were drawing on the screen and wanted to start again, what command would I use?

a. ERASE
(b) CS
c. ST
d. ERPS

94

4. If I went RT 70 but only wanted to go RT 60, how could I correct it?

a. FD 10
b. RT 10
(c) LT 10
d. BK 20

63

5. RT 180 is the same as

a. RT 360
b. LT 90
c. RT 45
(d) LT 180

75

6. RT 90 is the same as

a. LT 90
b. RT 45
(c) LT 270
d. RT 180

31

3.

7. If you had written a procedure and called it HOUSE, what command would you use to see what the house looked like? — Percent Correct

a. EDIT "HOUSE
(b) HOUSE
c. DRAW "HOUSE
d. LOAD "HOUSE — 50

8. Suppose you wrote a procedure called HOUSE (in the editor) and wanted to go back and change the program, what command would you use?

a. FIND HOUSE
(b) EDIT "HOUSE [1]
c. DRAW "HOUSE
d. CHANGE "HOUSE
(e) TO HOUSE [1] — 66

9. Suppose you have written three procedures but have not saved them on disk. What command would you use to get a list of the procedures you have written?

(a) POTS
b. ERPS
c. CATALOG
d. NAMES — 31

10. If you wanted to see what files are stored on the disk what command would you use?

(a) CATALOG
b. LIST
c. POTS
d. NAME
e. Don't know — 59

11. What is the command you would use to move a file named HOUSE from the disk to the turtle's memory?

a. USE "HOUSE
b. LIST "HOUSE
(c) LOAD "HOUSE [1]
d. FIND "HOUSE
(e) READ "HOUSE [1] — 64

12. If you wanted to save a procedure named HOUSE on disk, what command would you use?

(a) SAVE "HOUSE
b. LOAD "HOUSE
c. CATALOG "HOUSE
d. LIST "HOUSE — 81

[1] Responses differed depending on the version of Logo that was used.

Percent Correct

13. The following commands:
FD 10 RT 10 FD 10 RT 10 FD 10 RT 10
are the same as:

a. REPEAT 3 [FD 10 RT 5]
b. FD 30 RT 30
c. REPEAT 3 [FD 10 RT 10]
d. REPEAT 3 [FD 10 LT 15] 84

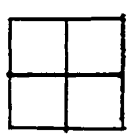
14. If I wanted to erase all procedures that were on the computer, what command would I use?

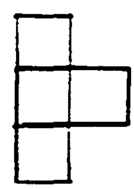
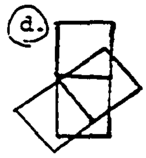
a. ERPS
b. POTS
c. ERASE ALL
d. LOAD 47

15. Suppose you have written the following procedure:

```
TO SQUARE
REPEAT 4 [FD 50 RT 90]
END
```
35

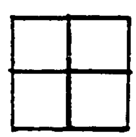
What picture would you get with the following commands?
REPEAT 4 [SQUARE RT 45]

a.

b.

c.

d.


21

16. Write a procedure using the SQUARE procedure listed in question 15 to draw the following picture:



13

Please write your answer on a separate piece of paper.

Final Score	Number	Percent	
21	4	1.1	
17 - 20	66	17.8	
13 - 16	112	30.3	
9 - 12	144	38.9	
4 - 8	44	11.9	Mean = 12.8 S.D. = 3.7

APPENDIX E - RESULTS OF FACTOR ANALYSIS

Table 1. Factor Matrix for Pre-Logo In-School Activity Preferences

Item	Factor 1	Factor 2	Factor 3
Learn a new social studies lesson	.77	.14	.05
Work on a class assignment	.76	.08	.09
Work with my teacher	.65	.12	.07
Go to the media center	.40	.17	.44
Watch a movie or filmstrip	.16	.73	.16
Go to the gym	.00	70	.23
Conduct a science experiment	.29	.70	-.12
Draw or paint a picture	.21	.41	.32
Talk to my friends	-.01	.05	.65
Read a book	.35	.05	.59
Go to recess	-.21	.40	.55
Work on a project in a small group	.45	.22	.47

Table 2. Factor Matrix for Pre-Logo Out-of-School Activity Preferences

Item	Factor 1	Factor 2	Factor 3	Factor 4
Go to a football, baseball or basketball game	.85	.05	-.02	.13
Play an outdoor sport such as soccer, baseball, football or basketball	.79	.02	.01	.15
Play with my friends	.20	.68	-.12	.18
Go to a movie	.50	.63	.01	-.20
Make cookies	-.14	.59	.33	.09
Ride my bicycle	-.04	.57	.11	.29
Do my homework	.26	-.22	.76	.07
Take a music lesson	-.20	.12	.64	.08
Read a book	.04	.40	.62	.02
Put together a model	.17	-.02	-.05	.70
Play a board game	-.14	.36	.23	.63
Watch television	.34	.24	.13	.56

Table 3. Factor Matrix for Mathematics Inventory

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
My teacher really wants me to do well in math	.65	-.03	.10	.01	-.10
I like my teacher to work a few example problems before I have to do a new problem by myself	.56	.07	-.01	-.24	.01
I like to learn about math best by listening to my teacher	.54	.06	-.05	.01	.14
Do you learn a lot in math class?	.51	-.25	-.27	.10	.00
Getting my math problems correct is really important to me	.49	-.22	-.31	.15	.17
Are you proud to be in math class?	.47	-.09	-.44	.31	.02
Getting all my math problems correct is really important to me	.46	-.14	-.36	.09	.19
Before I start working new math problems, I like to make sure I can do them	.45	-.02	-.01	.24	.13
I do not need any practice work before I start work on new math problems	-.44	-.01	-.01	.24	.13
Do you talk in class discussions in math class?	.44	.07	.25	.22	.12
I like to figure out how to work new math problems without my teacher's help	-.44	-.13	-.01	.28	.24
Does the math teacher help you enough?	.42	-.25	-.11	-.02	-.09
Do you always do your best in math class?	.59	-.32	-.20	.19	.02
I need to learn math	.30	-.02	-.03	-.07	.03

Table 3. (continued)

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
I sometimes forget to do my assignments	-.01	.73	.03	-.07	-.07
I sometimes lose my books and papers	-.02	.67	.03	-.05	.01
I need to be reminded often to get my math assignment done	-.04	.66	-.06	-.09	.14
I usually finish the easy math problems but not the hard ones	.05	.54	-.03	-.15	.28
I get into trouble in school about once every week	-.04	.53	.36	.08	-.10
I usually finish my math assignments	.17	-.52	.07	.34	-.04
My math teacher last year yelled at me a lot.	.01	.52	.22	.10	-.02
I can always remember what I am told to do	.09	-.43	-.02	.25	.28
If I have a question in my math class, I ask the teacher right away	.26	-.28	-.01	.10	-.04
It's not that important to know math	-.13	.28	.19	-.12	.01
If I know my math problems will not be checked, I do not work on them very much	-.09	.27	.24	.03	.12
I like to be able to choose what our class does in math	.12	-.01	.67	.06	.05
I always like to choose what math problems to do	.10	.06	.67	.11	.23

Table 3. (continued)

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Do you ever feel like staying away from math class?	-.02	.04	.56	-.13	.17
Do you like being in math class?	.27	-.05	-.55	.36	.02
Do you have much fun in math class?	.36	-.11	-.51	.30	.02
I learn about math best by reading my math book	-.04	.15	-.41	.04	.36
I like to do math problems in my own way	-.23	.17	.40	.10	.05
I do not like to check my math problems	.01	-.03	.33	-.21	-.19
Other subjects are more important than math	-.04	.24	.28	.05	-.01
I am good at working math problems in my head	-.22	-.09	.14	.72	-.28
I like to work math problems in my head	-.11	.06	.09	.71	-.08
I will do well in math this year	.11	-.31	-.21	.56	-.05
I like to work math problems by myself	-.05	-.13	-.17	.51	-.11
If I find out why I made a mistake on a math problem, I usually do not miss that kind of problem again	.25	-.23	-.14	.44	.15
I want to do well in math just to show my friends	-.27	.18	-.01	.34	.31

Table 3. (continued)

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
I work harder on math problems that I know will be checked	.08	.04	.00	-.07	.56
I like to know if a math assignment will be checked	.01	.04	.08	.01	.54
I like to work my math problems with several other students	-.02	.05	.19	-.20	.50
I like to check my math problems to see which problems I missed	.17	-.19	-.17	.32	.36
I want to do well in math just for myself	-.05	-.15	.10	.19	.36
I am not good at math games	.02	.17	-.09	-.19	.33
I like to have my parents help me with my math problems	.31	-.08	.02	-.12	.33
I do not like to work alone	-.14	.07	.15	-.16	.18

Table 4. Factor Matrix for Post-Logo Attitudes and Perceptions

Item	Factor 1	Factor 2	Factor 3
My parents want me to learn Logo	.68	.26	.07
I learned a lot using Logo	.68	.21	.13
I am good at writing Logo programs	.67	-.19	.37
My teacher wants me to learn Logo	.62	-.01	-.34
I need to learn Logo	.13	.78	.00
It is very important to know Logo	.37	.72	.08
When I have a problem with Logo, I ask the teacher or aide what is wrong right away	-.18	.44	-.26
When I come to the computer I usually know what I want to do	.09	.16	.67
When I come to the computer I like to have the teacher or aide suggest something for me to do	.14	.23	-.61
I like to work on Logo by myself	.14	-.05	.58

Table 5. Factor Matrix for Post-Logo In-School Activity Preferences

Item	Factor 1	Factor 2	Factor 3
Learn a new social studies lesson	.74	-.12	.19
Work on a class assignment	.71	.09	.18
Work with my teacher by myself	.69	.22	-.15
Work on a project in a small group	.44	.39	.35
Talk to my friends	.08	.66	.21
Draw or paint a picture	.22	.64	.23
Go to recess	-.19	.62	.40
Read a book	.44	.62	-.17
Conduct a science experiment	.23	-.13	.76
Go to the gym	-.08	.29	.62
Watch a movie or filmstrip	.14	.23	.50
Do computer work other than Logo	.08	.25	.42

Table 6. Factor Matrix for Post-Logo Self-Evaluation Items

Item	Factor 1	Factor 2
Changing procedures which you have written	.76	.01
Correcting mistakes in programs	.76	-.02
Saving a procedure on a disk	.74	-.40
Finding mistakes in programs	.72	-.09
Working in the editor or writing procedures	.70	-.01
Getting a procedure back that was saved on a disk	.69	-.42
Writing procedures that use variables (SQUARE:SIDE, for example)	.51	.25
Driving the turtle around (using commands such as FD, BK, RT and LT)	.35	.68
Using the repeat command (for example Repeat 4 FD 20 RT 90)	.51	.59

APPENDIX F - RELIABILITY ESTIMATES FOR FACTORS DERIVED FROM EVALUATION INSTRUMENTS

Table 7. Reliability Estimates for In-School and Out-of-School Activity Preference Factors Derived from Pre-Logo Questionnaire

Factor and Items	Mean	S.D.	Avg. Corr.	Alpha
IN-SCHOOL ACTIVITIES				
Academic Preferences/Traditional Activities (ACDPREF)	15.58	3.15	.32	.66
Go to the media center				
Work on a class assignment				
Work with my teacher				
Learn a new social studies lesson				
Other School Activities (ACTPREF)	8.70	2.78	.34	.61
Watch a movie or filmstrip				
Conduct a science experiment				
Go to the gym				
OUT-OF-SCHOOL ACTIVITIES				
Sports Activities (OUTSPORT)	4.95	2.50	.57	.73
Go to a football, baseball or basketball game				
Play an outdoor sport such as soccer, baseball, football or basketball				
Recreational Activities (OUTSOC)	11.29	3.13	.24	.56
Play with my friends				
Ride my bicycle				
Go to a movie				
Make cookies				
Intellectual Activities (OUTACAD)	11.70	4.35	.25	.50
Do my homework				
Take a music lesson				
Read a book				

Table 8. Reliability Estimates for Factors Derived from Mathematics Inventory

Factor and Items	Mean	S.D.	Avg. Corr.	Alpha
Dependence on Teacher/Importance of Doing Well (MATHDEP)	21.17	2.83	.27	.65
I like my teacher to work few example problems before I I have to do a new problem by myself				
I like to learn math best by listening to my teacher				
My teacher really wants me to do well in math				
Getting my math problems correct is really important to me				
Do you learn a lot in math class?				
Conscientiousness/Behavior (MATHNEG)	14.20	5.13	.30	.75
I need to be reminded often to get my math assignments done				
I sometimes forget to do my math assignments				
I usually finish the easy math problems but not the hard ones				
I usually finish my math assignments[1]				
I sometimes lose my books and papers				
I get into trouble in school about once every week				
My math teacher last year yelled at me a lot				

Table 8. (continued)

Factor and Items	Mean	S.D.	Avg. Corr.	Alpha
Achievement/Learning Styles (MATHIND)	13.90	2.99	.34	.67
I will do well in math this year				
I am good at working math problems in my head				
I like to work math problems by myself				
I like to work math problems in my head				
Choice/Like Math (MATHBOR)	13.40	3.7	.31	.69
I always like to choose what math problems to do				
I like to be able to choose what our class does in math				
Do you like being in math class?				
Do you ever feel like staying away from math class?				

[1] Recoded (5=1)(4=2)(3=3)(2=4)(1=5)

Table 9. Reliability Estimates for Factors Derived from Post-Logo Questionnaire

Factor and Items	Mean	S.D.	Avg. Corr.	Alpha
Importance of Learning Logo (LOGIMP)	5.41	2.00	.46	.63
I need to learn Logo				
It is very important to know Logo				
Traditional School Activities (ACAPRE2)	14.84	3.55	.31	.64
Go to the media center				
Work on a class assignment				
Work with my teacher by myself				
Learn a new social studies lesson				
Other School Activities (ACTPRE2)	7.46	2.75	.26	.52
Watch a movie or filmstrip				
Conduct a science experiment				
Go to the gym				
Social/Solitary Activities (SOCPRE2)	11.03	3.54	.33	.67
Draw or paint a picture				
Go to recess				
Read a book				
Talk to my friends				
Evaluation of Logo Skills (LOGEVAL)	27.93	6.75	.41	.85
I am good at writing Logo programs				
I learned a lot using Logo				
Working in the editor or writing procedures				
Changing procedures which you have written				
Finding mistakes in programs				
Correcting mistakes in programs				
Saving a procedure on a disk				
Getting a procedure back that was saved on a disk				

APPENDIX G - IDENTIFICATION OF INDICATORS USED IN THE CAUSAL MODEL

Indicator and (Abbreviation)	Item(s)
DEMOGRAPHIC VARIABLES	
Sex	
Grade in School	
ENTRY CHARACTERISTICS (BLOCK 1)	
Mathematics Indicators	
ITBS Mathematics Score (ITBS)	Total mathematics score on ITBS
Dependence on Mathematics Teacher Importance of Doing Well (MATHDEP)	I like my teacher to work a few example problems before I have to do a new problem myself I like to learn math best by listening to my teacher My teacher really wants me to do well in math Getting my math problems correct is really important to me Do you learn a lot in math class?
Mathematics Conscientiousness/ Behavior (MATHNEG)	I need to be reminded often to get my math assignment done I sometimes forget to do my math assignments I usually finish the easy math problems but not the hard ones I usually finish my math assignments[1] I sometimes lose my books and papers I get into trouble in school about once every week My math teacher last year yelled at me a lot
Achievement/Learning Styles (MATHIND)	I will do well in math this year I am good at working math problems in my head I like to work math problems by myself I like to work math problems in my head

Indicator and (Abbreviation)	Item(s)
Choice/Like Mathematics (MATHBOR)	I always like to choose what math problems to do I like to be able to choose what our class does in math Do you like being in math class?[1] Do you have much fun in math class?[1] Do you ever feel like staying away from math class?
Pre-Logo Computer Experience	
In-School Computer Experience (NUMGRAD)	In what grades have you used the computer (prior to grade 4)?
Home Ownership of Computer (FAMOWN)	Does your family own a computer?
Academic Activities (ACADACT)	Using the computer for math problems Using the computer for social studies Using the computer for science Using the computer for spelling
Programming Activities (PROGACT)	Computer programming Logo
Simulation Activities (SIMACT)	Oregon Trail Lemonade Stand
Game Activities (GAMEACT)	Space Invaders Other space games Hangman Other word games Pac Man or Snack Attack Frogger Eamon Dragons Sports games Other games
Activity Preferences	
Favorite School Subject (FAVSUBJ)	Name your favorite school subject (science and mathematics were assigned values of 1; other subjects were assigned 0)

Indicator and (Abbreviation)	Item(s)
Traditional School Activities (ACDPREF)	Go to the media center Work on a class assignment Work with my teacher Learn a new social studies lesson
Other School Activities (ACTPREF)	Watch a movie or filmstrip Conduct a science experiment Go to the gym
Talking to friends (PREF5)	Talk to my friends
Out-of-School Sports Activities (OUTSPORT)	Go to a football, baseball or basketball game Play an outdoor sport such as soccer, baseball, football or basketball
Out-of-School Recreational Activities (OUTSOC)	Play with my friends Ride my bicycle Go to a movie Make cookies
Out-of-School Intellectual Activities (OUTACAD)	Do my homework Take a music lesson Read a book
POST-LOGO ATTITUDES AND PERCEPTIONS (BLOCK 2)	
Difficulty in learning Logo (DIFFIC)	Would you say that Logo was. . .very hard to learn. . .very easy to learn?
Preference of Draw or Edit Mode (MODE)	Which of the following ways do you like to work with Logo? Working right on the screen Working in the editor (writing procedures)
Importance of Learning Logo (LOGIMP)	I need to learn Logo It is very important to know Logo

Indicator and (Abbreviation)	Item(s)
Working Independently (LOGO2)	I like to work on Logo by myself
Parents' Expectations (LOGO8)	My parents want me to learn Logo
Teacher's Expectations (LOGO10)	My teacher wants me to learn Logo
Traditional School Activities (ACAPRE2)	Go to the media center Work on a class assignment Work with my teacher by myself Learn a new social studies lesson
Other School Activities (ACTPRE2)	Watch a movie or filmstrip Conduct a science experiment Go to the gym
Social/Solitary Activities (SOCPRE2)	Draw or paint a picture Go to recess Read a book Talk to my friends
SELF-EVALUATION (BLOCK 3)	
Knowledge of Logo Primitives (EVAL1)	Driving the turtle around
Evaluation of Logo Skills (LOGEVAL)	I am good at writing Logo programs I learned a lot using Logo Working in the editor or writing procedures Changing procedures which you have written Finding mistakes in programs Correcting mistakes in programs Saving a procedure on a disk Getting a procedure back that was saved on a disk
PERFORMANCE ON OBJECTIVE TEST (BLOCK 4)	
Final Score (TESTTOT)	Final score on objective test on Logo

[1]Item recoded as follows: 5=1, 4=2, 3=3, 2=4, 1=5

APPENDIX H - ZERO-ORDER CORRELATIONS

Table 10. Zero-order Correlation Coefficients for Indicators in Matched Model

Indicator	SEX	DUM1	DUM2	DUM4	DUM5	FAMOWN	NUMGRAD	ACADACT	PROGACT	SIMACT	GAMEACT	ACDPREF	ACTPREF	PREFS	OUTSPORT	OUTSOC	OUTACAD
SEX	--	-.06	-.04	.12	.23**												
FAMOWN	.16*	-.03	.09	-.04	.14*	--											
NUMGRAD	.10	.41**	-.25**	.43**	-.21**	.11	--										
ACADACT	.05	-.04	.08	-.02	.05	.20**	.06	--									
PROGACT	.14*	.24**	-.17*	.27**	-.12**	.20**	.01	.16*	--								
SIMACT	.21**	-.10	-.16*	-.04	-.10	.26**	.01	.27**	.24**	--							
GAMEACT	.10	-.06	-.14	-.02	-.11	.36**	.02	.36**	.20**	.38**	--						
ACDPREF	.10	.05	-.16*	.04	-.11	.05	.13	-.03	.17*	.06	.11	--					
ACTPREF	-.15*	.12	-.08	.06	-.10	.06	-.03	-.08	.14	.05	.03	.37**	--				
PREFS	.16*	.07	.06	.05	.10	.08	-.02	.11	.01	-.09	-.02	.16	.23**	--			
OUTSPORT	-.34**	.10	.07	.02	-.02	.00	-.14	-.15*	.13	-.12	-.19**	.11	.39**	.02	--		
OUTSOC	.20**	.07	.06	.10	-.09	.10	-.02	.04	.08	-.12	-.04	.16*	.41**	.39**	.12	--	
OUTACAD	.24**	.05	-.10	.13	-.06	.10	.09	-.01	.17*	.05	.13	.51**	.27**	.13	-.01	.30**	--
FAVSUBJ	.08	.05	.08	.06	.10	.14*	-.02	.17*	-.02	-.01	-.01	.01	-.08	.14*	-.11	.13	.02
MATHDEP	-.09	.23**	-.07	.22**	-.08	-.01	-.12	.16*	.09	-.04	.00	-.09	-.05	.11	.01	.09	.01
MATHNEG	.06	-.21**	.19**	-.20**	.16*	-.12	-.16*	.00	-.18**	-.21	-.01	-.04	-.10	-.01	.11	-.06	.01
MATHIND	.23**	.07	-.22**	.16*	-.15*	.07	.06	.10	.13	.16	.14	.04	.00	.08	-.14	.12	.01
MATHBOR	.15*	.03	-.09	.10	-.03	-.07	.14	-.07	.03	.02	.07	.19	-.10	-.24**	.06	-.12	.19**
MODE	.16*	-.12	.06	-.07	.08	.11	.00	.10	.24**	.08	.09	.10	.04	.12	.02	.16*	.07
DIFFIC	-.15*	.01	-.04	.02	-.07	-.22**	.13	-.20**	-.26**	-.14	-.12	-.05	-.17*	-.17*	.14	-.24**	-.13
ACAPRE2	.00	.05	.05	.04	.06	-.11	.02	-.01	.11	-.10	-.06	.37**	.13	-.04	.10	.02	.28**
SOCPRE2	.00	-.05	.09	-.04	.07	-.10	.02	.03	.01	-.09	-.05	.16*	.14*	.22**	.15*	.15*	.11
ACTPRE2	-.32**	.00	.11	-.08	.05	-.05	-.04	-.20	-.02	-.02	.00	.06	.35**	.06	.30**	.06	-.05
LOGO2	-.01	.07	-.22**	.03	-.19**	-.08	-.04	.08	.17*	-.01	-.05	.01	-.10	.07	.09	.06	.05
LOGO8	.05	-.16*	.09	-.14	.12	.10	-.08	-.08	.13	.08	.10	.08	-.06	.11	.09	.03	-.07
LOGO10	.07	-.26**	.17*	-.23**	.17*	-.06	-.04	.03	-.11	.01	-.08	-.12	-.17*	-.03	-.17*	-.05	-.16*
LOGIMP	-.03	-.10	.04	-.13	.05	-.03	-.08	.04	.08	.01	.03	.07	.03	.02	.06	.05	-.08
EVAL1	.12	-.01	-.08	.03	-.02	.14	.02	.18*	.14	.10	.11	.05	.02	.06	.10	.14*	.05
LOGEVAL	.14	-.03	.04	.00	.09	.22**	.05	.36**	.28**	.19**	.23**	.05	.06	.23**	.00	.18*	.10
TESTTOT	.13	-.09	-.02	-.06	.02	.12	.04	-.12	.28**	.18*	.05	.14	.23**	.07	.05	.18*	.04

Table 10. (continued)

Indicator	FAVSUBJ	MATHDEP	MATHNEG	MATHIND	MATHBOR	MODE	DIFFIC	ACAPRE2	SOCPRE2	ACTPRE2	LOGO2	LOGO8	LOGO10	LOGIMP	EVAL1	LOGEVAL	TESTTOT
SEX																	
FAMOWN																	
NUMGRAD																	
ACADACT																	
PROGACT																	
SIMACT																	
GAMEACT																	
ACDPREF																	
ACTPREF																	
PREF5																	
OUTSPORT																	
OUTSOC																	
OUTACAD																	
FAVSUBJ	--																
MATHDEP	.07	--															
MATHNEG	-.09	-.15	--														
MATHIND	.17*	-.07	-.31**	--													
MATHBOR	-.17*	-.20**	.29**	-.14	--												
MODE	.00	.07	-.01	.04	.07	--											
DIFFIC	-.01	-.07	.12	-.12	.10	-.18	--										
ACAPRE2	-.04	-.09	.07	-.05	.21**	.06	-.04	--									
SOCPRE2	.03	-.03	.02	-.06	-.06	.25**	-.16*	.41**	--								
ACTPRE2	-.01	-.06	-.04	-.06	-.02	.05	.03	.30**	.36**	--							
LOGO2	-.08	.10	.07	.07	.16*	.10	-.10	.08	.10	-.05	--						
LOGO8	.00	.13	-.04	.01	.02	.18**	-.15*	.03	.12	.05	.08	--					
LOGO10	.01	-.05	.15*	.04	-.02	.00	.10	-.12	-.06	-.12	.01	.11	--				
LOGIMP	-.03	.08	.04	-.16*	-.05	.06	.01	.08	.08	.14	.06	.37**	.15*	--			
EVAL1	.05	.20**	-.17*	.21**	-.02	.06	-.23**	.01	.13	-.03	.18*	.21**	-.04	.04	--		
LOGEVAL	.01	.14	-.13	.14	-.05	.49**	-.38**	.01	.31**	-.04	.18**	.27**	.11	.10	.23**	--	
TESTTOT	-.09	-.17*	-.12	.22**	-.02	.33**	-.08	.08	.18*	.15*	.17*	.03	.12	.08	.20**	.32**	--

Note. $n = 193$

** $p < .01$
* $p < .05$

Table 11. Zero-order Correlation Coefficients for Indicators in Post-Logo Model

Indicator	SEX	DUM1	DUM2	DUM4	DUM5	MODE	DIFFIC	ACAPRE2	SOCPRE2	ACTPRE2	LOGO2	LOGO8	LOGO10	LOGIMP	EVAL1	LOGEVAL	TESTTOT
SEX	--	-.05	-.01	.14**	.23**												
MODE	.14**	-.05	-.01	-.03	.02	--											
DIFFIC	-.20**	-.07	-.02	-.09	-.06	-.14**	--										
ACAPRE2	.01	-.04	.09	-.03	.11*	.07	-.02	--									
SOCPRE2	.11*	.00	.06	.03	.10	.21**	-.12*	.32**	--								
ACTPRE2	-.24**	-.09	.12*	-.16**	.08	.04	.04	.26**	.38**	--							
LOGO2	.07	.06	-.13*	.07	-.10	.14*	-.16**	.11*	.13*	.00	--						
LOGO8	.08	.05	-.15**	-.11	.05	-.21	-.08	.07	.12*	.08	.07	--					
LOGO10	.02	.05	-.18**	-.15**	.05	.07	.12*	-.04	-.05	-.09	.00	.22**	--				
LOGIMP	-.02	-.08	.01	-.08	.01	.04	.00	.05	.10	.16**	.01	.39**	.16**	--			
EVAL1	.11*	-.03	-.06	-.02	.00	.08	-.18**	.00	.11*	-.01	.15	.27**	.10	.04	--		
LOGEVAL	.18**	-.02	.01	.02	.06	.46**	-.35**	.00	.24**	.00	.24**	.34**	.18**	.12*	.26**	--	
TESTTOT	.11*	-.18**	-.08	-.13*	-.05	.34**	-.08	.08	.14*	.13*	.22**	.14**	.18**	.08	.19**	.38**	--

Note. n=338.

*$p < .05$
**$p < .01$

APPENDIX I - PATH ANALYSIS RESULTS FOR MATCHED MODEL

Table 12. Means and Standard Deviations for Indicators in Matched Model

Indicator	Mean	Standard Deviation
Exogenous Variables		
SEX	1.513	0.501
DUM1 (Grade 4 vs. 6)	0.249	0.433
DUM2 (Grade 5 vs. 6)	0.425	0.496
DUM4 (Grade 4 vs. 6 x Sex)	0.363	0.679
DUM5 (Grade 5 vs. 6 x Sex)	0.632	0.806
Block 1: Pre-Logo Attitudes and Experiences		
MATHDEP	4.239	0.548
MATHNEG	2.017	0.767
MATHIND	3.496	0.719
MATHBOR	2.673	0.750
FAMOWN	0.508	0.501
NUMGRAD	0.642	0.772
ACADACT	2.135	1.226
PROGACT	0.290	0.558
SIMACT	0.891	0.717
GAMEACT	5.119	1.794
ACDPREF	3.861	0.807
ACTPREF	2.924	0.899
PREF5	2.689	1.193
OUTSPORT	2.469	1.222
OUTSOC	2.846	0.780
OUTACAD	3.877	0.835
FAVSUBJ	0.627	0.485
Block 2: Post-Logo Attitudes and Perceptions		
MODE	0.539	0.500
DIFFIC	2.446	0.841
LOGIMP	2.632	0.969
LOGO2	3.482	1.191
LOGO8	2.948	1.045
LOGO10	3.674	1.076
ACAPRE2	3.696	0.858
SOCPRE2	2.785	0.888
ACTPRE2	2.571	0.953
Block 3: Self-Evaluation of Logo Skills		
EVAL1	4.290	0.883
LOGEVAL	3.230	0.851
Block 4: Score on Objective Test		
TESTTOT	12.466	3.647

Note. *n* = 193.

Table 13. Reduced Path Model for Matched Group
Partial Regression Coefficients (Standard and Non-Standard)
and Variance Explained for Score on Objective Test (TESTTOT)

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Partial Regression Coefficient Non-standard	Variance Explained R^2
TESTTOT	LOGEVAL	.249	1.069**	.103
	MODE	.168	1.228*	.143
	ACTPRE2	.170	.649**	.166
	MATHIND	.172	.873**	.205
	MATHDEP	-.171	-1.139**	.235
	PROGACT	.187	1.222**	.262
	ACADACT	-.157	-.468*	.283

* $p < .05$.

** $p < .01$.

Table 14. Reduced Path Model for Matched Group
Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Self-evaluation of Logo Skills (LOGEVAL)

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Non-standard	Variance Explained R^2
LOGEVAL	MODE	.353	.600**	.239
	DIFFIC	-.205	-.207**	.329
	SOCPRE2	.239	.229**	.355
	LOGO10	.125	.099*	.377
	LOGO8	.101	.083	.391
	ACTPRE2	-.157	-.140**	.404
	ACADACT	.272	.189**	.472
	MATHNEG	-.124	-.138*	.487

* $p < .05$.

** $p < .01$.

Table 15. Reduced Path Model for Matched Group
Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Block 2 Indicators: Attitudes and Perceptions of Logo

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Non-standard	Variance Explained R^2
MODE	PROGACT	.273	.245**	.057
	OUTSOC	.150	.096*	.077
	DUM1	-.193	-.222**	.112
DIFFIC	PROGACT	-.189	-.285**	.065
	OUTSOC	-.198	-.214**	.113
	ACADACT	-.142	-.097*	.137
	NUMGRAD	.149	.162*	.155
	FAMOWN	-.148	-.248*	.175
ACTPRE2	ACTPREF	.287	.304**	.125
	OUTSPORT	.098	.077	.157
	SEX	-.279	-.530**	.209
	DUM5 (Grade x Sex)	.142	.168*	.228
SOCPRE2	PREF5	.216	.158**	.047
	OUTSPORT	.149	.108*	.069
LOGO8	DUM1 (Grade)	-.155	-.375*	.024
LOGO10	ACTPREF	-.144	-.172*	.031
	DUM1 (Grade)	-.243	-.604**	.088

* $p < .05$.

** $p < .01$.

Table 16. Reduced Path Model for Matched Group
Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Block 1 Indicators:
Pre-Logo Attitudes and Experiences

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Partial Regression Coefficient Non-standard	Variance Explained R^2
MATHIND	SEX	.224	.321**	.054
	DUM2 (Grade 5 vs 6)	-.216	-.313**	.100
MATHDEP	DUM1 (Grade 4 vs 6)	.229	.289**	.052
MATHNEG	DUM1 (Grade 4 vs 6)	-.208	-.368**	.043
FAMOWN	SEX	.160	.160*	.026
NUMGRAD	DUM4 (Grade x Sex)	.427	.486**	.183
ACADACT	--	--	--	--
PROGACT	DUM4 (Grade x Sex)	.271	.222**	.073
ACTPREF	SEX	-.152	-.273*	.023
OUTSPORT	SEX	-.339	-.828**	.115
OUTSOC	SEX	.200	.311**	.040

* $p < .05$.
** $p < .01$.

Table 17. Zero-order Correlations of Dummy Variables in Matched Model with Final Test Score

Indicator	Correlation (r)
DUM1 (Grade 4 vs. 6)	-.087
DUM2 (Grade 5 vs. 6)	-.018
DUM4 (Grade 4 vs. 6x Sex)	-.060
DUM5 (Grade 5 vs. 6 x Sex)	-.016
DUM6 (School 1 vs. 2)	.081
DUM8 (School 1 vs. 2 x Grade 4 vs. 6)	.116
DUM10 (School 1 vs. 2 x Grade 5 vs. 6)	-.010
DUM12 (School 1 vs. 2 x Sex)	.119
DUM46 (MATHIND x Grade 4 vs. 6)	-.075
DUM47 (MATHIND x Grade 5 vs. 6)	.031
DUM48 (MATHIND x School 1 vs. 2)	.114
DUM49 (MATHDEP x Grade 4 vs. 6)	-.113
DUM50 (MATHDEP x Grade 5 vs. 6)	-.020
DUM51 (MATHDEP x School 1 vs. 2)	.058
DUM58 (MATHNEG x Grade 4 vs. 6)	.083
DUM59 (MATHNEG x Grade 5 vs. 6)	-.075
DUM60 (MATHNEG x School 1 vs. 2)	.044
DUM52 (PROGACT x Grade 4 vs. 6)	.057
DUM53 (PROGACT x Grade 5 vs. 6)	.183*
DUM54 (PROGACT x School 1 vs. 2)	.284**
DUM55 (ACADACT x Grade 4 vs. 6)	-.107
DUM56 (ACADACT x Grade 5 vs. 6)	-.007
DUM57 (ACADACT x School 1 vs. 2)	-.007
DUM22 (LOGO10 x Grade 4 vs. 6)	-.025
DUM23 (LOGO10 x Grade 5 vs. 6)	-.037
DUM24 (LOGO10 x School 1 vs. 2)	.075
DUM26 (MODE x Grade 4 vs. 6)	.051
DUM27 (MODE x Grade 5 vs. 6)	.133
DUM28 (MODE x School 1 vs. 2)	.299**
DUM30 (ACTPRE2 x Grade 4 vs. 6)	-.042
DUM31 (ACTPRE2 x Grade 5 vs. 6)	.025
DUM32 (ACTPRE2 x School 1 vs. 2)	.132
DUM38 (DIFFIC x Grade 4 vs. 6)	-.069
DUM39 (DIFFIC x Grade 5 vs. 6)	-.002
DUM40 (DIFFIC x School 1 vs. 2)	-.010
DUM14 (LOGEVAL x Grade 4 vs. 6)	-.047
DUM15 (LOGEVAL x Grade 5 vs. 6)	.044
DUM16 (LOGEVAL x School 1 vs. 2)	-.168*

Note. $n = 193$.
* $p < .05$.
** $p < .01$.

Table 18. Reduced Path Model for Matched Group with Addition of Dummy Variables Representing School and Grade
Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Score on Objective Test (TESTTOT)

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Partial Regression Coefficient Non-standard	Variance Explained R^2
TESTTOT	LOGEVAL	.249	1.069**	.103
	MODE	.168	1.228*	.143
	ACTPRE2	.170	.649**	.166
	MATHIND	.172	.873**	.205
	MATHDEP	-.171	-1.139**	.235
	PROGACT	.187	1.222**	.262
	ACADACT	-.157	-.468*	.283
	DUM26 (MODE x Grade 4 vs. 6)	-.801	-1.830*	.303

Note. *n* = 196.

* $p < .05$.
** $p < .01$.

Table 19. Means and Standard Deviations for Indicators in Matched Model with Addition of ITBS Total Mathematics Score

Indicator	Mean	Standard Deviation
Exogenous Variables		
SEX	1.477	0.501
DUM1 (Grade 4 vs. 6)	0.349	0.479
DUM2 (Grade 5 vs. 6)	0.373	0.486
DUM4 (Grade 4 vs. 6 x Sex)	0.352	0.662
DUM5 (Grade 5 vs. 6 x Sex)	0.632	0.806
Block 1: Pre-Logo Attitudes and Experiences		
ITBS	60.230	25.747
MATHDEP	4.223	0.563
MATHNEG	2.062	0.782
MATHIND	3.452	0.735
MATHBOR	2.724	0.775
FAMOWN	0.500	0.502
NUMGRAD	0.754	0.807
ACADACT	2.214	1.324
PROGACT	0.325	0.604
SIMACT	0.881	0.688
GAMEACT	5.024	1.852
ACDPREF	3.921	0.760
ACTPREF	2.942	0.921
PREF5	2.651	1.155
OUTSPORT	2.425	1.217
OUTSOC	2.881	0.772
OUTACAD	3.966	0.846
FAVSUBJ	0.643	0.481
Block 2: Post-Logo Attitudes and Perceptions		
MODE	0.540	0.500
DIFFIC	2.389	0.867
LOGIMP	2.611	0.994
LOGO2	3.540	1.224
LOGO8	2.794	1.061
LOGO10	3.492	1.144
ACAPRE2	3.679	0.862
SOCPRE2	2.743	0.883
ACTPRE2	2.586	0.977
Block 3: Self-Evaluation		
EVAL1	4.270	0.862
LOGEVAL	3.126	0.830
Block 4: Score on Objective Test		
TESTTOT	12.048	3.496

Note. *n* = 126.

Table 20. Matched Model with Addition of ITBS Total Mathematics Score: Zero-order Correlations with Score on the Objective Test (TESTTOT) and Self-evaluation of Logo Skills (LOGEVAL)

Indicator	TESTTOT	LOGEVAL	ITBS
Exogenous Variables			
SEX	.073	.144	.058
DUM1 (Grade 4 vs. 6)	.004	.059	.235**
DUM2 (Grade 5 vs. 6)	-.110	-.049	-.100**
DUM4 (Grade 4 vs. 6 x Sex)	.056	.076	.265
DUM5 (Grade 5 vs. 6 x Sex)	-.105	-.017	-.093
Block 1: Pre-Logo Attitudes and Experiences			
MATHDEP	-.121	.159	-.064
MATHNEG	-.038	-.048	.335**
MATHIND	.122	.127	.381**
MATHBOR	-.031	-.076	-.195*
FAMOWN	.046	.212**	.151
NUMGRAD	.115	.055	.191*
ACADACT	.006	.381**	.070
PROGACT	.341**	.274**	.290**
SIMACT	.242**	.215*	.307**
GAMEACT	.055	.301**	.044
ACDPREF	.127	-.022	.001
ACTPREF	.278**	.066	.045
PREF5	.020	.267**	-.026
OUTSPORT	.040	.030	.022
OUTSOC	.144	.248**	.024
OUTACAD	.112	.178*	-.106
FAVSUBJ	-.085	.057	.117
Block 2: Post-Logo Attitudes and Perceptions			
MODE	.305**	.484**	.156
DIFFIC	-.009	-.446**	-.045
LOGIMP	.039	.114	-.156
LOGO2	.207*	.161	-.078
LOGO8	-.004	.292**	-.013
LOGO10	.092	.092	-.127
ACAPRE2	.038	-.145	.020
SOCPRE2	.203*	.310**	.004
ACTPRE2	.147	-.028	.129
Block 3: Self-Evaluation			
LOGEVAL	.304**	--	-.030
EVAL1	.229**	.328**	.095
TESTTOT	--	.304**	.388**

Note. $n = 126$.
* $p < .05$.
** $p < .01$.

Table 21. Reduced Path Model for Matched Group with Addition of ITBS Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Score on Objective Test (TESTTOT) and Self-evaluation of Logo Skills (LOGEVAL)

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Partial Regression Coefficient Non-standard	Variance Explained R^2
TESTTOT	LOGEVAL	.212	.892*	.092
	MODE	.148	1.037	.125
	LOGO2	.239	.682**	.159
	ITBS	.369	.050**	.303
	ACTPREF	.256	.970**	.369
	MATHDEP	-.152	-.944*	.392
LOGEVAL	MODE	.393	.651**	.234
	DIFFIC	-.268	-.257**	.358
	LOGO2	.230	.156**	.387
	LOGO10	.115	.083	.408
	ACADACT	.223	.140**	.460
	PREF5	.190	.137**	.493

Note. *n* = 126.

* $p < .05$.

** $p < .01$.

APPENDIX J - PATH ANALYSIS RESULTS FOR POST-LOGO MODEL

Table 22. Means and Standard Deviations for Indicators in Post-Logo Model

Indicator	Mean	Standard Deviation
Exogenous Variables		
SEX	1.512	.501
DUM1 (Grade 4 vs. 6)	.266	.443
DUM2 (Grade 5 vs. 6)	.382	.487
DUM4 (Grade 4 vs. 6 x Sex)	.391	.699
DUM5 (Grade 5 vs. 6 x Sex)	.574	.794
Post-Logo Attitudes and Perceptions		
MODE	.621	.486
DIFFIC	2.420	.820
LOGIMP	2.663	.987
LOGO2	3.503	1.224
LOGO8	3.133	1.099
LOGO10	3.911	1.075
ACAPRE2	3.727	.885
SOCPRE2	2.767	.890
ACTPRE2	2.565	.907
Self-Evaluation of Logo Skills		
EVAL1	4.470	.775
LOGEVAL	3.410	.853
Score on Objective Test		
TESTTOT	12.917	3.668

Note. *n* = 338.

Table 23. Reduced Path Model for Post-Logo Group
Partial Regression Coefficients (Standard and Non-Standard)
and Variance Explained for Score on Objective Test (TESTTOT)

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Non-standard	Variance Explained R^2
TESTTOT	LOGEVAL	.246	1.056**	.143
	MODE	.178	1.346*	.176
	ACTPRE2	.137	.555**	.192
	LOGO10	.109	.371*	.209
	LOGO2	.120	.361*	.225
	DUM1	-.237	-1.957**	.247
	DUM2	-.204	-1.539**	.276
LOGEVAL	MODE	.330	.579**	.211
	DIFFIC	-.271	-.282**	.293
	LOGO8	.193	.150**	.347
	LOGO10	.151	.120**	.368
	LOGO2	.128	.089**	.385
	SOCPRE2	.106	.101*	.395

Note. *n* = 338.
* $p < .05$.

** $p < .01$.

Table 24. Reduced Path Model for Post-Logo Group
Partial Regression Coefficients (Standard and Non-Standard) and Variance Explained for Block 2 Indicators: Attitudes and Perceptions of Logo

Dependent Variable	Independent Variable	Partial Regression Coefficient Standard	Non-standard	Variance Explained R^2
MODE	SEX	.141	.136**	.020
DIFFIC	SEX	-.200	-.328**	.040
LOGO2	DUM2 (Grade 5 vs 6)	-.129	-.324**	.017
LOGO8	DUM1 (Grade 4 vs 6)	-.146	-.363**	.021
LOGO10	DUM1 (Grade 4 vs 6)	-.174	-.424**	.031
ACAPRE2		--	--	--
SOCPRE2	SEX	.108	.192*	.012
ACTPRE2	SEX	-.277	-.501**	.060
	DUM5 (4 vs 6 x Sex)	.140	.160**	.079

Note. *n*=336.
* *p* < .05.

** *p* < .01.

APPENDIX K - GENDER DIFFERENCES ANALYSIS FOR MATCHED MODEL

Table 25. Number (N), Mean and Value of t-test for Males and Females on Indicators in Matched Model

Indicator	Female N	Female Mean	Male N	Male Mean	t-Value
Mathematics Scores					
ITBS Mathematics Score	76	59.30	81	55.78	0.92
Dependence on Teacher/ Importance of Doing Well	114	4.22	125	4.24	-0.37
Conscientiousness/Behavior	114	2.03	125	2.10	-0.73
Achievement/Learning Styles	114	3.35	125	3.58	-2.54*
Choice/Like Mathematics	114	2.58	125	2.79	-2.11*
Computer Experience Prior to Logo					
In-school Computer Experience (Number of Grades)	114	0.56	125	0.74	-1.76
Home Ownership of Computer	111	0.44	121	0.58	-2.10*
Computer Applications					
Academic Activities	113	2.03	121	2.07	-0.25
Computer Programming	113	0.27	121	0.34	-1.14
Simulations	113	0.78	121	1.06	-3.02**
Games	113	4.99	121	5.29	-1.25
In-School Activity Preferences					
Favorite Subject	111	0.54	115	0.64	-1.58
Traditional School Activities	113	3.78	117	3.98	-1.83
Other School Activities	113	3.04	117	2.81	1.85
Talk to my Friends	113	2.49	116	2.94	-2.82**
Out-School Activity Preferences					
Sports Activities	113	2.88	118	2.06	5.23**
Recreational Activities	113	2.66	118	2.94	-2.55*
Intellectual Activities	113	3.67	118	4.04	-3.42**

Table 25. (continued)

Indicator	Female N	Female Mean	Male N	Male Mean	t-Value
Post-Logo Attitudes					
Difficulty in Learning Logo	110	2.58	122	2.30	2.62**
Preference of Draw or Edit Mode	106	0.45	119	0.63	-2.70**
I like to work on Logo by myself	109	3.50	122	3.45	0.28
My parents want me to learn Logo	108	2.94	121	2.98	-0.35
My teacher wants me to learn Logo	110	3.65	120	3.72	-0.49
Importance of Learning Logo	110	2.62	122	2.54	0.65
Activity Preferences					
Traditional School Activities	110	3.66	121	3.70	-0.34
Other School Activities	110	2.90	121	2.26	5.46**
Social/Solitary Activities	110	2.73	121	2.65	-0.31
Self-Evaluation					
Knowledge of Primitives	106	4.20	121	4.39	-1.66
Evaluation of Logo Skills	110	3.08	122	3.31	-2.01*
Score on Objective Test	113	11.92	124	12.74	-1.78

* $p < .05$.
** $p < .01$.

Table 26. Means by Grade Level and Gender for Indicators in Matched Model with Significant Gender Differences

Indicator	Grade 4 N	Grade 4 Mean	Grade 5 N	Grade 5 Mean	Grade 6 N	Grade 6 Mean
Mathematics Attitudes						
Achievement/Learning Styles						
Female	28	3.25	46	3.16	35	3.61
Male	26	3.93	46	3.45	48	3.51
Choice/Like Mathematics						
Female	28	2.43	46	2.44	35	2.87
Male	26	2.94	46	2.71	48	2.75
Computer Experience Prior to Logo						
Home Ownership of Computer						
Female	25	0.48	29	0.34	20	0.30
Male	25	0.52	25	0.68	27	0.63
Simulations						
Female	29	0.59	48	0.65	36	1.11
Male	27	1.04	43	0.91	46	1.24
In-School Activity Preferences						
Talk to my friends						
Female	29	2.90	48	2.60	36	2.00
Male	27	3.04	43	3.02	46	2.80
Out-School Activity Preferences						
Sports Activities						
Female	29	3.05	47	2.99	35	2.60
Male	27	2.07	44	2.09	42	1.93
Recreational Activities						
Female	29	2.84	47	2.73	35	2.46
Male	27	2.97	44	2.95	42	2.89
Intellectual Activities						
Female	29	3.63	47	3.64	35	3.73
Male	27	4.33	44	3.89	42	4.03

Table 26. (continued)

Indicator	Grade 4 N	Grade 4 Mean	Grade 5 N	Grade 5 Mean	Grade 6 N	Grade 6 Mean
Post-Logo Attitudes						
Difficulty in Learning Logo						
Female	28	2.39	45	2.56	33	2.79
Male	26	2.42	45	2.31	47	2.23
Preference of Draw or Edit Mode						
Female	28	0.36	45	0.51	33	0.45
Male	26	0.54	45	0.64	47	0.66
Activity Preferences						
Other School Activities						
Female	28	2.95	45	2.87	33	2.84
Male	26	2.04	45	2.56	47	2.16
Self-Evaluation						
Evaluation of Logo Skills						
Female	27	3.08	45	3.09	31	3.11
Male	25	3.36	45	3.39	49	3.20

Table 27. F-Ratios for ANOVAs by Source for Indicators in Matched Model with Significant Gender Differences: Pre-Logo Indicators

Indicator	Source: Sex	Grade	Sex x Grade	Scheffé[1]
Mathematics Attitudes				
Achievement/Learning Styles	4.90**	7.17**	3.54	5 vs. 6
Choice/Like Mathematics	3.61	1.77	3.08	
Computer Experience Prior to Logo				
Home Ownership of Computer	8.56	0.08	1.48	
Simulations	8.39**	8.18*	0.39	6 vs. 4,5
In-School Activity Preferences				
Talk to my friends	9.43**	4.06*	0.27	4 vs. 6
Out-School Activity Preferences				
Sports Activities	28.27**	1.41	0.32	
Recreational Activities	6.08*	1.39	0.58	
Intellectual Activities	11.79**	1.16	0.24	
Post-Logo Attitudes				
Difficulty in Learning Logo	6.86**	0.19	2.08	
Preference of Draw or Edit Mode	6.57*	1.27*	0.11	
Activity Preferences				
Other School Activities	24.76**	1.66	2.08	
Self-Evaluation				
Evaluation of Logo Skills	3.58*	0.29	0.36	

[1]Significant at $p < .05$.

* $p < .05$.
** $p < .01$.

APPENDIX L - GENDER DIFFERENCES ANALYSIS FOR POST-LOGO MODEL

Table 28. Number (N), Mean and Value of t-test for Males and Females for Indicators in Post-Logo Model

Indicator	Female N	Female Mean	Male N	Male Mean	t-Value
Post-Logo Attitudes					
Difficulty in Learning Logo	181	2.58	188	2.27	3.76**
Preference of Draw or Edit Mode	177	0.54	188	0.68	-2.69**
I like to work on Logo by myself	180	3.43	187	3.59	-1.26
My parents want me to learn Logo	178	3.07	186	3.20	-1.14
My teacher wants me to learn Logo	181	3.92	185	3.94	-0.11
Importance of Learning Logo	181	2.65	187	2.63	0.18
Activity Preferences					
Traditional School Activities	181	3.68	186	3.72	-0.43
Other School Activities	181	2.76	186	2.34	4.54**
Social/Solitary Activities	181	2.65	186	2.84	-2.11*
Self-Evaluation					
Knowledge of Primitives	176	4.38	186	4.55	-2.12*
Evaluation of Logo Skills	181	3.24	187	3.54	-3.40**
Score on Objective Test	182	12.34	188	13.26	-2.37*

* $p < .05$.
** $p < .01$.

Table 29. Means by Grade Level and Gender for Indicators in Post-Logo Model with Significant Gender Differences

Indicator	Grade 4 N	Grade 4 Mean	Grade 5 N	Grade 5 Mean	Grade 6 N	Grade 6 Mean
Difficulty in Learning Logo						
Female	51	2.57	65	2.54	58	2.78
Male	44	2.20	68	2.24	68	2.31
Preference of Draw or Edit Mode						
Female	51	0.51	65	0.55	58	0.57
Male	44	0.64	68	0.68	68	0.72
Activity Preferences						
Other School Activities						
Female	51	2.72	70	2.83	60	2.72
Male	46	1.99	69	2.57	70	2.32
Self-Evaluation						
Evaluation of Logo Skills						
Female	48	3.23	69	3.19	55	3.26
Male	44	3.53	68	3.61	70	3.51
Driving the turtle around						
Female	48	4.29	69	4.17	55	4.65
Male	44	4.55	68	4.59	70	4.51
Score on Objective Test						
Female	48	11.29	69	12.19	55	13.84
Male	44	12.43	68	13.03	70	14.26

Table 30. F-Ratios for ANOVAs by Source for Indicators in Post-Logo Model with Significant Gender Differences

Indicator	Source: Sex	Grade	Sex x Grade	Scheffe[1]
Difficulty in Learning Logo	14.35**	2.78	0.95	
Preference of Draw or Edit Mode	6.73**	0.60*	0.03	
Activity Preferences				
Other School Activities	22.38**	4.32	2.03	4 vs. 5
Self-Evaluation				
Evaluation of Logo Skills	13.16**	0.02	0.34	
Driving the turtle around	4.70*	2.02	4.34*	
Score on Objective Test	4.16*	10.69**	0.28	6 vs 4,5

[1]Significant at $p < .05$.

* $p < .05$.
** $p < .01$.