1985

A Study of the Influence of Logo on Locus of Control, Attitudes toward Mathematics, and Problem-Solving Ability in Children in Grades 4, 5, 6

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A STUDY OF THE INFLUENCE OF LOGO ON LOCUS OF CONTROL, ATTITUDES TOWARD MATHEMATICS, AND PROBLEM-SOLVING ABILITY IN CHILDREN IN GRADES 4, 5, 6

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of

Doctor of Education

University of San Diego

1985

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A STUDY OF THE INFLUENCE OF LOGO ON LOCUS OF CONTROL, ATTITUDES TOWARD MATHEMATICS, AND PROBLEM-SOLVING ABILITY IN CHILDREN IN GRADES 4, 5, 6

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This study was designed to determine the influence of the Logo computer environment on locus of control, attitudes toward mathematics, and problem-solving ability. An experimental design was employed to test whether students in grades 4, 5, 6 who studied Logo showed more positive attitudes toward mathematics and scored higher on locus of control measures than a control group. The intact non-equivalent control group design was employed. The experimental group of 174 youngsters studied Logo for 12 weeks. Ninety-eight youngsters comprised the control group.

Differences between groups pre and post Logo training were tested using two instruments, "A Study of Attitude toward Arithmetic" and the "Intellectual Achievement Responsibility Questionnaire." Interactions of pretest and posttest scores with group, sex and grade were examined using analyses of variances (ANOVAS); pretest and posttest differences were tested within various group, sex and grade level combinations. Logical thinking and problem solving skills of youngsters who studied Logo were examined separately with several observational data gathering methods.

There were significant ($p < .01$) test-retest differences in attitudes toward arithmetic between groups by sex. A subgroup analysis revealed that boys' attitudes improved significantly after studying Logo while girls' attitudes declined. No changes in attitude were shown in the control group.

No significant differences were shown in locus of control measures between groups. However, a test-retest analysis revealed that boys and girls in the experimental group increased their scores ($p < .01$ and $p < .05$, respectively) as did girls in the control group ($p < .01$). Boys in the control group showed no change in test-retest scores.

Observational research revealed that Logo did not significantly improve problem-solving abilities even though most children enjoyed the computer and found Logo fun. Different social organizational patterns were shown between boys and girls in their willingness to spend "free time" on the computer and in their response to making errors. Teachers expressed reservations about how much learning actually occurred and felt that a comprehensive curriculum and more and better inservices were necessary.

It is recommended that research be conducted to find ways in which Logo can be used to benefit children of both sexes.

DEDICATION

The true purpose of education is to cherish and unfold the seed of immortality already sown within us; to develop, to their fullest extent, the capacities of every kind with which the God who made us has endowed us.

Mrs. Jameson

Winter Studies and Summer Rambles

To my dad, Aaron H. Weinstein, and my husband, Martin M. LeWinter. Thank you for cherishing and nurturing that seed within me.

ACKNOWLEDGEMENTS

For a number of years I worked as a school psychologist and teacher of the gifted. A number of youngsters recommended to me were children who found mathematics and problem-solving "hard" and, therefore, "boring." More girls than boys fell into this category, and I began to wonder what the consequences of classifying mathematics in this way might be. Research suggested that such attitudes resulted in youngsters taking fewer mathematics courses, thereby limiting future career options and opportunities. If this be the case, was there any program of study or new technology that could change students' attitudes early in their school career and help them view mathematics in a more positive fashion?

With the help of my chair, Dr. Zgliczynski, and the encouragement of the other members of my committee, Dr. Edward De Roche, Dr. Edward Kujawa, and Dr. Janice Coop, I began to explore the application of the computer language, Logo, and Papert's philosophy to this problem. I want to thank my committee for asking the difficult but necessary questions at the start of the study and for seeing me through my writer's block by setting deadlines and giving me continual feedback, excellent suggestions and necessary words of support. I also want to thank Dr. Joseph Rost for stressing the importance of maintaining standards and integrating observations with my experimental study.

Obviously, without a supportive school district and school board my study would still be at the questioning stage. I would like to thank the administration, staff, board, parents and youngsters of the Oceanside school district who were willing participants, honest and open with their concerns, and helpful with their suggestions. I shall always be grateful to them for their generous sharing of time, staff, students and facilities to further my research interests.

I also want to thank all the professionals and scholars in the field who were generous with their advice, ideas, and manuscripts. Their working drafts and words of encouragement proved invaluable, especially in a field moving as rapidly as this one has in the last five years.

Finally, I must acknowledge the role my family played in this drama. Thank you for understanding the hurried take-out dinners, the piled-up laundry, the scattered papers carpeting the floors, the constant rushing and the always late carpools, the hours spent in the library and at the computer instead of at soccer games and weekend outings, and the frazzled cries for help. To my daughters, you have helped put meaning into all of this and given me the perspective necessary to maintain my sanity, especially through all the retypings. You have been my greatest boosters and supporters, encouraging me even on those days

when I was not the ideal mother. Hopefully, in a few years, we all can look back on this time, laugh and agree it was worthwhile. And last, but certainly in my mind first, I would like to thank my husband, Marty, for his patience, encouragement, and good humor throughout this ordeal. Your editorial suggestions and advice were invaluable, but it was your love and belief in me and your continual support throughout every new crisis that I shall treasure forever.

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CHAPTER I

INTRODUCTION

> Today, more than ever before, the study and appreciation of mathematics are vital to the intellectual development of a society and to its scientific, industrial, technological, and social progress. It is essential that administrators, parents and the general public work together to provide the best mathematics education possible for all students, regardless of sex...(National Council of Teachers of Mathematics, 1978, p. 147).

In recent years, it has become evident that the teaching of mathematics at the elementary and upper school levels must be upgraded if our students are to compete successfully in the modern technological world (Wirszup, 1981). Urgent recommendations made by the National Commission on Excellence in Education (1983) echo the NCTM statement and stress the need to provide more mathematics and computer education classes in our schools.

Nonetheless, problems of underenrollment in and stressful experiences with mathematics remain. As youngsters progress through the elementary grades, tasks in mathematics change from simple computation to an emphasis on application and problem-solving. In the typical mathematics classroom the pace is often set by the need to assimilate concepts, not by the learning abilities or learning styles of the students (Confrey as quoted in Strausberg, 1984). Classroom situations often expose a youngster's weaknesses (for example, going to the blackboard, taking timed tests and quizzes which stress the right answers, excessive competitiveness) and raise anxiety levels (Tobias, 1980). As one way of coping, many children memorize algorithms without understanding the general "mathematics principles" underlying them. Others, unable to cope, formulate a negative self-image of their mathematical abilities and ultimately do not continue with their mathematics education (Tobias, 1980).

The problems of underenrollment and stressful experiences with mathematics appear to be even more acute among females. In England one-quarter of the entire female population succeeds in English in secondary school but fails in mathematics (MacKernan, 1983). In the United States according to a 1978 study of high school seniors by the College Entrance Examination Board, approximately 63% of college-bound males and only 43% of females had taken four or more years of high school mathematics (Fox, 1981).

A number of instructional approaches have been proposed in order to rekindle an interest in mathematics. One, which has generated great excitement in the last few years, is teaching children to program microcomputers. A position statement prepared by the Instructional Affairs Committee of Mathematics Teachers (1978) and approved by the NCTM Board of Directors states that:

> An essential outcome of contemporary education is computer literacy. Every student should have first hand experiences with both the capabilities and limitations of computers through contemporary applications. Although the study of computers is intrinsically valuable, educators should also develop an awareness of the advantages of computers both in interdisciplinary problem-solving and as an instructional aid.

Logo, a computational style of computerized geometry developed by Seymour Papert, Wallace Feurzeig and associates at the Massachusetts Institute of Technology in the late 1960s and early 1970s, is a computer programming language based on the developmental learning principles espoused by Piaget. Papert (1980) and others have suggested that through learning to program in Logo children will develop powerful cognitive skills, improve their spatial reasoning abilities, and enhance their self-esteem. The fostering of self-confidence at the elementary and junior high school levels may be critical for participation by both sexes in high school mathematics (Brush, 1979; Armstrong, 1979; Sherman, 1979). Teachers report that through learning Logo programming many students achieve a sense of power which is a source of self-esteem and self-confidence (Milner, 1973; Fire Dog as quoted in Clements, 1985). Logo is designed to allow the learner to take the initiative and use the computer as an interactive educational tool. Through the use of spatial visualization skills, Logo places the learner in command of the computer environment and helps the child learn to recognize, isolate and correct his/her errors. It is believed that through such a process the child will begin to understand and internalize mathematical principles and become more responsible for his/her learning.

In devising new approaches to the teaching of mathematics it is important to recognize that there are distinctive differences in learning style between the sexes. Although in their review of the literature, Maccoby and Jacklin (1974) concluded that there is no difference between the sexes in aptitude or achievement in mathematics at the elementary level, differences are shown in spatial abilities. Liben and Golbeck (1980) report significant differences between girls and boys in the performance of Piagetian spatial tasks as early as the third grade. Boys have been shown to outperform girls in problem-solving tasks though girls do equally as well in computation. Fennema and Sherman (1977) attribute these sex differences in mathematics achievement to a complex interaction of environmental influences. Sherman (1979) suggests that differences in sociocultural roles prescribed for the two sexes may contribute to females failing to have the requisite experience to maximally develop spatial skills. Consequently, there is an increased need to integrate visualization skills in the teaching of mathematics in the elementary grades if females are to perform as well as males.

Poplin, Drew, and Gable (1984) have found that although women in general lag in interest in mathematics and related subjects, they have the same computer aptitude as men. Still, societal attitudes, software bias and limited computer access often alienate some girls despite aptitude for the computer (Strausberg, 1984). More boys than girls enroll in computer classes and camps and boys, as a group spend more time on the computer (Miura & Hess as quoted in Hawkins, 1984).

Confrey's (1982) studies with high school girls suggest that math anxiety can be overcome by the use of Logo because Logo permits control of the computer environment. By commanding the movements of a "turtle" cursor, children can better understand spatial and mathematical concepts (Strausberg, 1984). Schwartz, Bull, and Tipps (1984) report similar findings regarding mathematics anxiety. Fourth graders trained in Logo showed slightly less anxiety toward mathematics and more confidence in learning mathematics than control students. Brown and Rood (1984) found small (but not significant) increases in self-esteem and internalized locus of control in gifted students after programming experiences in BASIC or Logo.

However, others have failed to document a positive effect. DuBoulay and Howe (1982) did not find consistent improvement in mathematics in student teachers who had taught Logo. Pea and Kurland's (1983) studies at Bank Street cast doubt on whether the promise of Logo can be fulfilled without directed teaching and a well-structured developmental curriculum. Hawkins (1984) found that boys performed consistently better on all measures of programming expertise in Logo than did girls. Thus, sex differences were not narrowed by the use of Logo.

Statement of the Issue

Despite enthusiasm and popularity Logo remains only partially understood by many educators (Lough, 1983). While it would appear that Logo can serve as a tool in encouraging independence and self-esteem, few studies have undertaken to answer the following questions experimentally using large numbers of children within an ordinary school setting. Do elementary-age children gain in self-confidence and motivation from working with a procedural language such as Logo? Does learning to program in Logo really produce more positive attitudes toward the learning of mathematics? Will the computer and languages such as Logo which increase exposure to spatial tasks and visualization activities provide a new avenue for incorporating sexual equality in the learning of mathematics? As Clements (1984) suggests, more research is required before we will know what abilities are requisite for learning, and learning from, Logo.

Purpose of the Study

This study was designed to examine the influence of the Logo environment upon a youngster's attitude toward mathematics, locus of control and problem-solving ability. The study examined questions concerning attitude toward mathematics and locus of control experimentally, and questions concerning problem-solving through an ethnographic approach.

The following questions were studied experimentally:

1. Can internal-external beliefs (locus of control) be modified through specific experiences or exposure to a Piagetian-based developmental curriculum such as Logo? Specifically:

a. Will experience with Logo produce more internal responses on the Intellectual Achievement Responsibility Questionnaire (see Appendix A)?

b. Will differences be shown between girls' and boys' responses to exposure to Logo instruction as measured by the Intellectual Achievement Responsibility Questionnaire?

2. Will students who have been introduced to Logo demonstrate improved attitudes toward mathematics as evidence by (changes in) attitude measures on Dutton's "A

Study of Attitudes toward Arithmetic" instrument? (see Appendix B) Specifically:

a. Will differences be shown between girls' and boys' responses to exposure to Logo instruction as measured by the Dutton, "A Study of Attitudes toward Arithmetic" instrument?

These questions concerning attitude and locus of control were stated as formal hypotheses in order to subject them to experimental manipulation:

Hypotheses

Ho 1. There will be no significant differences shown in attitudes toward mathematics between students in grades 4, 5, and 6 who study Logo and control group students who do not study Logo.

a. There will be no significant differences shown in attitudes toward mathematics between girls and boys in fourth grade who study Logo and control group students in fourth grade who do not study Logo.

b. There will be no significant differences shown in attitudes toward mathematics between girls and boys in fifth grade who study Logo and control group students in fifth grade who do not study Logo.

c. There will be no significant differences shown in attitudes toward mathematics between girls and boys in sixth grade who study Logo and control group students in sixth grade who do not study Logo.

d. There will be no significant differences shown in attitudes toward mathematics between girls and boys, aged 9, who study Logo and control group students, aged 9, who do not study Logo.

e. There will be no significant differences shown in attitudes toward mathematics between girls and boys, aged 10, who study Logo and control group students, aged 10, who do not study Logo.

f. There will be no significant differences shown in attitudes toward mathematics between girls and boys, aged 11, who study Logo and control group students, aged 11, who do not study Logo.

g. There will be no significant differences shown in attitudes toward mathematics between girls and boys, aged 12+, who study Logo and control group students, aged 12+, who do not study Logo.

Ho 2. There will be no significant differences shown in total locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

a. There will be no significant differences shown in total locus of control measures between girls and boys in fourth grade who study Logo and control group students in fourth grade who do not study Logo.

b. There will be no significant differences shown in total locus of control measures between girls and boys in fifth grade who study Logo and control group students in fifth grade who do not study Logo.

c. There will be no significant differences shown in total locus of control measures between girls and boys in sixth grade who study Logo and control group students in sixth grade who do not study Logo.

d. There will be no significant differences shown in total locus of control measures between girls and boys, aged 9, who study Logo and control group students, aged 9, who do not study Logo.

e. There will be no significant differences shown in total locus of control between girls and boys, aged 10, who study Logo and control group students, aged 10, who do not study Logo.

f. There will be no significant differences shown in total locus of control between girls and boys, aged 11, who study Logo and control group students, aged 11, who do not study Logo.

g. There will be no significant differences shown in total locus of control between girls and boys, aged 12+, who study Logo and control group students, aged 12+, who do not study Logo.

Ho 2.1 There will be no significant differences shown in positive locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

Ho 2.2 There will be no significant differences shown in negative locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

As indicated above, questions concerning problem-solving were examined using an ethnographic approach which included students' self-reports, observations, classroom interactions and informal interviews with teachers and students. Using this approach the following questions were addressed:

1. Will students who have been trained in Logo demonstrate improved logical thinking and problem-solving abilities including planning and sequential organization skills (ability to divide a problem into subparts and learn from errors) as evidenced by: a) classroom observation? b) computer work?

2. Will children who have had experience with Logo demonstrate increased persistance, motivation and ability to sustain interest in a project as per: a) teacher observation? b) time on task?

3. Will children who have had Logo training show improvement in their ability to perform tasks on the Brookline Logo worksheets of: a) line estimation? b) angle estimation? c) sequencing? d) route planning?

4. Will there be differences between boys and girls in their approaches to problem-solving and the strategies they use in programming tasks? Will differences be age related or sex related?

Significance of the Study

It is important to look at what children are actually doing with the computer if we wish to better understand what happens when children work with Logo. Pea (1983) stresses the necessity of documenting in a more systematic manner what children are really learning as they learn to program. Most prior research has been primarily qualitative in nature relying upon anecdotal reports which result in claims that are difficult to substantiate (Papert, 1980 and Byte, August 1982). The belief that through learning to program using Logo children will improve not only their cognitive skills but enhance their self-esteem needs to be examined in a more rigorous fashion.

Definition of Terms

Locus of Control: Locus of control is a personality construct referring to an individual's perception of the outcome or occurrence of events as determined primarily by internal focus; i.e., by his/her own own behavior, as opposed to external forces such as fate or luck. Beginning with Phares (1957) a number of psychologists have developed questionnaires designed to measure this construct. These questionnaires allow persons to be rated on a continuum from highly internal to highly external.

IAR: The Intellectual Achievement Responsibility Scale developed by Crandall, Katkowsky, and Crandall in 1965 measures children's locus of control and perception of responsiblity for intellectual-academic achievement by a questionnaire procedure. The child is asked whether s/he attributes his/her good or poor grades to his/her own efforts or to the vicissitudes of the external environment. Crandall et al. (1962) found that locus of control has a high correlation with academic success.

Attitudes: Refers to a point of view, bias, and/or feelings a youngster has towards arithmetic. Dutton's, "A Study of Attitudes toward Arithmetic" scale consists of 15 weighted statements describing feelings about arithmetic. The youngster is asked to check off the five statements that best describe his/her feelings.

Logo: A computational style of computerized geometry developed at the Massachusetts Institute of Technology by Seymour Papert and others in the late '60s and '70s based upon the developmental learning principles espoused by Piaget.

Problem-Solving: The process of applying previously acquired knowledge to new and unfamiliar situations. It is a set of strategies which involves the ability to plan, organize material sequentially, analyze a problem into subparts and then synthesize it into a whole.

George Polya (1945) describes problem-solving as a four-phase process consisting of:

1. understanding the problem
2. devising a plan
3. carrying out the plan
4. checking and verifying the results

Statz (1973) in her work on Logo and problem-solving expands Polya's definition to a sex-step process:

1. defining the problem
2. devising a plan
3. gathering information
4. executing the plan
5. revising the plan
6. evaluating the results

Brookline Tasks: A series of tasks developed by Papert and teachers at the Brookline school in Massachusetts in the late '70s to administer to youngsters studying Logo. These tasks consist of line estimation, angle estimation, sequencing and route planning.

Rationale

One of the important goals of mathematics education is to help youngsters become independent problem-solvers who can perform in high-level cognitive tasks. Previous studies have demonstrated that the middle school years (grades 4 through 8) are crucial in the development of students' attitudes toward mathematics. Grades 4 through 6 were chosen for this study because these are important grades for developing an awareness of the importance of mathematics achievement for school success. In addition, Taynor's (1973) study suggests that sexual differences in confidence levels appear to be acquired between the ages of 9 and 15 (grades 4 through the beginning of high school). The link between achievement expectancies and performance in mathematics has been shown by a number of researchers, with girls often found to have lower expectancies (Dweck & Brush, 1976; Parsons, Ruble, Hodges & Small, 1976) and less positive attitudes than boys (Fennema & Sherman, 1976; Frieze, Fisher, Harysa, McHugh, & Valle, 1978). Papert

(1980) notes how powerfully self-reinforcing such self-images can be. Purkey (1969) includes problems associated with a lack of perseverence among a number of causes of underachievement during the elementary school years. Zilli (1971) identifies inadequate motivation and rigidity in teaching techniques as two of the five major causes of underachievement. Messer (1972) notes that as early as fourth grade girls tend to take blame for their failures whereas boys the same age tend to take credit for successes. According to Fennema (1982) this particular combination of attributes strongly affects mathematics achievement.

Papert (1960) describes programming as an activity that encourages the use of organizational and analytical skills. In order to become an independent problem-solver, Fennema (1982) believes it is necessary to develop confidence in one's ability to perform difficult learning tasks. Learning to successfully program in Logo requires thinking and working in an analytical fashion. If, as Papert (1980) believes, Logo can increase motivation and self-confidence, including Logo in the elementary school curriculum should have important consequences in improving the performance of underachievers in mathematics, especially females.

Papert (1980) describes programming as an activity that encourages the use of organizational and analytical skills. In order to become an independent problem-solver, Fennema (1982) believes it is necessary to develop confidence in one's ability to perform difficult learning tasks. Learning to successfully program in Logo requires thinking and working in an analytical fashion. If, as Papert (1980) believes, Logo can increase motivation and self-confidence, including Logo in the elementary school curriculum should have important consequences in improving the performance of underachievers in mathematics, especially females.

Limitations

The setting of this research was limited to only one suburban school district. The district was chosen because it recently had established a computer magnet school and was interested in teaching Logo as its primary programming language. The magnet school had a computer laboratory with 13 computers available to serve a class of 26 children at one time. While this is not representative of most elementary school districts, such a setting allowed a maximal number of children to participate in the study.

The experiment was designed to cover a semester of school instruction--approximately a 12 week period in which 25 hours were devoted to computer time. Prior studies at Brookline (Papert, 1980) have covered a similar period of time and documented significant findings. However, it is possible that novelty could have influenced results and a longer term experiment might differ in its conclusions. Due to school holidays, equipment problems, absenteeism, transiency and scheduling changes strict adherence to experimental conditions could not always be maintained. Teachers did not always follow lesson plans nor keep records on individual student's progress. Technical failures such as the mainframe not booting up properly or single machines "going down" lowered the amount of time some classes spent on Logo. Some youngsters stayed during lunch or after school to work on the computer and this additional exposure may have made some difference. Because of these additional variables this study is probably best considered quasi-experimental. On the other hand, these uncontrolled variables may better reflect the realities of implementing a new program within a school setting.

In addition to pre and posttests, observational data was gathered by this researcher, functioning as a participant-observer. This data was basically in the form of anecdotal reports. Each teacher's level of confidence with Logo varied and some teachers were more receptive than others in permitting classroom observations.

The school district provided recent group achievement scores (California Achievement Profiles) but would not release individual student records on prior achievement in mathematics. Thus, this research did not attempt to study the relationship between attributes (locus of control) and prior achievement or computer studies and achievement in mathematics.

Implications for Leadership

This study offers a number of major implications for educational leadership.

A lack of skill and/or knowledge in mathematics is an important barrier to women who aspire to enter or advance in technical business and professional fields. At all educational levels past elementary school far fewer women than men elect to pursue more than a minimum of mathematics requirements (Fennema & Sherman, 1977). Women are greatly under-represented in mathematics-based occupations and leadership positions. It is, therefore, important to determine ways to improve the quality of the mathematics curriculum beginning in elementary school, in order to increase women's accomplishments in mathematics.

The basic question of how to encourage a child to become competent, creative and positively interested in mathematical sciences is a major issue all schools must face. Computers are rapidly being integrated into the schools as our society becomes more technologically oriented. Sheingold and associates (1983) found that microcomputers encourage more peer collaboration and the use of children as resources for each other. Logo, as a language, stresses a discovery-learning approach. It encourages children to invent their own goals (Hawkins, 1983). It is a model which encourages children, in a sense, to become their own teachers. Such a model is believed by Papert to contribute to children's positive views of themselves and their own competence.

Many schools are interested in implementing Logo in their curricula and want to know what changes in attitudes will result. To use Logo in the ways for which it was designed may require new teaching strategies or approaches, since Logo places much more emphasis on the means than the end. New approaches to the learning situation may have a positive influence on developing self-confidence and independence of thought, both of which are believed necessary for success in mathematics. Integrating Logo into the traditional classroom environment may also require a rethinking of the pedagogy currently in use in most classrooms today. Detailed analysis of a Logo program as it was implemented in the elementary school curriculum by classroom teachers should prove helpful in determining whether such a learning approach makes a positive contribution to a child's self-esteem.

CHAPTER II

REVIEW OF THE LITERATURE

The child's self-image and attitudes toward mathematics appear to play important roles in determining academic success. Thus, characteristics such as persistence and willingness to take risks seem to be as important as memory and logical thinking for success in mathematics (Grieb & Easley, 1982). Negative attitudes, on the other hand, have been shown to interfere with the learning of mathematics (Fennema, 1982). Anxiety as well has been shown to lower effectiveness (Tobias, 1978).

Papert (1980) notes that self-images are extremely robust and powerfully self-reinforcing. He states:

> If people believe firmly enough that they cannot do math, they will usually succeed in preventing themselves from doing whatever they recognize as math. The consequences of such self-sabotage is personal failure, and each failure reinforces the original self (p.65).

The extent to which a child perceives him/herself as responsible for the outcome of achievement-oriented events affects his/her attitude toward success and failure. It has been shown that a child who perceives academic performance as contingent on his/her own effort and abilities as opposed to luck or other external factors generally performs better in school. Such a child is likely to more readily develop a feeling of being in control of his/her academic destiny and demonstrates more confidence, greater initiative and better use of environmental feedback, striving to do those things that will result in academic rewards and teacher approval. Entwisle and Baker (1983) suggest that expectations for success can also serve as an important link between a child's innate mathematical reasoning ability and the subsequent development application of this ability.

Locus of Control

Rotter's (1945) social learning theory hypothesizes that the individual who is internally oriented believes that reinforcements are contingent upon certain aspects of his/her own behavior such as a particular skill or competence in a given area. Conversely, an individual whose orientation is external believes that reinforcements are determined by forces independent of his/her own behavior such as fate, chance, luck or other individuals. The expectations that a given individual has of attaining his valued goals determine whether goal-directed behavior will actually occur. These expectations develop as consequences of experience in particular psychological situations and ultimately affect persistence in future tasks.

Weiner (1972, 1974) identifies four perceived causes of success and failure at achievement tasks: ability (power), effort, task difficulty, and luck. These four elements are comprised within two basic dimensions: locus of control (internal versus external) and degree of stability (fixed versus variable):

	Stable	Variable
Internal	ability	effort (personal qualities)
External	task	luck (environmental factors)

In attempting to explain the outcome (success or failure) of an achievement-related event, the individual assesses his/her own or the performer's ability level, the amount of effort that was expended, the difficulty of the task and the magnitude and direction of experienced luck. Ability and task difficulty are seen as having somewhat stable or enduring characteristics whereas the two remaining components (effort and luck) are viewed as variable. If an individual believes that success is due to either high ability (an internal stable dimension) or a relatively easy task (external, stable), on subsequent occasions the individual anticipates success when attempting the task. If, on the other hand, failure is attributed to low ability or a difficult task (both stable causes) the belief that failure will be encountered the next time one attempts the tasks cannot be avoided. Conversely, if failure is ascribed to unstable, variable causes, such as luck or effort, success might just be as easily expected on subsequent occasions if one's luck changes or one works harder.

Weiner et al. (1972) note that persons high in achievement motivation frequently persist in the face of failure since they ascribe failure to a lack of effort, a situation which they see as modifiable. Individuals with low achievement needs or those with a tendency to ascribe failure to a lack of ability tend to abandon an activity in progress when they encounter difficulty since they feel that no amount of effort can alter the outcome.

In relation to mathematics achievement it is important to examine how a youngster interprets success and/or failure feedback. Licht and Dweck (cited in Hawkins, 1984) suggest that achievement orientations in mathematics may differ by sex, with boys more likely to attribute failure to situational factors (external) and girls attributing difficulty in solving problems to a lack of ability (internal). According to Entwisle and Baker (1983), these differences may begin as early as first grade. They found that differences in parental expectations for sons and daughters led boys to expect to do better in arithmetic than warranted by their grades, whereas girls expected to perform more poorly in arithmetic than would be suggested by their grades. From middle childhood on, these sex differences in expectancies for success in mathematics and in self-concept are well documented, with females often found to have lower confidence levels than males (Fennema &

Sherman, 1977).

Wolleat et al. (1980) note that, unlike males, when females succeed in mathematics, they attribute their success to factors other than their own ability, such as luck. Using this model, Fennema (1982) states that one can believe that success or failure occurs in mathematics because one is smart or dumb (ability), one did or did not try (effort), the mathematics is easy or difficult (task), or one has or does not have a good teacher (luck/environment).

Many studies have reported that females and males tend to exhibit different "attribute" patterns (Deaux, 1976; Bar-Tal & Frieze, 1977). Males tend to attribute successes to internal causes and failures to external or unstable causes. Females tend to attribute successes to external or unstable causes and failures to internal causes. Wolleat et al. (1980) hypothesize that this attributional pattern affects both long- and short-term persistence in mathematics. Messer (1972) notes that among fourth grade girls, taking blame for one's failures is tied more closely to academic performance, whereas for boys the same age taking credit for successes is more saliently related to school achievement. He suggests that for a girl it may be considered too assertive or masculine to take credit for one's success (admitting inherent ability) or to blame others for lack of it. Girls instead choose to account for superior performance by attributing it more to external variables and account for failure by attributing it to internal variables (lack of effort). Fennema (1982) notes that such a combination of attributes--success linked to external variables and failure linked to internal ones--strongly affects academic achievement and, in particular, females' achievement in mathematics. Males, on the other hand, according to Messer (1972), do not have to explain away their superior performance, since it is consonant with the masculine role to claim for oneself the credit for success.

Sexual Differences in Attitudes toward Mathematics

Many researcher (Dutton, 1962; Aiken, 1970) have labeled grades 4 through 8 as crucial in developing attitudes toward mathematics. During these grades, tasks change from simple computation to an emphasis on application and problem-solving. At the same time, Antonnen's (1969) studies show a decline in students' attitudes toward mathematics as they progress in school.

As girls progress through elementary and secondary school, they appear to lose interest in studying mathematics as demonstrated by the fact that fewer women than men enroll in advanced mathematics and science courses (EQUALS, 1980). A number of studies in the last decade have related this differential course taking to negative attitudes towards mathematics, lack of confidence in one's math ability, poor career counseling and stereotypic cultural benefits that mathematics is inappropriate for females to study (Casserly, 1975; Fennema & Sherman, 1977; Fox, 1977).

Another difference between the sexes may be in the way boys and girls view the nature of the tasks posed in mathematics. If achievement orientations are different for the two sexes, as proposed by Licht and Dweck (1982 as cited in Hawkins, 1984), then certain mathematical topics in the syllabus and question-wordings may be viewed differently by boys than by girls (MacKernan, 1983) and influence their attitudes toward the study of mathematics. Topics, such as number concepts and computation, that are subject to a more flexible approach and/or stress the use of language and memory skills may be favored more by girls than boys. Other topics such as geometry and probability may be preferred by boys who find these topics relevant to activities outside the classroom. As one mathematics teacher in Great Britain noted at the ATM conference (1983):

> Maths is a male subject dominated by males who order the curriculum and make it appropriate to their requirements. Therefore, boys are good at maths because maths is designed by men so that boys are good at maths.

Gowen (1980) reports that at about fourth grade level a drop in overall creativity occurs in both sexes. This drop has been documented by Torrance (1962), Wheatley (1979) and others. Gowen hypothesizes that the drop in creativity is due to extinction of right hemisphere imagery as a result of overteaching of left hemisphere functions and a corresponding lack of stimulation of right hemisphere functions. Hersberger and Wheatley (1980) note that mathematics programs at the elementary school level are heavily computationally oriented, or as Gowen might describe, confined to left hemisphere functions. The emphasis tends to be on rule-oriented, semantically based behavior and routine practice. Such an approach requires a mental set stressing convergent thinking, that is, finding the correct answer as opposed to developing creative problem-solving skills and utilizing visual-intuitive thought. Papert (1980) calls this an example of "dissociated learning."

Social Factors Affecting Attitudes

Clark (1979) suggests that female children have an entirely different experience as a member of a family and larger community than do boys. From the beginning girls are taught to be passive, accepting and nurturing. They are expected to enjoy quieter games and activities and to not take risks. Serbin and O'Leary (1975) discovered that girls and boys in nursery school receive different kinds of help from others. While boys learn to manipulate the environment openly, girls often sit passively and watch. These differences in interaction, they feel, influence the development of spatial and analytic reasoning abilities.

The social organization and patterns of interaction in boys' and girls' groups also appear to be quite different from each other. Boys tend to interact in larger, more age heterogeneous groups whereas girls tend to interact in smaller groups and often in pairs. Interactions within groups are different as well, with boys favoring competition and girls tending to be more cooperative (Goodwin, 1980). Even in the use of language, Goodwin (1980) found differences, with boys using more direct commands, insults and challenges while girls more often use directives which merge speaker and listener (e.g., "we feel...").

Differences in Sex-Typed Interests

Maccoby (1974) suggests that differences in mathematics achievement are the direct effect of sex-typed interests. Fox (1977) notes that girls learn a more global style of problem-solving, while boys learn analytic approaches and thus become more skilled at quantitative tasks. Sherman (1979) and Wexler (1980) both feel that a girl's own expectations for success at tasks affect behavior in task situations. Maccoby and Jacklin (1974) note that girls have lower expectations for success than boys. Girls have a greater tendency to attribute failure to a lack of ability and set lower expectations for success. Entwisle and Baker (1983) found that young boys develop higher expectations for their own performance in arithmetic than do young girls even though boys' marks and/or general aptitude do not exceed girls. Fox (1977) notes that mathematically gifted girls have significantly less favorable attitudes than boys towards school acceleration for themselves. They are also more anxious than boys in academic settings. Their "fear of failure" seems to inhibit them from taking part in new and different academic activities, especially in the areas of mathematics and science. Tobias (1978) labels such anxiety as the "I can't do math syndrome." Fennema (1982) postulates that confidence in learning mathematics is related to self-esteem in general. High confidence in mathematics appears to be located at one end of a continuum while anxiety toward learning mathematics is at the other end. Females who display positive self-images should accordingly do better in mathematics than girls who are less positive about their abilities.

Teacher Attitudes

Teachers' expectations have been shown to affect student performance and teacher-student interactions. Praise and criticism seem to affect in varying degrees a child's concept of him/herself as a learner of mathematics. Brophy and Good (1974) found that teacher-student interaction patterns are in part a function of the sex of the student. Specifically, if a teacher holds high expectations of a boy's ability, interactions tend to be favorable while if a teacher's expectations are low, interactions tend to be favorable while if a teacher's expectations are low, interactions tend to be critical. Girls, on the other hand, appear to receive less criticism and praise than boys regardless of their ability level.

Success in mathematics appears to be dependent upon achieving a delicate balance between personal curiousity and the process of coming to terms with what is expected in the school environment (Grieb & Easley, 1982). According to Parsons, Kaczala and Muce (1982) social processes in the classroom may give rise to differential feedback for boys and girls and influence self-confidence and expectations. Grieb and Easley (1982) report that many children are sensitive to teacher expectations and encouragement (or discouragement). But in choosing behaviors designed to gain the teacher's approval, a child may in fact be limiting his/her risk-taking behaviors.

Ernest (1976) found that many elementary and secondary teachers are convinced that boys are better at mathematics than girls. Casserly (1975) reported that many high school women were not encouraged to continue with mathematics despite high ability. Parsons, Kaczala and Muce (1982) found that girls have lower expectations for their own performance in classrooms in which they are treated differently than boys. When both sexes were treated similarly, Parsons et al. (1982) found that children have equivalent achievement expectations.

The perceived attitude of a teacher towards his/her students as learners appears to be extremely important in shaping classroom behavior. Cooper (1979) finds that teachers use praise and criticism to shape student questioning behavior. Parsons et al. (1982) found that girls in elementary and junior high school ask more procedural questions and have fewer of their responses criticized (Parsons et al., 1982). Thorne (1982) notes that in school settings gender often is the determinant for class groupings. In most schools there are playground areas that are favored by either boys or girls. Teachers often will set up competitions between the sexes and dismiss (line up) the class by sex. This "gender divide" is so extensive that Thorne believes it is meaningful to speak of somewhat separate girls' and boys' worlds. Hyffine and Silvern (1979) note differences in the way kindergarten teachers treat male and female children. They found that females are given lengthy responses to their questions whereas males' questions are answered briefly or not at all. The authors suggest that such differences may serve to inhibit independent functioning in females, promoting instead dependency upon others and sensitivity to adult approval. A quotation from Hoyenga and Hoyenga (1979) illustrates this phenomenon well:

> In some respects schools represent a feminine environment. Obedience, neatness, and social and

> verbal skills are emphasized. And most teachers are female though their bosses are male. But that may be what boys need most to optimize their development. They are weaker in verbal skills, and so need extra time, help and effort in that area. And socialization in the school is more apt to create communion in boys than agency in girls. If androgynous people are really healthier and happier and more effective, the femininity of the school benefits males. But it does so at an awful price. Boys pay by having greater failure rates because some cannot cope with constant drills in the skills they most lack and that are foreign to them. Girls pay by growing up to avoid achievement, to have math phobias, to thank luck for their success, and to blame lack of ability for their failure (p. 146).

Sex Differences in Problem Solving

Sensitivity towards social consequences may vary by sex. Grieb and Easley (1982) hypothesize that people with successful mathematics-based careers have, at an early time, achieved personal trust in their own intuitions and avoided becoming afraid of the social consequences of error. Mathematics tasks which emphasize creativity and interpretation rather than success or failure appear to be one way to involve children who are anxious about their performance.

On the 1978 CAP girls consistently scored better than boys in basic arithmetic computation; however, in all areas where multiple step reasoning was involved, boys scored consistently higher than girls.

Biological Basis for Difference in Mathematical Ability

There has been considerable research attempting to explain sexual differences in cognitive abilities on hormonal basis. Maccoby and Jacklin (1974) report sexual differences in spatial reasoning tasks. Kolata (1983) suggests that extremely high levels of the male hormone testerone during fetal life may influence the development of genius-level mathematical ability. Stanley and Benbow (1980) relate the superior performance of 12-14 year old males on the Scholastic Aptitude Test to biological factors. Peterson (1981) found that children who reached puberty late scored higher on spatial tasks than children who matured early. Berenbaum and Resnick's (1982) study examining somatic androgyny suggests, however, that environmental influences are also important.

Environmental Factors Affecting Ability

Males appear to have a greater opportunity to develop right hemisphere function (integrated learning) through endeavors outside of the classroom. Peterson (1981) finds that boys who excel in athletics also excel in spatial reasoning-- a skill controlled by the right hemisphere of the cerbral cortex. Girls, on the other hand, tend to be less athletic than boys, and hence, may be given less opportunity to develop the area of the brain specialized for spatial control. Recent studies in Canada (reported in Newsweek, 4-1-85) suggest that standardized test scores in mathematics improve when children's fitness levels rise.

Sexual Differences in Mathematics Achievement

Several studies have explored the effects of one or more environmental influences upon a child's mathematical ability and achievement. Liben and Golbeck (1980) report significant sex differences in the performance of girls and boys on Piagetian spatial tasks for youngsters in grades 3, 5, 7, 9, and 11. Their results suggest that there may be differences between males and females in a factor they call "competence." The authors hypothesize that females may have lower motivation in problems viewed as "mathematical" and lack confidence in their ability to do mathematical problems. Taynor (1973) notes that differences in confidence levels appear to be acquired between the ages of 9 and 15. He suggests that in our society men are rewarded for success while women are excused for failure.

Vardya and Chansky (1980) find that youngsters who exhibit field independent cognitive styles show higher mathematical achievement levels than youngsters who are classified as field dependent. Field independence is positively related to cultural conditions which allow one to be more assertive and less restricted. Preliminary analysis of Vardya and Chansky's data do no indicate sex differences in children in grades 2, 3, and 4; yet Maccoby and Jacklin's (1974) findings suggest that girls are at a disadvantage in developing field independence because they are not encouraged to be assertive and are restricted in play and exploration of their environment.

Logo

Logo, a computer language based on the developmental learning principles espoused by Piatet, is an interactive or interpretive computer language that provides children with an environment that encourages autonomous or "discovery" learning. The learner is placed in command of the computer environment and "doing" becomes the central process of learning. Children are encouraged to use and control the computer by giving their own names to the procedures and variables they create. The child is, in a sense, personalizing the computer by creating and defining his/her own language. Programming in Logo involves using what exists to make new things, and using these in turn to make more new things (Solomon, 1982). Logo responds in simple English-like syntax. If a child tells the computer to do something it cannot do or has been programmed to do, the computer responds, "I don't know how to do that."

Papert (1980), one of the creators of Logo, argues that computers can help children learn better. He notes that as children program they reflect on how they might do the task and, in turn, focus on how they think. "In teaching the computer how to think, children embark on an exploration about how they themselves think" (Papert, 1980, p. 19). Using a computer-controlled triangular figure (a "cybernetic animal" called turtle) which leaves a trace of its path as it moves along the display screen, children can see concretely the effects of their inputs. Shapes, pictures, designs and drawings are made as the turtle's position and heading are changed. At the same time, Papert argues that children are really learning about the world in mathematical terms. They learn firsthand about lines, angles, values, repetition, variables, and how to design and solve problems as they more the turtle Forward, Back, Right or Left a certain number of steps.

Logo programs are created by combining commands into groups (procedures) and using these as building blocks (subprocedures) for more complex procedures. The child is thus encouraged to divide a task into small manageable segments and to write a separate "procedure" for each. This aspect of the language is thought to encourage logical thinking, planning and problem-solving skills. Breaking a task into small parts also permits more careful examination of the separate components. As Papert notes, when you program a computer, you almost never get it right the first time. Learning to be a master programmer means learning to become highly skilled at isolating and correcting "bugs" which keep the program from working. Errors help the child understand and internalize mathematical principles, because in order to fix a "bug" one first has to understand what has happened in its own terms. Through such a process of studying mistakes, the child begins to recognize that learning can be separated from being "right" or "wrong."

In this framework, the computer and Logo become powerful teaching tools. The child learns to make connections between the structures of different ideas and to recognize comparisons through his/her own discoveries. As the child's ability to manipulate his/her environment is expanded through the use of the computer, mathematical ideas begin to be formulated from personal experience. Logo provides the child with a procedural approach to problem solving--an opportunity to explore and experiment with mathematical principles and be in control of his/her own learning. Papert (1980) states that through Logo:

> Children are learning a language for talking about shapes and fluxes of shapes, about velocities and rates of change, about processes and procedures. They are learning to speak mathematics, and acquiring a new image of themselves as mathematicians (p. 48).

If in fact Logo can create such an environment, it is reasonable to hypothesize that the use of this learning tool might also alter attitudes toward learning and strengthen self-image.

Social-Emotional Effects of Logo

A number of studies have examined the effects of Logo on social and emotional development. Anecdotal reports from teachers suggest that Logo promotes gains in self confidence, self-esteem, and enthusiasm for learning (Kull, Cohen, Strong, Ferraro, and Bonnano, 1984; Fire Dog, 1984). Newman (1984), in his studies at Bank Street, noted that the children he worked with found Logo an interesting classroom activity and were generally enthusiastic about learning to program. He comments, however, that although the children may have been engaged in Logo, from the teacher's perspective they were not learning how to program. Schwartz, Bull, and Tipps (1984) found that fourth graders who were taught Logo showed slightly less anxiety toward mathematics, and more confidence in learning mathematics than control students. Brown and Rood (1984) found small (but not significant) increases in self-esteem and internalized locus of control in gifted students after they learned to program in BASIC or Logo.

Logo in the Classroom

Studies at Bank Street College of Education and the Lamplighter School in Dallas suggest that considerable increases in social interaction occur when children are engaged in computer activities. Hawkins, Sheingold, Gearhart and Berger (1982) found that children tend to work in a more collaborative manner and talk to each other more about their work when they are at the computer. Hawkins (1983) observed that children work cooperatively on projects and go to each other for help while doing Logo. Many programs were the result of collaborative effort, and the children traded information freely. However, the fact that children viewed the computers as "game devices" and saw Logo as an activity outside of regular schoolwork raises the question of how such perceptions may have altered social context and behavior in the classroom. In other words, since Logo was not defined as a legitimate subject having the same status as reading or mathematics, it is possible that both teachers and students viewed it as a supplementary activity. According to Hawkins such an activity might be seen more in the realm of fun or "play" thereby permitting different types of behaviors and interactions to occur. Clements and Nastasi (1984) found that first and third graders tend to cooperate and communicate in a helpful way with each other when doing Logo on the computer. They concluded that Logo can serve as a tool in encouraging prosocial interaction.

Logo and Problem-Solving Strategies

Studies of youngsters using Logo indicate that different problem-solving strategies are used in programming tasks.

Papert, Watt, diSessa and Weir (1979) define two types of strategies that children usually use in writing programs. Top-down programmers prefer to start with a plan. They use an analytic strategy, writing the main procedure in terms of a few, general parts and then breaking these down into smaller components. Bottom-up programmers do little overt planning. They discover what works as they proceed, relying upon visual approximation and using what they see on the screen to decide what to do next (Dytman and Wang, 1984). Rampy and Swensson (1984) working with a small sample of fifth graders also identify two styles of programming strategies. Product-oriented children state with an idea in mind. They use small steps as they watch their pictures take form on the screen, correcting as they go along until the picture is "right." Procedural-oriented children like to tinker and seldom have a particular design in mind. They experiment with procedures and variables using the designs produced from their experimenting to lead them in new directions.

Papert envisioned Logo as an environment that encourages children to be self-directed and learn through discovery. According to his Piagetian approach, formal teaching in programming is unnecessary.

> Each time one prematurely teaches a child something he could have discovered for himself, that child is kept from inventing it and consequently from understanding it completely (1980, p. 175).

However, sixth grade younsters at the University of Haifa in Israel who were introduced to Logo through a discovery based teaching method were found to use more of a bottom-up trial-and-error approach to problem solving. They did not reflect on what they were doing as they solved problems, and they were often found to change their goals mid-stream or quite the project entirely when encountering difficulty (Leron cited in Cron, 1983). Most of the children were observed writing long, step-by-step, unstructured procedures rather than defining simple procedures and building upon them. Weakness was shown in designing interfaces between subprocedures, and many children had difficulty orienting the turtle's heading and position as they moved from one procedure to the next.

Studies conducted by Pea and Kurland (1984) at Bank Street College showed that third and sixth grade students who had had a year's experience with Logo did not differ significantly from age-matched controls in various developmental comparisons of planning strategies and their effectiveness. Pea's (1983) observations of students learning Logo showed that very little planning was involved in their programming processes:

> Rather than constructing a plan, then implementing it as a program to achieve a well-defined goal and afterwards running the implemented plan on the computer, children would evolve a goal while writing lines of Logo programming language, run their program,

see if they liked the outcome, explore a new goal, and so on...(p.5).

Pea & Kurland concluded that there does not appear to be automatic improvement of planning skills from learning Logo. In Pea's opinion learning how to plan well is not intrinsically guaranteed by the Logo programming environment. Pea challenges Papert's contention that learning to program through "learning without curriculum" can be "a process that takes place without deliberate or organized teaching." Because the transfer of problem-solving strategies between dissimilar problems is difficult to achieve even in adults, Pea advocates using instructional guidance and a structured curriculum in order to help children develop more mature thinking strategies.

Logo and Sex Differences

Mathematics achievement involves interest and experience as well as innate abilities and aptitudes. As discussed earlier in this chapter, females appear to receive less opportunity than males to study mathematics through exploratory activities in their daily lives.

Feurzig et al. (1969) states that programming encourages children to study mathematics through exploratory activity, and it gives key insight into certain mathematical concepts. Accordingly, programming provides a context for problem solving and may, therefore, be viewed as one way of helping girls improve their mathematical skills. The Computer

Aptitude, literacy and Interest Profile developed by Poplin, Drew and Gable (1984) suggests that women have as equal computer aptitude as men. Still, results show that men have more interest in and experience with computers than women. Such lack of interest may result in less time being spent in less time being spent on the computer in an exploratory manner.

Logo has been used to help high school females explore spatial and mathematical concepts and overcome math anxiety (Confrey, 1982). Studies with younger girls and Logo have not been as promising. Hawkins (1984) reports that classroom teachers using Logo frequently expressed concern about a noticeable sex difference in interest and accomplishment with programming work. She includes a perceptive comment from a primary teacher who taught Logo:

> Girls' involvement was highly correlated with my interest in Logo. There seemed to be less clearcut benefits for girls--boys wanted to control it. They acted as if it were made for them (p. 7).

After a second year of studying Logo, teachers at Bank Street reported that they continued to see sex differences in amount of interest in and commitment to programming tasks. A teacher of 11- and 12-year olds commented that boys in general talked much more than girls about the computer and were very interested in machine hardware. Hawkins noted that although there were individual girls who tended to be competent with computers, these youngsters were judged competent in all subjects. This characteristic did not necessarily pertain to boys. Some boys actually became more involved in school, when they started working with computers, showing more interest and competence in their schoolwork.

Results from another project at Bank Street (Hawkins, 1984) suggest that the software used by children may influence interest in and time spent on the computer. Software emphasizing a scientific approach tended to be used more by boys than girls, with boys working in small groups crowded around the computer. Software that was not specifically math /science oriented and tended to invite collaboration and cooperation (such as games requiring a partner) appealed more to girls. These observations support Goodwin's (1980) studies on different patterns of interaction and social organization between boys and girls. Hawkins concludes that differences in interest and attitude appear related to the particular use of the computer and the way it is supported in the classroom.

A number of the studies discussed in this chapter involved a small number of subjects (usually less than 20) and few, if any, controls. Much of the data were gathered by participant-observers who also served as primary instructors of Logo. A number of the researchers had strong feelings about Logo which might have influenced their conclusions. Few felt it necessary to subject Papert's claims to controlled experimental trials.

It was thought to be important to study the impact of Logo on a well-characterized experimental group in comparison to an appropriately matched control group. The design of this study is discussed in Chapter III. Results follow in Chapter IV.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

Ths purpose of this study was to determine the influence of the Logo environment upon a youngster's attitude toward mathematics, locus of control and problem-solving ability. This study was interested in determining whether Logo positively affects children's social and emotional development (locus of control), attitudes toward mathematics, and problem-solving abilities. Observational reports (Fire Dog, 1984; Kull, Cohen, Strong, Ferraro & Bonnano, 1984) support the contention that Logo promotes positive feelings of self-esteem, but few studies have assessed experimentally or quantitatively the effects of Logo training on these three variables.

Many claims have been made for Logo, and it reasonably may be asked if Logo has been oversold, promising more than it can be expected to deliver. A considerable body of research consisting of teachers' self-reports documents students' success in learning to program using Logo (special Logo issues of Byte, 8/82; The Computing Teacher, December January, 1983-84). Few of these studies, however, have employed a controlled experimental design using "ordinary" classroom teachers--those with a very modest level of training, experience and interest in computers. It is, therefore, of interest to behavioral scientists, educators and policy makers to determine whether Logo promotes changes in attitudes and strengthens locus of control and problem solving skills when it is implemented in the classroom with an "ordinary" teacher.

This study employed an experimental design measuring differences between experimental and control groups in two dependent variables: (1) locus of control measures, and (2) attitudinal measures. Sex, age, and grade level were fixed variables. Logo was the treatment.

This study also addressed through an ethnographic approach questions concerning problem-solving ability. Using students' self-reports, classroom observations and informal interviews with teachers and students the following questions were addressed:

1. Will students who have been trained in Logo demonstrate improved logical thinking and problem-solving abilities including planning and sequential organization skills?

2. Will children who have had experience with Logo demonstrate increased persistence, motivation, and ability to sustain interest in a project?

3. Will children who have had Logo training show improvement in their ability to perform tasks of line and angle estimation and route planning?

4. Will a difference be shown between boys and girls in their approaches to problem-solving and the strategies they use in programming tasks?

Site of the Study

The sample for this study was selected from two public elementary schools (grades K-6) in a single school district of moderate size located in a city (population 77,000) in north San Diego county. One school was designated as the experimental site and the other as the control site. Both schools' populations are drawn from basically middle-class suburban environments, with 82% of the parents at a semiskilled level of employment or above (Table C, Socioeconomic Status Report, California Assessment Program, 1983).

The experimental site draws children primarily from its immediate environs. In addition, 60 children, or 24% of the upper grades (4, 5, 6) come from outside the school's immediate area as part of its recent magnet designation as a Computer, Mathematics and Science Center. The school's socioeconomic index of 2.34 is higher than 74% of the schools in the state (Table C, Socioeconomic Status Report, California Assessment Program, 1983).

The control site is a neighboring school (less than five miles distant) which draws from a similar population. It, too, is designated a magnet school from Gifted and High

Achievers and draws primarily gifted youngsters (about 20% of total enrollment) to its site from outside the school's immediate area. Its socioeconomic index of 2.15 is higher than 58% of the schools in California (Table C, C.A.P., 1983). Both schools' socioeconomic indexes fall within the Q_2-Q_3 for the state (in a range which represents 66% of all schools in the state).

Children in both schools performed above district norms in mathematics achievement on the 1982 California Assessment Program but within band expectancies in math as designated by California state norms. A comparison of the percentage of thir grade students in each quarter of the state's student distributions shows close similarities:

	Site	
	Experimental	Control
Below Q_1	16	8
Between Q_1-Q_2	23	29
Between Q_2-Q_3	33	29
Above Q_3	28	34

A comparison of the percentage of sixth grade students in each quarter of the state's student distribution also reflects close similarities between the two populations:

	Site	
	Experimental	Control
Below Q_1	17	29
Between Q_1-Q_2	23	18
Between Q_2-Q_3	32	23
Above Q_3	28	30

Another similarity between both groups was shown by their responses to the questions, "How much do you like mathematics?" Third graders from both sites responded in the following manner:

	Site	
	Experimental	Control
Very much	60%	56%
A little	32%	29%
Not at all	7%	14%

Individual school norms for this same question were not available at sixth grade level. It should be noted, however, that be sixth grade considerable changes in attitudes toward mathematics occur for the district as a whole as indicated by responses to the same question:

	Grade	
	3	6
Very much	61%	41%
A little	27%	44%
Not at all	10%	8%

These results confirm Antonnen's (1969) studies which show that as youngsters progress through elementary school, positive attitudes toward mathematics tend to decrease. If Logo can be shown to produce positive changes in attitudes toward mathematics, this would suggest that including Logo in the elementary curriculum is beneficial.

Classroom Teachers

The seven teachers at the experimental site had teaching experience ranging from 4 to 30 years. Three of the teachers were male. Two of these taught sixth grade and one taught a four-five combination class.

Both male six grade teachers were comfortable with programming and knew BASIC well. One of these teachers served as the computer specialist for the school and assisted the other teachers in running the resource room. The other teachers were familiar with some computer procedures (DOS, AROS, BOOTING) but felt uncertain about hard disk procedures. All the teachers were eager to try Logo with their students. Two of the female teachers (fourth and fifth grade) enrolled in a 6 week program on Logo offered through the San Diego county Teacher Education and Computer Center (TEC center).

All the teachers at the control site were female. Their teaching experience was comparable, ranging from 9 to 17 years. They had little or no experience with computers or programming. None of the teachers at either site majored in mathematics as an undergraduate or held a mathematics credential in addition to the multiple subjects credential.

Mathematics Instruction in the Schools

All classes in both schools were taught the standard district mathematics curriculum (Heath Mathematics, Heath Publications, grades 4, 5, 6, 1982). This included computational skills, fractions, decimals, word problems, geometry and measurement.

None of these classes at the control site had a computer nor a resource room devoted solely to computer instruction. Children in fourth and fifth grades were taught mathematics in their home room classes. Sixth grade children were grouped for mathematics by ability level based on test results from the Comprehensive Test of Basic Skills

(CTBS) and teacher's observations. Each sixth grade teacher taught one ability level, and the children changed classes for instruction.

This same format for mathematics instruction was followed at the experimental site--home room instruction for fourth and fifth grades, grouping by ability level for sixth graders.

Experimental Setting

The resource/computer room at the experimental site is a square classroom approximately 29' x 29' in size (see Appendix C). It houses 13 microcomputers (Apple II+ models with 16K empty RAM cards equalling 64K capacity), each with its own keyboard and separate monitor (Zenith data systems display screen). A remote operating system (ROS) links 12 of the computers to the thirteenth, which serves as the central machine. This central machine has access to two disk drives and a hard disk system (X Comp 5 x 5 MB hard disk subsystem). Half of the volume is used to store original programs; the other half is used as backup (reformed to 10 MB). A printer is connected to the central computer and can print out programs stored on the hard disk.

The Terrapin version of Logo as well as Instant Logo was available on hard disk. It was planned that each youngster would be given his/her own password so that his or her programs could be filed (saved) and later printed out.

This part of the system, however, was not in place until the last three weeks of the program. Additional versions of Logo on floppy disks were available for backup and often needed to be used. A high school teacher assistant (TA) came in to the resource room once a week after class to assist in running the printer, maintaining the files and printing out the children's programs.

In addition, a computer was assigned to each grade level and rotated from classroom to classroom for 3-week periods. These computers were set up in the classroom as part of the learning centers and were not used specifically for Logo instruction. It should be noted, however, that a few teachers used the classroom computer to demonstrate to their class a technique or procedure covered in that week's Logo lesson. During the time this study was carried out, two of the participating teachers had the extra computer in their classrooms. Both teachers demonstrated new procedures to their classes before the students had an opportunity for a hands-on experience in the computer room. After the lesson, the computer was made available on a rotating basis to all youngsters in the class. Handouts and Abelson's (1982) Terrapin Logo book were made available, but the teacher did not provide any specific help to youngsters at the learning center. Both teachers who had the extra computer during the 3 week period signed up for only two 30-minute periods in the resource room instead of three

30-minute periods. Although there was vairation in the amount of time spent in the computer laboratory, the total time spent studying Logo was the same.

Selection of the Sample

The intact non-equivalent control group design was employed for the purposes of this study. This quasi experimental design (Huck, Cormier & Bounds, 1974) is suggested when the researcher cannot do a random assignment but must rely upon naturally assembled groups.

Experimental Site

The total population of grades 4, 5, 6 in the experimental site numbered 250 students composed of two fourth, two fifth, one four-five combination, one four-five-six bilingual combination and three sixth grade classes. More than 85% of the students were fluent in English (C.A.P., 1982). For this study, the following classes were chosen at random to participate: two fourth grade classes, two fifth grade classes and two sixth grade classes. It was decided to omit the bilingual class from the study because all test materials, handouts and Logo commands were written in English.

The teachers met with the researcher to review the experimental protocol before the experiment began. One fourth grade teacher asked to be excused from participating in the study. The sixth grade teacher who had not originally been chosen requested that her class also participate. To substitute for the dropped fourth grade class, the four-five combination class was added to the study. The final sample was composed as follows:

Class	Boys	Girls	Total
4th grade	19	14	33
4-5 grade	19	13	32
5th grade	36	35	71
6th grade	50	41	91
Total	124	103	227

Attrition, absenteeism, and relocations reduced the actual sample of 227 to 98 boys and 76 girls or 174 children, which is 77% of the original sample and 70% of the upper school population. The following number of children from the 7 classes participated in both pre and posttests:

Class	Boys	Girls	Total
4th grade	14	10	24
4-5 grade	14	12	26
5th grade	16	11	27
5th grade	13	10	23
6th grade	14	12	26
6th grade	17	11	28
6th grade	10	10	20
Total	98	76	174

The children ranged in age from 9 to 13. For the purposes of analysis they were placed in four different age groups with two 13-year olds included with the 12-year olds.

Age	Boys	Girls	Total
9 Year	10	9	19
10 Year	25	18	43
11 Year	45	37	82
12+ Year	18	12	30
Total	98	76	174

As part of regular classroom instruction all youngsters at the experimental site had at least six months' experience on the computer before the experiment began. This experience consisted of an orientation, simple games, and some beginning programming experiences. A home survey (Appendix D) sent to each student's family and returned by 50% of the children revealed that less than 13% of the students owned a home computer and less than 4% had taken programming classes. Approximately 20% of the children's fathers and 14% of their mothers knew a programming language, with BASIC the most common language mentioned (53%). Almost all the parents described their children as eager to learn programming (94%), and an even greater percent (99%) of the parents stated that they were eager for their children to learn how to program. More than half the parents (58%) volunteered to attend a parent training session in programming.

By the time the experiment began all of the children participating in the study were familiar with simplified operating commands and were comfortable with the mechanics involved in Computer Assisted Instruction (CAI) and computer games. Some of the fifth and sixth graders had beginning experience with BASIC and had copied programs from resource books located in the computer room. However, none of the activities that the children had been involved with prior to the experiment specifically involved geometric concepts or the type of programming stressed in Logo.

Control Site

The control site had a total population of 233 students for grades 4, 5, 6. There were two 3-4 combination classes, one 4-5 combination, and two 5-6 combinations composed primarily of district youngsters identified as gifted. At each grade level there was also one self-contained class. Four classes were chosen to be compared to the experimental classes:

Class	Boys	Girls	Total
4th grade	20	14	34
5th grade	20	12	32
6th grade	20	13	33
5-6 grade	20	13	33

Absenteeism, attrition, and moves reduced the actual sample to 98 children or 74% of the original sample of 132:

Class	Boys	Girls	Total
4th grade	14	12	26
5th grade	11	9	20
6th grade	18	8	26
5-6 grade	13	13	26
Total	56	42	98

As in the experimental sample, the children at the control site ranged in age from 9 to 13 and were grouped by age as follows (This group also had two 13-year olds who were included with the 12-year olds):

Age	Boys	Girls	Total
9 Year	10	7	17
10 Year	13	10	23
11 Year	22	23	45
12+ Year	11	2	13
Total	56	42	98

The following charts compare both the experimental and control groups by sex and age, and sex and grade:

	Group			
	Control		Experimental	
	Boys	Girls	Boys	Girls
9 Year	10	7	10	9
10 Year	13	10	25	18
11 Year	22	23	45	37
12+ Year	11	2	18	12
Total	56	42	98	76

	Group			
	Control		Experimental	
	Boys	Girls	Boys	Girls
4th grade	13	12	21	13
5th grade	18	14	36	30
6th grade	25	16	41	33
Total	56	42	98	76

Logo Program of Instruction

All classes at the experimental site were taught the Terrapin version of Logo, which was developed at the Massachusetts Institute of Technology, in addition to the standard mathematics curriculum used by the district (Heath Publications, 1982, Grades 4, 5, 6). The control group did not receive this instruction.

Each classroom teacher was responsible for teaching Logo to his or her own class. A sixth grade classroom teacher also served as the school's resource specialist. His classroom adjoined the resource room but could be separated by a sliding door. The resource teacher was available on request and was responsible for inservices, scheduling, systems maintenance, curriculum planning and development, program assistance and coordination, as well as teaching his sixth grade students. The researcher assisted the resource teacher in Logo inservices and teacher training and also served as a participant-observer when requested.

Children kept their own work folders. These varied from class to class and included Logo commands as well as the children's ideas and designs. Graph paper, drawing paper and different kinds of pens, pencils and markers were made available. Children were encouraged to enter a description of what they did each day at the computer in their notebooks.

It was planned to save the programs the children wrote on the hard disk and to provide children with copies of their printouts. Technical difficulties, however, prevented saving most programs; and it was not until the last two weeks that any designs could be saved and printed out.

Every Wednesday during conference time (2:30-3:00 P.M.) the staff met with the computer resource teacher and the researcher to review the lesson on Logo to be taught the following week (see Appendix E).

Each subject received approximately 60 to 90 minutes per week of Logo instruction on the computer from 3/14/83 through 6/11/83 (approximately 12 weeks or 18 hours of instruction). The original experiments at Brookline in 1977-78 covered a similar time period though Logo instruction was estimated to be 25 to 37 hours for each participant. Clements and Guillo's (1984) studies also used a 12-week period. It should also be noted that the youngsters at the experimental site had already logged a considerable number of hours each week on the computer doing Computer Assisted Instruction (CAI) and were comfortable with the mechanics involved in running the machines. Most San Diego elementary schools offer Logo in three-week instructional blocks (approximately 15 hours of instruction); therefore, the time period employed during this study was felt to be a reasonable approximation of current school practices.

Each classroom teacher introduced Logo by first presenting a simplified version called Instant Logo in order to familiarize the youngsters with the basic concepts involved in moving the turtle (triangular cursor) around the screen. Instant Logo allowed the children to make simple designs as they turned the turtle right or left 15° at a time or moved the turtle forward or backward in 10-step increments. A three-dimensional truck called BIG TRAK was made available to the classroom teachers to permit them to demonstrate to their classes how to program an object to move around the floor. Unfortunately, only two classes had the opportunity to try out the BIG TRAK before it stopped working properly.

Each classroom teacher was assigned to the computer room three times a week (Appendix F) with the exception of two teachers who had the computer in their classrooms and were assigned for two periods a week. Youngsters usually worked together in pairs with two children of the same sex assigned to a computer when possible. Some teachers permitted children to choose their companions; other teachers grouped the children in random fashion. Occasionally three youngsters shared a computer if more than 26 children were present or it a machine was down. Two teachers of the younger children (fourth and fifth graders) divided their classes in half, allowing for fewer children in the room at a time. This permitted a few children the opportunity to work along at the computer but reduced the actual amount of time spent in front of the machine. Studies by Levin and Kareev (1980) demonstrate that pairs of children working together on the computer substantially reduce the number of problems encountered which require outside help. This is because low level problems (typos, pressing the wrong key) encountered by one child are usually solved by the other. Another positive outcome of such pairing is to lower demands on the teacher's time and to lower the ration of teacher to student (as the teacher can teach to the pair of youngsters together). The classroom teacher's role then becomes that of a resource teacher and/or facilitator. In addition, other studies have shown that social interaction increases when children work together, resulting in more peer tutoring (Kull et al., 1984) and collaborative activity (Hawkins et al., 1982).

The teachers did not control participation at the machines in any set manner, and in some cases one of the partners dominated while the other primarily observed. However, this was not usually the case, as most children wanted the opportunity to participate and work the machines. Children were also encouraged to take turns and assist one another, and most did.

A teacher's logbook was located at the entrance to the resource room. Each teacher was asked to record attendance and comment upon the lesson noting whether objectives were met.

Logo Curriculum

Logo inventors argue against a curriculum with a specific scope and sequence because it would prove contrary to a discovery learning approach. A specific scope and sequence may invite the belief that students should be accountable for learning Logo programming concepts in a certain way (and order) and thus encourage teachers to try to evaluate how their students are learning. However, without a curriculum guide it would be impossible to conduct a controlled experiment. Furthermore, Pea and Kurland (1982) suggest that a number of Logo features are not spontaneously discovered without specific instruction. Thus, in order to assure that each chld covered the same material, outlines of lessons were drawn up each week and discussed with each classroom teacher during inservice sessions:

Materials were drawn from four primary sources:

1. The Turtle Sourcebook is a curriculum guide developed by Donna Bearden, Jim Muller, Young People's Logo Association and Dr. Kathleen Martin, University of Dallas (1982). This guidebook provided the basic outline which the teachers followed. The monthly Young People's Logo Association (YPLA) newsletter provided additional ideas and programs to demonstrate.

2. Logo for the Apple II, Harold Abelson's (1982) primer on Terrapin Logo, provided background and specific examples of procedures.

3. Introduction to Terrapin Logo, the San Diego County's Teacher Education Computer Center (TEC) curriculum booklet developed by Allan L. Roger (April, 1983), was integrated into the weekly lessons as well due the positive response from two teachers who were enrolled in the TEC center's program.

4. LOGO: An Introduction, by J. Dale Burnett (1982) provided lessons on polygons, rotating polygons about a vertex, symmetry and coordinates.

Teachers were given a weekly lesson plan outline with specific activities related to the mathematics curriculum (see Appendix E). During the 12-week session, the following concepts of Logo geometry were introduced:

Use of numbers to measure lengths and angles

Group properties of numbers

Internal relations of angles defining polygons

Similarity and symmetry

Non-cartesian coordinate systems

Curves as composed of "infinitesimal" line segments.

Classes in the control site did not receive any formal instruction in Logo during the school day but followed the same mathematics curriculum as prescribed by the district.

A Typical Day

Each participating teacher was observed by the experimenter at least three times during the course of the experiment (Appendix F). Below is a description of some of the behaviors observed during a typical day.

The computer room was opened from 8:30 A.M. to 2:45 P.M. Teachers were scheduled for three 30/35-minute periods each week. Most of the teachers brought their children into the computer room as a class. Two teachers divided their classes in half allowing some of the children recess time while others worked on the computers. These teachers felt that this arrangement permitted more individualized instruction. Not all this time was spent on Logo, however. Some teachers used this time to present other computer acitivities such as CAI, simulation games or BASIC. Each teacher did make certain that at least one hour (or two periods) of the 105 minutes per week was devoted to Logo.

On a typical day four to five classes used the computer room in 30-minute blocks. Each teacher presented the lesson in a slightly different fashion. Some teachers gathered their classes around one machine and demonstrated a procedure they wanted the children to explore. Other teachers used the blackboard to demonstrate a procedure and then asked the children to guess what might happen if they tried it. Still other teachers gave their students mimeographed handouts to follow and had them immediately sit down at the computers and try out the procedures, saving the discussion until the children had an opportunity to see what happened.

Charts of Logo graphic commands, basic control functions and simple editing procedures were taped to the walls. Some teachers focused exclusively upon the basic mechanics of Logo for the first few lessons, stressing the "CTRL" functions and special keys on the keyboard and having the children practice using them until they became comfortable. Other teachers allowed the children to explore more freely and tryout these features as they needed them. Some teachers had the children use graph paper to make a design and then had them try to replicate their efforts on the computer. Still others only told the children to try and draw a square or a house and then let them work it out in a trial-and-error fashion on the machine.

The children worked on the computers at their scheduled times. The computers were also available during lunch and after school if an adult was present in the room. Some teachers permitted the children to go directly to the machines and choose their own partners. Other teachers arbitrarily assigned two youngsters at a time to a machine. Occasionally, due to the fact that a machine was "down" or more than 26 youngsters were present, it was necessary for three youngsters to share a machine. Sometimes children would volunteer to wait until a machine was available rather than share the machine with two others. Interestingly, most of the children who volunteered to wait were female.

All the teachers walked around the room as the children worked, answering their questions or assisting when necessary. Children usually raised their hands if they wanted attention and patiently waited for assistance. Most questions concerned the operation of the machines. Occasionally, a machine would not function properly or took a while to boot up. Sometimes a child just wanted to show the teacher what he/she had accomplished or ask for reassurance ("Is it okay to do...?). Teachers usually responded by telling the child to try and see what happened.

One teacher actually graded the children's efforts although it was not clear what criteria were used other than aesthetics. Occasionally, a teacher called attention to one of the children's efforts and asked the other children to gather around and look.

The laboratory setting was a somewhat freer environment than the classroom. Children were permitted to talk to each other as they worked and encouraged to share ideas. They were cautioned to use the machines appropriately and to recognize that they were not toys. Keys were to be pressed only by fingers (not pencil tips), and machines were not to be left unattended unless the teacher requested that the children leave their places to see what others were doing. It was rare to have to discipline a youngster for inappropriate behavior.

Pairs of youngsters developed different approaches to the tasks at hand. Usually one typed while the other pointed out errors on the screen or made suggestions. When the first child finished, the roles would switch.

Occasionally, one member of the dyad dominated, but more often the children were able to compromise without one spending more time on the machine than the other.

As the children became more comfortable, they began to collaborate more. Occasionally, one child would make an interesting design (often inadvertently), and a child sitting next to him/her would ask how it was done and then try to reproduce it. Interesting designs usually were picked up quickly, and it was not unusual to see three or four variations of the same theme as the children peered over each other's shoulders.

Children were encouraged to keep notes on their work as printouts were not available until the last two weeks of the experiment. As the youngsters became more competent with the edit mode, it became possible to save more of their efforts on the hard disk. All the youngsters seemed genuinely pleased when their work was able to be printed out and displayed.

Instrumentation

Attitudes

The W.H. Dutton, "A Study of Attitude toward Arithmetic" Form C, Scale 5 (1962) was administered as a pre and posttest to subjects in both the experimental and control groups. The study consists of 15 statements about attitudes toward arithmetic.

Instructions: Read the sentences below. Choose the ones which show your feelings toward arithmetic. Place a check ( ) before those sentences which tell how you feel about arithmetic. Pick only the sentences which tell your true feelings--probably not more than five.

For each statement of this Thurstone-type scale, a scale value has been estqablished that has been standardized and validated. Permission was obtained from the author to duplicate the scale and make any changes or adaptations the researcher felt appropriate (note Appendix G) on items 16-20. Items 16-18 address general feelings about arithmetic and ask the child to note average grades made in the subject. When the researcher piloted the instrument with several neighborhood youngsters, it was found that these items were not well understood and did not appear internally consistent. Therefore, in order to address the question posed in item 16,

Place a circle around one number to show how you feel about arithmetic in general.

1 2 3 4 5 6 7 8 9 10 11

Dislike Like

two questions were substituted in its place. Youngsters in the pilot study had an easier time responding to:

Which subject do you like most? Circle one.

Arithmetic Reading Science Social Studies

Which subject do you like least? Circle one:

Arithmetic Reading Science Social Studies

These subjects were chosen because they comprise the standard 4, 5, 6 curricula, and every fall CTBS testing is conducted in these subject areas.

The last two items of the Dutton scale (19 and 20) were designed to elicit spontaneous feelings "for" and/or "against" arithmetic. Both these items were included in the revised questionnaire:

List two things you like about arithmetic:

List two things you dislike about arithmetic:

and felt to be a good opportunity for the children to spontaneously share their feelings and concerns about arithmetic.

The final item to be included in the attitude scale technically was an item concerning locus of control:

When you get a poor grade, which reason do you think usually casues the poor grade?

I had bad luck.

I didn't work had enough.

The teacher didn't like me.

I'm not good at this subject.

It was placed on the questionnaire because its format was of similar design to the other items, and in relation to mathematics achievement and attitudes it is important to examine how a youngster interprets failure feedback. Since the children were administered both the attitude scale and the locus of control questionnaire during the same seating, it was felt that this last item could be included on either questionnaire and would help focus upon the question of whether there were differences in the way girls and boys attribute failure (Appendix B).

The entire attitude scale was read aloud to the youngsters to ensure that the items were understood by all.

Locus of Control

The Intellectual Achievement Responsibility Questionnaire developed by Crandall, Katkowsky, and Crandall (1965) was administered to students in both the experimental and control groups at the beginning and end of the 12-week experimental period.

The IAR questionnaire is composed of 34 forced-choice items divided into an equal number of situation reflecting success and failure. A child's internal positive (I+) score is obtained by summing all positive events for which he she assumed credit. His/her internal negative (I-) score is the total of all negative events for which he/she assumes blame. The sum of I+ and I- subscores comprise the total internal locus of control (I) score.

The IAR measures the extent to which a child feels he or she has control over his/her environment as opposed to his/her being controlled by outside forces.

The coleman (1966) study found locus of control to be one of the overall best predictors of children's academic achievement. Bryant's (1980) study suggested that differences in students' locus of control may also affect their techer's perception of them. Messer (1972) found that the IAR is a good predictor of grades and motivational factors. Children with high I scores (internals) were found to have higher achievement scores than children with low I scores (externals). Saunders and Yeary (1979) report that students with an internal locus of control attain higher science achievement scores than students with an external locus of control.

Crandall et al. (1965) propose that the I+ and I- subscale scores may actually be independent of each other. In other words, acknowledging responsibility for success may be a measure of something different from acknowledging responsibility for failure.

For the purposes of this study, the original instructions of IAR were replaced by the general instructions used in the modified version of the IAR (MIAR) which was designed for younger elementary school children.

> General Instructions: This is not a test. I am trying to find out how children your age think about certain things. I am going to ask you some questions and you pick the answer that best describes what happens to you. Choose the one that most often describes what happens to you. Put a circle around the "A" or the "B" in front of that answer. Be sure to answer each question according to how you really feel.

Both instruments are included in Appendices A for comparative purposes and were piloted on neighborhood children. Language modifications were made to ease comprehension. Four of the original items (all pertaining to parent-child interaction) were eliminated by request of the school board. The revised questionnaire was thus composed of 30 forced-choice items instead of the original 34, divided into an equal number of situations reflecting success or failure.

The entire test was read aloud (a practice suggested by Crandall) by the researcher to each participating class to control for reading difficulties. Test-retest correlations for the original instrument at a two-month interval is .69 for total I; .66 for I+ and .74 for I- (significant at the $p < .001$ level). No significant sex differences have beenshown in total I score for grades 4, 5, 6, but it should be noted that between third and fourth grades, girls assume a level of responsibility for negative events and show a corresponding rise in I- scores. Crandall (1962) states that for both girls and boys, total I scores correlate positively and significantly with almost all achievement test measures and report card marks for grades 3, 4, 5.

Problem-Solving

A number of observational techniques were employed to measure problem-solving. Children were observed during their computer lab period by the researcher and the computer resource specialist. Each class was observed in session at least three times with the majority of the classes observed more times (Appendix E) during the course of the experiment.

The children's folders were informally examined for evidence of planning and sequential organization skills (ability to divide a problem into subparts and learn from their own errors). An example of a child's design is included in Appendix G.

In additions, the children were administered four pages of the Brookline Logo Project (1977-78) tasks pre and post Logo instruction. These tasks (#1.21-1.24) consist of line estimation, angle estimation, sequencing (analysis of forward and backward movement) and route planning (describing a path). Ninety-eight (56%) of the children in the experimental group took part in this phase of the study:

Grade	Boys	Girls	Total
6th	34	30	64
5th	9	6	15
4th	8	11	19
Total	51	47	98

The different tasks were scored as follows:

1. Each child was required to estimate the length of five lines after being given an example which served as the standard. The difference between actual length and estimated length of the line was scored. A median difference score for the five lines measured was computed. This difference score was used for pre and post measures.

2. Each child was required to estimate the size of four angles after being given a standard. As above, differences between actual and estimated size were scored. The median difference score was used for pre and post comparisons.

3. Each child was required to "give one step for a series of forward and backward steps given." In other words, the child was given a Logo sequence and had to figure out how far forward or backward the turtle travelled.

Example: FD 20, BK 10, FD 20, BK 10----> FD 20

There were four of these sequences to answer. Children were given one point for each sequence correctly answered, with four being the maximum number of points that could be earned.

4. The child was asked to start at the arrow and go to the X on a path and then describe how many blocks he/she travelled and how many turns were made. Children were awarded $\frac{1}{4}$ point for corretly noting the number of blocks travelled and given $\frac{1}{4}$ points for correct orientation of turns. The maximum number of points earned was 1. For each error $\frac{1}{4}$ point was subtracted.

There are no published norms by age or grade for these exercises (see Appendix H).

In addition, teacher's comments during inservices were noted. Unfortunately, despite the researcher's requests teachers did not consistently record their concerns, impressions or observations of the Logo session in the lab book after each lesson. At the conclusion of the experiment, however, the teachers were invited to an informal "rap" session to discuss their overall impressions of the Logo program and curriculum. Teachers ended this session by completely a written questionnaire that asked their feelings about the Logo program (see Appendix I).

Finally, students in the experimental groups were asked to complete three questions at the conclusion of the Logo training:

What did you like about computers?

What did you like about Logo?

What did you not like about Logo?

There was no specific question relating Logo training to mathematics or arithmetic (see Appendix J).

Treatment of Subjects

The treatment of the subjects was as follows:

1. Subjects in both experimental and control groups were administered the W.H. Dutton, "A Study of Attitude toward Arithmetic." Form C, Scle 5 (1962) in March, 1983, and again in June, 1983.

2. Subjects in both experimental and control groups were administered the Crandall et al., "Intellectual Achievement Responsibility Questionnaire," in March, 1983, and again in June, 1983.

3. Subjects in both experimental and control groups were taught the same grade level mathematics curricula as set out in Heath Mathematics.

4. Home surveys were sent in March, 1983, to parents of children at the experimental site requesting information about home computers and computer training. At the request of the school district a similar survey was not sent at the control site.

5. Subjects in the experimental group were administered the Massachusetts Institute of Technology "Brookline exercises #1.21-1.24" in March, 1983, and again in June, 1983.

6. Teachers at the experimental site were given questionnaires in March, 1983, to complete surveying their level of computer training and inservice needs.

7. A series of teacher training inservices on Logo were conducted weekly by the computer resource teacher and the researcher beginning the last week of March, 1983, and continuing through June 10, 1983. In addition, a special Saturday Logo inservice was arranged and paid for by the district in April, 1983. A specialist in Logo from the county TEC center conducted the two-hour session.

8. Students at the experimental site attended computer lab sessions at least twice weekly for periods ranging from 60-90 minutes beginning late March, 1983, and ending the first week in June, 1983.

9. A parent evening was offered in April, 1983. Twenty parents attended the session and were given an introduction to Logo with hands-on experience at the computer.

10. Observations of students were made on a rotating schedule with each class visited by the researcher three to eight times during the 12-session (median 5 visits).

11. Teachers at the experimental site were invited to a final session in June, 1983, to compete questionnaires about their experiences with Logo and to make plans for the following year.

12. Students in the experimental group were asked to record what they liked about computers, what they liked about Logo and what they did not like about Logo.

Methods of Analysis

Both quantitative and qualitative methods were used on the data collected for this study. It is important to recognize that a school environment is not a controlled laboratory and is subject to the vagaries of everyday life. Therefore, it would be unrealistic to exclude observations and situations that may realistically be encountered by administrators and teachers planning to implement Logo in the school curriculum.

The non-equivalent control group design was employed in this study. This design is appropriate for research conducted in natural or field settings. Both experimental and control groups were administered the Dutton, "A Study of Attitude toward Arithmetic" scale and Crandall's, "Intellectual Achievement Responsibility Questionnaire" at the beginning of the experiment. The experimental group studied Logo for the next 12-weeks. Both groups were then retested on these same two scales at the end of the 12-week period, and their scores were compared.

Statistical Analysis

For the Dutton, "A Study of Attitude toward Arithmetic" scale, and the Positive, Negative, and Total IAR scores, multifactor analyses of variances (ANOVAS0 with repeated measures allowed testing for pre and pottest differences within each group for boys and girls, and interactions between grade level and sex, group and sex, age and sex, group and grade, group and age. Parametric statistical procedures were employed as the data supported the assumption of homogeneous variances, and the samples came from normally distributed populations (Borg & Gall, 1979). Logarithmic transformations were performed where necessary in order to make variances more homogeneous.

Medians of pre- and post-training scores were computed for the experimental subjects on the Brookline tasks and the Mann-Whitney U-test, a non-parametric test analogous to the parametric independent samples t-test (Borg & Gall, 1979), was used to test whether there was a significant difference between girls' and boys' pre and post scores.

In order to test the direction of the difference and magnitude of change of scores pre and post for each sex, the Wilcoxon matched-pairs signed-ranks test was employed.

Student responses to the evaluative questions included in the "A Study of Attitude toward Arithmetic" scale were analyzed by means of independent samples chi-square test. Likewise, student responses to evaluative questions posed about Log and computers were also analyzed by means of the chi-square test when testing the proportion of responses between groups.

Qualitative Data

The parent surveys and initial teacher surveys were tabulated for informational purposes, and these results have been reported earlier in the discussion of the sample.

Teacher responses to the evaluative questions asked in the questionnaire given at the conclusion of the experiment were analyzed and are reported in Chapter IV, Section II. Teachers' inservice needs are included in the same section, and the implications are discussed in Chapter V.

Students' comments about arithmetic (their likes and dislikes) and their comments about computers and Logo were analyzed and grouped into categories. These results are reported in Chapter IV, Section II with its implications discussed in Chapter V.

Finally, educators and researchers need to know what children are learning when they work with Logo and how they solve problems. Statistical analysis presents only part of the picture. Social interaction, interest and motivation are important factors that influence behavior and are not easily reduced to simple measures. Therefore, anecdotal reports become extremely important in helping to provide a fuller picture of what really is occurring. Anecdotal observations are included in Chapter IV, Section II, and are discussed further in Chapter V.

Assumptions

It is assumed that self-confidence and motivation are not fixed attributes but are attributes that are responsive to environmental influences. The original Logo case studies (Brookline, 1978) cite imporved self confidence and motivation after a brief 10-week training period of Logo (25 hours).

Limitations

This study is limited by a number of factors:

1. The teachers who taught Logo to their students did not always follow the prescribed curriculum nor relate Logo to mathematics.

2. The teachers taking part in the experiment did not always feel comfortable being observed. Four teachers welcomed the researcher as a participant-observer; two teachers permitted the researcher to observe the lessons; and one teacher after the third observation asked that the researcher not return.

3. Children did not spend equal time on the computers despite careful scheduling. Some youngsters opted to stay during lunch or after school to work on the computers and, therefore, spend more time on the machines than others. Occasionally, one child in a pair dominated the other. Some children even volunteered to give up their machines if there were not enough machines available.

4. Technical problems at times reduced actual time on the computer. it was not uncommon for a machine to "go down," and this necessitated turning off all the machines in order to fix the difficulty.

5. The hard disk filing system and a reliable printout system were not in place until the end of the experiment, and thus, it was difficult to keep records of individual's efforts.

6. Absenteeism may have reduced the time a few youngsters spend on the computer. Schedule changes also may have interfered. Some teachers divided their classes and the time periods unequally.

7. The teachers did not always keep written records of what they had accomplished in their computer classes. If a teacher was absent, the substitute did not necessarily follow the lesson plan for the day.

8. Teachers' levels of expertise and comfort in operating the machines varied. Likewise, differences were noted in feelings of confidence and competence in the teaching of Logo.

9. Administrative support varied, and some of the teachers were sensitive to the fact that their efforts were not being rewarded.

10. Data that were collected through observation and interview are open to problems of validity and reliability. Teachers' and students' perceptions provide no guarantee of "fact" or "truth."

11. At times the researcher acted in the dual role of participant-observer. Observations that were recorded may in fact reveal some of the researcher's biases. Interpretations may not accurately reflect all that occurred during the computer sessions.

All results and findings of this study are summarized and presented in Chapter IV, which is divided into two sections. Section I is an analysis of the test results. Chapter IV, Section II is a presentation of ethnographic data.

CHAPTER IV

Section I

ANALYSIS OF DATA

The purpose of this study was to determine whether Logo influences a youngster's attitude toward mathematics, locus of control and problem-solving ability. An experimental design was employed to test whether students in grades 4, 5, 6 who study Logo show positive attitudes toward mathematics and score higher on locus of control measures than a control group of students. The differences between experimental and control groups pre and post Logo training were tested using the following instruments: "A Study of Attitude toward Arithmetic" and the "Intellectual Achievement Responsibility Questionnaire." Interactions of pre and posttest with group, sex and grade level were examined, and where appropriate pre and posttest differences were tested within various group, sex and grade level combinations. Findings are reported in Section I of this chapter.

Questions addressing the logical thinking and problem solving skills of youngsters who study Logo were examined separately through a combination of data gathering methods which included students' self-reports, class observations, informal interviews with teachers and students and pre and posttest measures of performance on the Brookline Logo worksheets. Findings are reported in Section II of this chapter.

Two surveys developed by the researcher were administered at the beginning of the experiment to parents and teachers of students from the experimental site. At the conclusion of the experiment participating teachers were asked to complete another questionnaire developed by the researchers regarding perceived effects of the Logo program.

The sample for the study was selected from two public elementary schools (K-6) in a single school district with one school designated as the experimental site and the other as the control site. Classes were chosen at random to participate in the experiment. The final sample consisted of seven classes with 174 children at the experimental site and four classes with 98 children at the control site. In March of 1983 members of both the experimental and control groups were asked to complete the "Intellectual Achievement Responsibility Questionnaire" and "A Study of Attitude toward Arithmetic." In addition, the children were asked to choose their favorate subject areas emphasized in the elementary school curricula and list two things they liked and two things they disliked about arithmetic. A final item included on the attitude scale was designed to examine how youngsters interpret failure feedback.

The experimental group was then introduced to Logo and received training in this computer language for approximately 90 minutes each week over a 12-week period (18 hours total, from the last week in March through June 10, 1983). Children at the experimental site were observed in their classes as they learned Logo, and anecdotal records were kept both by the participant-observer and classroom teachers. At the conclusion of the training period both experimental and control groups were readministered the "A Study of Attitude toward Arithmetic" scale and the "Intellectual Achievement Responsibility" instrument, and pre and posttest scores were compared by means of multifactor analyses of variance.

Methods of Data Analysis

The W.H. Dutton, "A Study of Attitude toward Arithmetic," Form C, Scale 5 (1962) consists of 15 statements about attitudes toward arithmetic. A scale value has been established for each statement on a Thurstone-type scale. Children were asked to check those sentences which told their true feelings about arithmetic (approximately five statements). Each student's score was then determined by computing the median of the five scaled values. Possible scores range from a low of 1.00 to a high of 10.5 with the higher scores representing more positive feelings toward arithmetic.

To test Hypothesis 1 (there will be a difference shown in attitudes toward mathematics between children who study Logo and those who do not) a multifactor analysis of variance (ANOVA) with repeated measures allowed testing for pre and posttest differences. Subhypotheses 1A through G were examined in the same manner with differences pre and post investigated in interactions with group, grade, and sex. Three-way interactions examined pre-post differences between group and grade level, group and sex, grade and sex, group and classroom, and group and age.

Additional analyses were performed on the data with square root transformations in order to make variances more homogeneous and permit parametric statistical procedures to be employed.

To test pre and posttest differences in children's favorite and lest favorite subjects the McNemar Test for Significance of Change - χ^2 test for dependent samples (Hinkle, Wiersma and Jurs, 1979) was employed. This allowed an examination of how many youngsters in the experimental and control groups became more positive toward mathematics and how many became more negative.

Children's comments (What I like/What I dislike about arithmetic) were classified into two separate categories: topics studies (such as multiplication, division); and feelings ("I sometimes find arithmetic hard."). Subjective comments were further categorized and results were expressed as a percent of the total responders. Both the experimental and control groups were compared to see if there was a difference in the way they viewed arithmetic and if any changes in feelings occureed after the intervention of Logo.

A modified version of Crandall et al.'s "Intellectual Achievement Responsibility Questionnaire" containing 30 forced-choice items was administered to each subject in order to test Hypothesis 2 (There will be a difference shown in locus of control measures between children who study Logo and children who do not). At the school board's request the four items referring to parent-child interactions were omitted (see Appendix A). IAR items comprise an equal number of situations reflecting success and failure. Responses that acknowledge responsibility for success are scored on the I+ subscale (1 point for each answer). Responses that acknowledge responsibility for failure are scored on the I- subscale (1 point for each answer). These subscores added together comprise the total IAR score. Crandall et al. (1965) proposed that the I+ and I- subscale scores may actually be independent of each other. Thus, three scores were obtained for each subject--a total I score and two subscale scores (I+ and I-) representing internal positive and negative responses respectively.

The child's internal positive (I+) score was obtained by summing all positive events for which he/she assumed credit. The internal negative (I-) score was the total of all negative events for which he/she assumed blame. The sum of I+ and I- subscores comprised the total internal locus of control (I) score. The highest possible total I score a student could receive was 30 (15 I+ and 15 I-).

To test Hypothesis 2 (There will be differences shown in locus of control measures between children who study Logo and those who do not) multifactor analyses of variances (ANOVAS) with repeated measures allowed testing for pre and posttest differences between total I scores and positive and negative IAR scores. Square root transformations were performed in order to make variances more homogeneous and permit parametric statistical procedures to be employed. Subhypotheses 2A through G were examined in this same fashion for pre and posttest differences by sex with interactions between grade level and sex, group and sex, age and sex, classroom and sex, group and grade, and group and age investigated.

The multiple-choice question designed to elicit failure feedback interpretation was examined by means of the McNemar Test for Significance of Change χ^2 test for dependent samples. This question asked children, "When you get a poor grade, which reason dod you think usually causes the poor grade?" The four choices correspond to the perceived causes of failure at achievement tasks described by Weiner (1974):

Cause	Statement	Characteristic
Luck	I had bad luck	External, variable
Effort	I didn't work hard enough	Internal, variable
Task	Teacher didn't like me	External, stable
Ability	I'm not good at this	Internal, stable

Youngsters who ascribed failure to a lack of effort on their part were seen as being more persistent and motivated.

Results

Hypothesis 1

Testing the Hypothesis

There are no significant differences shown in attitude towards arithmetic measures between girls and boys in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

Results for Attitude toward Arithmetic

A multifactor analysis of variance with repeated measures was employed to test for pre and posttest differences between groups and within groups by sex, group, and grade. The null hypothesis that there are no significant differences shown in attitudes toward mathematics between girls and boys in grades 4, 5, 6 who study Logo and control group students who do not study Logo was rejected at the $p < .01$ level (see Table 1).

Within each group the overall pre and post attitude scores were not different. There were no significant differences in the pretest scores between groups but significant differences were found in the posttest scores (see Tables 1 and 2). The interaction between sex and pre-post scores was significant ($F = 7.36, p < .01$). The interaction between sex and group pre-post was also significant ($F = 5.50, p < .02$) as Tables 1 and 3 show.

Boys and girls in the experimental group (Logo) showed significant changes in attitude, with the boys' scores going up ($F = 11.30, p < .005$) while the girls' scores ($F = 4.87, p = .06$) went down.

Table 1

Analysis of Variance Summary for Attitude Scores

Source of Variation		df	MS	F
Group (Experimental vs. Control)	(A)	1	68.08	10.11**
Grade Level	(G)	2	17.86	2.65
Sex	(S)	1	14.36	11.04**
A x G (Group x Grade)		2	11.48	1.70
A x S (Group x Sex)		1	12.03	1.79
G x S (Grade x Sex)		2	2.62	.39
A x G X S (Group x Grade x Sex)		2	10.84	1.61
Error		260		
Total		272		

**$p < .01$

Source of Variation		df	MS	F
Pre vs. Post Attitude Scores	(T)	1	3.60	2.40
T x A (Pre vs. Post x Group)		1	4.34	2.88*

	df	MS	F
Pre Exp. vs. Con.	1	12.14	2.92
Post Exp. vs. Con.	1	49.67	11.94**
Error	260	4.16	

		df	MS	F
T x G (Pre vs. Post x Grade)		2	1.50	.99
T x S (Pre vs. Post x Sex)		1	11.12	7.36**
T x A x G (Pre vs. Post x Group x Grade)		2	1.08	.72
T x A x S (Pre vs. Post x Group x Sex)		1	8.31	5.50*

	df	MS	F
Exp M Pre vs. Post	1	17.06	11.30**
Exp F Pre vs. Post	1	7.36	4.87
Con M Pre vs. Post	1	1.48	.98
Con F Pre vs. Post	1	3.70	2.45

	df	MS	F
T x G X S	2	1.22	.81
T x A x G x S	2	3.27	2.17
Error	260	1.51	
Total	272		

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

Table 2

Means and Standard Deviations of Pre and Post Attitude Scores by Group, Sex, and Grade Level

	Grade 4		Grade 5		Grade 6	
Group	Boys	Girls	Boys	Girls	Boys	Girls
Experimental (pre)						
M	6.89	7.58	6.51	6.53	6.70	6.29
SD	1.98	1.53	1.76	2.05	1.77	2.11
N	21	13	36	30	41	33
Experimental (post)						
M	7.51	6.50	7.26	6.15	7.12	6.09
SD	1.74	2.68	1.47	2.18	1.68	2.29
N	21	13	36	30	41	33
Control (pre)						
M	7.74	5.27	5.93	5.42	6.48	6.19
SD	.99	2.36	2.31	2.04	2.24	2.02
N	13	12	18	14	25	16
Control (post)						
M	6.82	5.21	5.78	4.40	6.55	6.03
SD	2.49	1.97	2.55	2.08	2.40	2.17
N	13	12	18	14	25	16

Table 3

Means and Standard Deviations of Pre-Post Interaction by Sex and Group

	Group					
	Experimental			Control		
Condition	Boys		Girls	Boys		Girls
Pretest	6.67**	M	6.61*	6.60	M	5.67
	1.80	sd	2.03	2.12	sd	2.12
	98	N	76	56	N	42
Posttest	7.26**	M	6.17*	6.36	M	5.25
	1.61	sd	2.29	2.46	sd	2.15
	98	N	76	56	N	42

* $p < .05$ Difference between Pre and Post scores (Exp. Girls)

**$p < .01$ Difference between Pre and Post scores (Exp. Boys)

This interaction is even more clearly shown in the square root transformation (see Table 4).

Table 4

Analysis of Variance Summary for Attitude Scores with Square Root Transformation

Source of Variation		MS	F	p
Exp. Males	Pre vs. Post	.7056	9.46	.01
Exp. Females	Pre vs. Post	.3800	5.10	.05
Ctrl Males	Pre vs. Post	.1372	1.84	NS
Ctrl Females	Pre vs. Post	.2100	2.82	NS

In the control group there were no significant changes in attitude scores for either sex. No significant interaction between sex and classroom was found pre and post ($F = 1.66, p < .14$), suggesting that the changes observed in the experimental group were not related to teacher behaviors.

There were no significant interactions pre-post between group and any other factors although a number of trends ($.05 < p < .09$) were shown on the group x sex x grade (pre post) interactions. In every grade the boys in the experimental group scored higher on posttest measures, with a significant difference shown ($p < .05$) among the fifth grade boys. Girls in the experimental group showed a decline in scores pre to post with the difference in scores for fourth grade girls being significant ($p < .05$). In the control group, posttest attitude scores were lower than pretest scores, with a significant decrease shown in scores for fourth grade boys and fifth grade girls ($p < .05$). Pre and posttest interactions by age, age and group, and age and sex were not significant.

Attitudes

Attitude changes toward mathematics as a favorite subject were tested by means of the McNemar Test and were found to be nonsignificant. An equal number of children reported a change of opinion about mathematics (as a favorite or least favorite subject) in both directions. More boys in the experimental group changed to a positive opinion about mathematics than did girls in the experimental group or children of either sex in the control group, but this difference was not statistically significant. Twenty two boys in the experimental group changed from negative to positive opinions about mathematics while 17 boys changed from positive to negative opinions χ^2 (1, N = 39) = .862, NS. Twelve girls in the experimental group became more positive about mathematics while 15 girls became more negative χ^2 (1, N = 27) = .33, NS. In the control group five boys became more positive and six became more negative (1, N = 11) =.09, NS. Among the girls, seven became more positive and nine became more negative χ^2 (1, N = 16) =.25, NS. Therefore, the null hypothesis of equal change in both directions was accepted.

Tables 5-8 compare both groups and sex for percent of responses for favorite and least favorite subjects. Children in the control group appeared to favor reading over mathematics as their favorite subject, whereas in the experimental group mathematics was chosen more often. Likewise, an inverse relationship was shown for least liked subjects. However, a 4 x 4 chi square comparison of pretests by group was not significant for sex suggesting that both groups were similar to each other at the beginning of testing.

Table 5

Comparison of Groups - Subject Children Like Most

	Group			
	Control (n = 98)		Experimental (n = 174)	
Subject	Pre	Post	Pre	Post
Mathematics	32%	34%	36%	36%
Reading	34%	38%	28%	29%
Science	23%	19%	27%	26%
Social Studies	4%	9%	4%	6%
Language	6%	0%	4%	.5%

Note There was one youngster missing from the pretest in the control group and 2 youngsters missing from the pretest in the experimental group. In the posttest there were 3 youngsters missing from the experimental group.

Table 6

Subjects Most Liked: Pre-Post Percentage Comparison by Sex

	Experimental Group			
	Pre		Post	
Subject	M (n = 98)	F (n = 76)	M (n = 98)	F (n = 76)
Mathematics	34	38	37	34
Reading	25	34	21	41
Science	37	16	33	17
Social Studies	3	7	7	7
Language	0	5	1	0

Note: One boy did not respond on the pretest. One boy and one girl did not respond on the posttest.

	Control Group			
	Pre		Post	
Subject	M (n = 56)	F (n = 42)	M (n = 56)	F (n = 42)
Mathematics	36	26	39	26
Reading	31	38	36	40
Science	24	24	16	24
Social Studies	7	0	9	10
Language	2	12	0	0

Table 7

Comparison of Groups: Subject Children Liked Least

	Group			
	Control (n = 98)		Experimental (n = 174)	
Subject	Pre	Post	Pre	Post
Mathematics	26%	30%	14%	12%
Reading	14%	11%	24%	23%
Science	6%	7%	9%	11%
Social Studies	52%	49%	50%	51%
Language	1%	0%	.5%	0%

Note: In the control group, one youngsters (1%) is missing the pretest and 3 (3%) the posttest. In the experimental group 3 (2%) are missing from the pretest and 5 (3%) from the posttest.

Table 8

Subjects Least Liked: Pre-Post Percentage Comparison by Sex

	Experimental Group			
	Pre		Post	
Subject	M (n = 98)	F (n = 76)	M (n = 98)	F (n = 76)
Mathematics	11	19	9	16
Reading	28	20	25	22
Science	7	12	10	12
Social Studies	52	49	55	50
Language	0	0	0	0

Note: Two boys did not complete this section on the pretest and one boy did not complete this on the posttest.

	Control Group			
	Pre		Post	
Subject	M (n = 56)	F (n = 42)	M (n = 56)	F (n = 42)
Mathematics	23	29	28	34
Reading	20	7	17	5
Science	7	5	5	10
Social Studies	46	59	50	51
Language	0	0	0	0

Note: Two boys did not complete this section on the pretest. All the youngsters completed this on the posttest.

Qualitative Responses to Attitude Survey

Children's spontaneous responses to the questions, "What I like about arithmetic/What I dislike about arithmetic," are summarized in Tables 9-12. Both the experimental and control groups listed the same topics in arithmetic as their favorites: fractions, multiplication, and addition (see Table 9). These percentages remained about the same pre and post. Similarly, the topics the children listed as liking least: division, subtraction, and word problems were the same for both groups and remained fairly constant pre and post (see Table 10).

Children's positive comments about arithmetic are summarized in Table 11. Approximately 17% of the children in both groups gave a reason why they liked arithmetic instead of specifying what they liked about the subject. The majority of the youngsters who made comments of this nature on the pretest (8 out of 14 in the control group - 57% 15 out of 33 in the experimental group - 45%) stated, "Arithmetic is fun" or "Arithmetic is a challenge" or "It's interesting. I like it." The percentage of this type of remark increased on the posttest for the youngsters in the experimental group (18 out of 24 - 75%) but remained the same for the control group students (13 out of 23 - 57%). The practicality of arithmetic was mentioned as important on the pretest by 3 out of 14 (21%) of the control group and 13 out of 33 (39%) of the experimental group. This response was less prevalent on the posttest (17% and 4% respoectively). On the pretest, five youngsters in the experimental group (15%) gave as their reason for liking arithmetic as simply, "I'm good at it." On the posttest only one youngster in the experimental group made this comment whereas three youngsters (13%) in the control group did. Another reason youngsters gave for liking arithmetic was that they felt that it was easy. One difference between the two groups was that a few children in the control group commented upon liking their teacher or the way their teacher taught as a reason for liking arithmetic whereas none gave this reason in the experimental group.

A larger percentage of youngsters from both groups commented on why they did not like arithmetic (approximately 27% of the control group and 22% of the experimental group). On the pretest more youngsters from the control group (18 out of 24 or 75%) stated that "Arithmetic is hard or boring" whereas only 15 out of 39 (38%) of the experimental group made this comment. On the posttest the percentage of youngsters who commented upon arithmetic as being hard or boring declined in both the control group (17 out of 29 - 59%) and the experimental group (10 out of 38 - 26%). There was a significant difference between the two groups $\chi^2(1, \underline{N} = 67) = 7.32$ $\underline{p} < .01$) in willingness to make negative comments about teachers or teaching methods. The students in the experimental group made more comments about teachers and teaching methods that they did not like (10 out of 39 25%, on the pretest and 17 out of 38 - 45%, on the posttest) than did the control students (2 out of 24 - 8% on the pretest and 4 out of 29 or 4% on the posttest). Students in the experimental group also made negative comments about homework and tests (13% on the pretest and 21% on the posttest) whereas students in the control group did not even mention this as a reason for not liking arithmetic. Another interesting difference between the two groups involved their feelings about failure and making mistakes. More youngsters in the experimental group gave this as a reason on the pretest for not liking arithmetic (8 out of 39 - 21% compared to 2 out of 24 - 8% of the control group), yet on the posttest these percentages were reversed for the groups (2 out of 38 - 5% of the experimental group compared to 5 out of 29 - 17% of the control group). Additional reasons that the children gave for disliking arithmetic involved showing their work, going to the blackboard, and just not liking school in general.

Table 9

Comparison of Groups: What Children Like about Arithmetic

	Group			
	Control (n = 98)		Experimental (n = 174)	
Topic	Pre	Post	Pre	Post
Fractions	22%	11%	16%	15%
Multiplication	19%	11%	14%	15%
Addition	12%	10%	13%	15%
Geometry	11%	2%	8%	5%
Division	9%	6%	5%	5%
Word Problems	4%	2%	3%	3%
Subtraction	2%	3%	2%	5%
Measurement	1%	5%	5%	8%
Decimals	1%	9%	2%	9%
Graphs/other	0%	5%	3%	2%
Comments	14%	23%	19%	14%
No Response	5%	12%	9%	4%

Table 10

Comparison of Children's Comments: What I Like About Arithmetic

	Group			
	Control		Experimental	
Comment	Pre (n = 14)	Post (n = 23)	Pre (n = 33)	Post (n = 24)
It's Fun	36%	30%	36%	42%
It's a Challenge	7%	26%	9%	33%
You Learn from It/ It's helpful	21%	17%	39%	4%
Good At It	0%	13%	15%	4%
Easy	14%	4%	0%	17%
Teacher/Teaching Style	7%	9%	0%	0%
Interesting	14%	0%	0%	0%

Note: Comments from both groups totalled less than 25% of possible responses. Most youngsters when asked what they liked about arithmetic gave specifics such as fractions or addition rather than affective responses.

Table 11

Comparison of Groups: What Children Do Not Like About Arithmetic

	Group			
	Control ($\underline{n}$ = 98)		Experimental ($\underline{n}$ = 174)	
Topic	Pre	Post	Pre	Post
Division	18%	14%	15%	17%
Subtraction	11%	9%	11%	9%
Word Problems	9%	5%	6%	9%
Geometry	6%	1%[a]	2%	1%
Multiplication	5%	6%	6%	3%
Fractions	5%	6%	4%	5%
Decimals	3%	1%[a]	3%	3%
Measurement	2%	3%	5%	4%
Addition	2%	2%[a]	3%	2%
Comments	24%	30%	22%	22%
No Response	13%	22%	22%	25%

[a]only girls

Table 12

Comparison of Comments: What I Do Not Like About Arithmetic

	Group			
	Control		Experimental	
Comment	Pre (n = 24)	Post (n = 29)	Pre (n = 39)	Post (n = 38)
It's Hard	67%	28%	28%	21%
It's Boring	8%	31%	10%	5%
Teacher/ Teaching Methods	8%	14%	25%	45%
Messing up/ Failing/ Not Understanding	8%	17%	21%	5%
Going to the Board/Showing Work	8%	3%	3%	3%
Homework/Tests	0%	0%	13%	21%
Other Comments	0%	7%	0%	0%

Note: Affective comments totalled about 25% of the number of total responses.

Hypothesis 2

Testing the Hypothesis

There are no significant differences shown in total IAR ocus of control measures between grils and boys in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

Results for Total IAR

To test pre and posttest differences between groups and within groups by sex, group, and grade in total IAr scores, a multifactor analysis of variance with repeated measures was employed. The results indicated that for the groups as a whole there were no differences in pretest total IAR scores. There were, however, significant differences between girls and boys in both the control and experimental groups on their pretest total IAR scores (F = 4.37, p < .04). In the experimental group, the boys scored significantly lower than the girls on total IAR pretest measures. In the control group the boys scored higher than the girls on total IAR pretest measures as seen in Table 13.

In order to make variances more homogeneous and permit parametric statistical procedures to be employed, square root transformations were performed on the data (see Table 14).

Table 13

Total IAR Pretest Measures

Sex	Group: Experimental		Control
Males	18.55	M	20.55
	4.43	sd	3.63
	98	n	56
Females	20.45	M	19.62
	4.30	sd	3.76
	76	n	42

Table 14

Total IAR Pretest Measures with Square Root Means

Sex	Group: Experimental	Control
Males	4.27	4.51
Females	4.50	4.41

Overall, pretest total IAR scores were found to be significantly different from posttest total IAR scores (F = 18.26, $p < .0001$). A significant interaction was found between groups pre and post by sex (F = 4.15, $p < .04$) (note Tables 16 and 17). Boys and girls in the experimental group (Logo) showed significant increases in posttest total IAR scores ($p < .01$ for boys, $p < .05$ for girls) as did girls in the control group ($p < .01$). This is clearly shown by an examination of cell means (see Table 15) and by an analysis of Pre-post x Group x Sex. Boys in the control group showed no significant changes in their pre and posttest total IAR scores.

Table 15

Comparison of Pre-Post Square Root Means

Group	Sex	Pre	Post	p
Experimental	Boys	4.27	4.45	< .01
Experimental	Girls	4.50	4.61	< .05
Control	Boys	4.51	4.57	NS
Control	Girls	4.41	4.61	< .01

Table 16

Analysis of Variance Summary for Total IAR Scores

Source of Variation		df	MS	F
Group (Logo vs. Control)	(A)	1	47.05	1.74
Grade Level	(B)	2	31.37	1.16
Sex	(C)	1	9.77	.36
A x B (Group x Grade)		2	26.18	.97
A x C (Group x Sex)		1	48.80	1.81
B x C (Grade x Sex)		2	85.30	3.16*
A x B x C (Group x Grade x Sex)		2	56.48	2.09
Error		260	27.20	
Total		272		

*p <.04

Source of Variation		df	MS	F
Pre vs. Post Total IAR Score	(D)	1	167.89	21.60**
D x A (Pre vs. Post x Group)		1	.05	.01
D x B (Pre vs. Post x Grade)		2	.81	.10
D x C (Pre vs. Post x Sex)		1	.85	.11
D x A x B		2	9.88	1.27
D x A x C		1	30.99	3.99*

	df	MS	F	p
Exp M Pre vs. Post	1	119.24	15.34	<.0001
Exp F Pre vs. Post	1	43.50	5.60	<.05
Con M Pre vs. Post	1	8.47	1.09	NS
Con F Pre vs. Post	1	65.05	8.37	<.05

Source of Variation	df	MS	F
D x B x C	2	2.56	.33
D x A x B x C	2	7.14	.92
Error	260		
Total	272		

*p <.05 **p <.0001

Table 17

Analysis of Variance Summary for Total IAR Scores with Square Root Transformation

Source of Variation		df	MS	F
Group (Logo vs. Control)	(A)	1	.80	2.12
Grade Level	(B)	2	.44	1.17
Sex	(C)	1	.15	.39
A x B (Group x Grade)		2	.27	.74
A x C (Group x Sex)		1	.60	1.61
B x C (Grade x Sex)		2	1.14	3.05*
A x B x C (Group x Grade x Sex)		2	.73	1.96
Error		260	.37	
Total		272		

*p < .05

Source of Variation		df	MS	F
Pre x Post Total IAR Score	(D)	1	2.009	18.26**
D x A (Pre vs. Post x Group)		1	.001	.02
D x B (Pre vs. Post x Grade)		2	.005	.05
D x C (Pre vs. Post x Sex)		1	.014	.13
D x A x B		2	.142	1.29
D x A x C		1	.456	4.15*

	MS	F	p
Exp M Pre vs. Post	1.59	14.43	.01
Exp F Pre vs. Post	.46	4.18	.05
Con M Pre vs. Post	.10	.92	NS
Con F Pre vs. Post	.84	7.64	.01

Source of Variation	df	MS	F
D x B x C	2	.044	.44
D x A x B x C	2	.104	.94
Error	260		
Total	272		

*p < .04 **p < .0001

Significant interactions of group with age were found ($F = 3.83, p < .01$). On overall pre-posttest IAR measures 9, 11, and 12 year olds in the control group scored higher on total IAR measures than did these same age groups in the experimental group whereas the reverse was true for 10 year olds (see Table 18).

Table 18

Total IAR: Group x Age Groups

	Age				
Group	9 Yr.	10 Yr.	11 Yr.	12 Yr.	Total
Experimental	19.34	21.40	19.46	20.20	20.05
N students	19	43	82	30	174
Control	20.88	19.28	21.26	20.96	20.69
N students	17	23	44	14	98
Total	20.07	20.66	20.09	20.44	
N students	36	66	126	44	

Significant interactions of grade level and sex were also shown (F = 3.05, $p < .05$). On overall pre-posttest measures fourth grade boys in both groups scored higher than fourth grade girls while fifth and sixth grade girls in both groups scored higher than boys in these same grades as shown in Table 19.

Table 19

Total IAR: Grade Level x Sex

	Grade		
Sex	4	5	6
Boys	20.56*	19.42	19.90
Girls	18.98	21.34*	21.27*

*$p < .05$

Group x Grade x Sex cell means are presented in Table 20. Grade level had no pre-post interaction with group.

Table 20

Means and Standard Deviations of Pre and Post Total IAR Scores by Group, Sex, and Grade Level with Square Root Transformations

		Experimental Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	13	4.27	.40	4.17	.65
5	30	4.59	.60	4.73	.49
6	33	4.50	.43	4.67	.38
Boys					
4	21	4.38	.46	4.60	.51
5	36	4.23	.56	4.38	.67
6	41	4.26	.54	4.44	.49

		Control Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	12	4.28	.42	4.60	.43
5	14	4.35	.44	4.53	.31
6	16	4.55	.45	4.68	.36
Boys					
4	13	4.47	.41	4.60	.53
5	18	4.49	.45	4.50	.55
6	25	4.55	.41	4.61	.37

For the experimental group (Logo) differences in overall total IAR were shown among classes ($p < .0001$) and between sexes ($p < .0148$). An interaction of sex with classes was shown for overall total IAR ($F = 2.30$, $p < .04$) (see Table 21).

Table 21

Means of Interaction of Sex and Class

	Class						
Sex	6H	6R	6D	5W	5C	4-5W	4C
Boys	20.60	17.71	19.89	19.77	17.06	21.15	20.75
N Stdents	10	17	14	13	16	14	14
Girls	20.35	20.23	22.75	25.85	18.82	23.14	17.25
N Stdents	10	11	12	10	11	12	10

In the control group, there were no differences shown among the classes.

Hypothesis 2.1

Testing the Hypothesis

There are no significant differences shown in positive IAR locus of control measures between girls and boys in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

Results for Positive IAR (I+)

Results of positive IAR measures (I+) parallel the results of total IAR measures. A multifactor analysis of variance with repeated measures employed to test pre and posttest differences between groups and within groups by sex, group, and grade showed overall posttest I+ scores to be significantly greater than pretest I+ scores ($F = 12.91, p < .001$) (note Tables 22 and 23). An interaction between sex and grade level was strongly suggested ($F = 2.56, p < .08$) and when examined further showed higher overall pre-posttest I+ measures for fourth grade boys, fifth grade girls, and sixth grade girls (see Table 24).

Table 22

Analysis of Variance Summary for Positive IAR Scores

Source of Variation		df	MS	F
Group	(A)	1	12.81	1.50
Grade Level	(B)	2	6.86	.81
Sex	(C)	1	2.25	.26
A x B (Group x Grade)		2	14.84	1.74
A x C (Group x Sex)		1	22.09	2.59
B x C (Grade x Sex)		2	21.81	2.56
A x B x C (Group x Grade x Sex)		2	12.01	1.41
Error		260	8.52	
Total		272		

Source of Variation		df	MS	F
Pre vs. Post IAR+ Score	(D)	1	34.85	12.91*
D x A (Pre vs. Post x Group)		1	.07	.02
D x B (Pre vs. Post x Grade)		2	.28	.11
D x C (Pre vs. Post x Sex)		1	3.33	1.23
D x A x B		2	1.51	.56
D x A x C		1	6.78	2.51
D x B x C		2	1.30	.48
D x A x B x C		2	2.32	.86
Error		260	2.70	
Total		272		

*$p < .0004$

Table 23

Means and Standard Deviations of Pre and Post Positive IAR Scores by Group, Sex, and Grade Level

		Experimental Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	13	9.46	2.40	9.92	2.59
5	30	11.53	2.84	12.07	2.45
6	33	10.93	2.04	11.97	1.94
Boys					
4	21	10.33	2.52	11.71	2.69
5	36	10.38	2.53	10.63	2.85
6	41	10.61	2.42	11.45	1.87

		Control Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	12	10.58	2.15	11.50	1.51
5	14	10.14	2.38	11.43	2.20
6	16	10.75	2.46	11.38	2.25
Boys					
4	13	11.92	2.18	11.76	2.09
5	18	11.05	2.53	11.11	2.80
6	25	22.48	2.02	11.92	2.20

Note: In all cells but one Positive IAR posttest scores are higher than pretest scores ($F = 12.91$, $p < .0004$)

Table 24

Means of Interaction of Grade and Sex

	Grade		
Sex	4	5	6
Boys	11.34	10.70	11.12
Girls	10.34	11.48	11.50

There were, however, no interactions shown between group and grade nor interactions shown pre vs. post.

Significant interactions were shown overall between group and sex ($F = 5.48, p < .02$) (see Table 25).

Table 25

Means of Interaction of Group and Sex

	Group	
Sex	Experimental	Control
Boys	10.73	11.45
N Students	98	56
Girls	11.40	10.96
N Students	76	42

Significant interactions were shown overall between group with age group ($F = 2.95, p < .03$) as seen in Table 26.

Table 26

Interactions of Group with Age Group

	Age			
Group	9	10	11	12+
Experimental	10.50	11.58*	10.73	11.37
Control	11.76*	10.63	11.45*	11.29

*$p < .05$

Neither age group x group nor group x sex showed significant interactions pre vs. post.

The experimental group showed differences in overall I+ scores among classes (F = 4.74, $p < .001$) and by sex (F = 3.76, $p < .05$) but there were no interactions seen between these two variables as shown in Table 27.

Table 27

Means of Interaction of Sex and Class

	Class						
Sex	6H	6R	6D	5W	5C	4-5W	4C
Boys	10.90	10.56	10.93	11.15	9.63	11.31	10.86*
N Students	10	17	14	13	16	14	14
Girls	11.95*	11.00*	12.17*	12.90*	9.86*	12.45*	9.25
N Students	10	11	12	10	11	12	10

*$p < .05$ Differences by Sex

In the control group, there were no significant interactions shown on I+ measures with sex and class.

Hypothesis 2.2

Testing the Hypothesis

There are no significant differences shown in negative IAR locus of control measures between girls and boys in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo.

Results for Negative IAR (I-)

A multifactor analysis of variance with repeated measures which was employed to test pre and posttest differences in Negative IAR (I-) scores by group, grade and sex indicated that there were significant differences between pre Negative IAR (I-) and post Negative IAR measures (F = 12.70, $p < .001$). A significant interaction was shown between group and grade level pre and post (F = 4.79, $p < .01$). Negative IAR (I-) scores increased significantly in both groups from the pretest to the posttest with grades 5 and 6 in the experimental group and grade 4 in the control group showing significantly higher scores ($p < .01$) (note Tables 28 and 29).

Table 28

Analysis of Variance Summary for Negative IAR Scores

Source of Variation		df	MS	F
Group (Logo vs. Control)	(A)	1	11.22	1.01
Grade Level	(B)	2	8.41	.76
Sex	(C)	1	20.54	1.85
A x B (Group x Grade)		2	16.44	1.48
A x C (Group x Sex)		1	5.31	.48
B x C (Grade x Sex)		2	22.96	2.07
A x B x C (Group x Grade x Sex)		2	22.26	2.01
Error		260	11.08	
Total		272		

Source of Variation		df	MS	F
Pre vs. Post IAR- score	(D)	1	47.38	12.70**
D x A (Pre vs. Post x Group)		1	.29	.08
D x B (Pre vs. Post x Grade)		2	.35	.09
D x C (Pre vs. Post x Sex)		1	.80	.21
D x A x B		2	17.89	4.79*

		df	MS	F	p
Exp. Gr. 4	Pre vs Post	1	.02	.004	NS
Exp. Gr. 5	Pre vs Post	1	29.16	7.82	<.01
Exp. Gr. 6	Pre vs Post	1	39.25	10.52	<.01
Con. Gr. 4	Pre vs Post	1	33.62	9.01	<.01
Con. Gr. 5	Pre vs Post	1	.36	.10	NS
Con. Gr. 6	Pre vs Post	1	.99	.27	NS

Source of Variation	df	MS	F
D x A x C	1	8.09	2.17
D x B x C	2	1.50	.40
D x A x B x C	2	1.97	.53
Error	260	3.73	
Total	272		

*$p < .009$ **$p < .0004$

Table 29

Means and Standard Deviations of Pre and Post Negative IAR Scores by Group, Sex, and Grade Level

		Experimental Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	13	8.92	1.75	7.92	3.25
5	30	9.87	2.76	10.57	2.31
6	33	8.91	2.44	9.94	2.29
Boys					
4	21	9.10	2.88	9.76	2.95
5	36	7.81	3.20	8.94	3.29
6	41	7.83	2.98	8.85	3.04

		Control Group			
		Pre		Post	
Grade	n	M	sd	M	sd
Girls					
4	12	7.92	2.35	9.83	2.41
5	14	9.00	2.48	9.21	1.71
6	16	10.13	3.03	10.63	2.85
Boys					
4	13	8.23	2.04	9.62	2.60
5	18	9.33	2.89	9.44	2.97
6	25	9.40	2.21	9.44	2.08

A significant difference in I- measures was shown between sexes ($F = 3.98, p < .05$), but there was no interaction by sex pre and post. Girls in both experimental and control groups scored higher than boys on overall I- measures as shown in Table 30.

Table 30

Means of Interactions of Sex by Group

	Group	
Sex	Experimental	Control
Boys	8.59	9.29 *
N Subjects	98	56
Girls	9.57	9.52
N Subjects	76	42

*p < .05

A significant interaction of group and age group was shown for overall I- measures ($F = 3.07, p < .03$) with 9, 11, and 12-year-old youngsters in the control group and 10-year-old youngsters in the experimental group achieving higher I- scores (see Table 31).

Table 31

Means of Interaction of Age by Group

	Ages			
Groups	9	10	11	12+
Experimental	8.87	9.81*	8.73	8.73
Control	9.12*	8.65	9.80*	9.68*

*$p < .05$

Within the experimental group, significant differences were shown among classes (F = 3.14, $p < .01$) and between sexes (F = 4.65, $p < .03$) with an interaction shown between these variables (F = 2.44, $p < .03$) (see Table 32).

Table 32

Interactions of Sex by Class

	Experimental Class						
Sex	6H	6R	6D	5W	5C	4-5W	4C
Boys	9.65	6.97	9.07	8.62	7.44	9.85	9.43
N Students	10	17	14	13	16	14	14
Girls	8.30	9.18	10.58	10.95	8.95	10.68	8.00
N Students	10	11	12	10	11	12	10

The total mean difference between the sexes was shown as follows ($p < .03$):

Boys	8.59	Girls	9.55
N	98		76

The total mean difference among classes was as follows ($p < .01$):

6H	6R	6D	5W	5C	4-5W	4C
8.98	7.84	9.77	9.63	8.06	10.23	8.83
20	28	26	23	27	26	24

Within the control group I- measures did not differ nor were overall I- measures different for sex. There was, however, a significant interaction of pre vs. posttest scores by class ($\underline{F}$ = 2.60, $\underline{p} < .06$) with two classes showing significant increases in I- measures (see Table 33).

Table 33

Pre-Post Class Interactions

	Control Class			
Condition	4E	5A	5-6W	6C
Pretest	8.19*	10.05	8.92*	9.50
N Students	26	20	26	26
Posttest	9.65	9.40	10.15	9.42
N Students	26	20	26	26

*$\underline{p} < .05$ Significant interaction pre-post for classes 4E and 5-6W

Results of the Perceived Causes of Failure Question

Failure feedback interpretation was examined by means of the McNemar Test for Significance of Change - χ^2 test for dependent samples. Responses for "getting a poor grade" were divided into the Weiner paradigm of internal vs. external, stable vs. variable causes.

	External	Internal
Variable	I had bad luck. (Luck)	I didn't work hard enough (Effort)
Stable	The teacher did not like me (Task)	I'm not good at this subject. (Ability)

The majority of youngsters in both groups gave internally oriented responses to the question, "When you get a poor grade, what reason do you think usually causes the poor grade?" stating either, "I didn't work hard enough" or "I'm not good at this subject" as reasons for not succeeding (see Table 34).

Table 34

Comparison of Control and Experimental Groups

Reasons for Getting a Poor Grade

	Group			
	Control (n = 98)		Experimental (n =174)	
Reasons	Pre	Post		Post
I had bad luck	6 (6%)	1 (1%)	17 (10%)	4 (2%)
I didn't work hard enough	56 (57%)	70 (71%)	97 (56%)	127 (73%)
Teacher didn't like me	3 (3%)	2 (2%)	9 (5%)	4 (2%)
I'm not good at this	31 (32%)	25 (26%)	50 (29%)	38 (22%)
Missing Data	2 (2%)	0 (0%)	1 (.5%)	1 (.5%)

A higher percentage of girls in both groups gave internally oriented responses to this question on the pretest, but on the posttest no differences were shown among the groups.

Group	Pretest	Posttest
Experimental Girls	96%	96%
Experimental Boys	80%	95%
Control Girls	93%	95%
Control Boys	89%	98%

On the pretest a similar percentage of boys and girls in both groups responded, "I didn't work hard enough," as their main reason for getting a poor grade.

Group	Percentage
Experimental Girls	58
Experimental Boys	56
Control Girls	57
Control Boys	56

On the posttest these percentages changed significantly for the boys in both groups with a higher percentage of boys citing "not working hard enough" as their main reason for getting a poor grade.

Group	
Experimental Girls	68
Experimental Boys	79
Control Girls	62
Control Boys	76

In the experimental group, 32 out of 44 boys changed from other responses to, "I didn't work hard enough," (an effort response on the Weiner paradigm) as their reason for getting a poor grade χ^2 (1, N = 44) = 9.09, $p < .01$. In the control group, 17 out of 22 boys changed from other responses to the "effort" response χ^2 (1, N = 22) = 6.53, $p < .02$). For the girls in both groups these changes were not significant (10 girls out of 19 in the control group; 14 girls out of 23 in the experimental group). A larger percentage of girls in both groups gave the response, "I'm not good at this subject," pre and post as their reason for failure, although the differences between the sexes were not significant:

Group	Pretest	Posttest
Experimental Girls	38%	28%
Experimental Boys	24%	16%
Control Girls	36%	33%
Control Boys	33%	22%

CHAPTER IV

Section II

OBSERVATIONAL FINDINGS

The experimental group was observed during the period that Logo was being taught in the classroom. Each class was observed an average of five times during the 12-week training period (note appendices). Children's planning and organizational skills as well as their involvement and interest in Logo was noted as they worked on the computer. Anecdotal records were kept of the sessions and some examples of what transpired follows:

First Week: Children are excited as they succeed in moving the turtle (cursor) across the screen. They practice moving the turtle forward and backwards occasionally forgetting to input numbers after the command FD or BK. Some children are genuinely confused as to why the turtle does not move when a number is not entered after FD or BK (4th grade class). Children are delighted that they can label their products whatever they want. Two girls ask for reassurance ("Can I really call this anything I want?") (5th grade class).

Children practice moving the turtle to a target on the screen (marked with a stick-on dot). The children have little little difficulty moving the cursor forward, backwards but often have problems with angles. Grid directrions (N, S, E, W) are not really helpful and seem to confuse many girls (6th grade class).

Second week: Using graph paper to draw designs seems to help fourth grade and fifth grade youngsters transfer their ideas to the screen (4-5 class).

Sixth grade teacher invites 4-5 teacher to demonstrate the graphing technique to her class. Children use graph paper to draw simple linear shapes and then try to transfer these to the screen (6th grade class).

Children in class are assigned two to a machine. Some of the partnerships are single sex, but a number are M-F due to the larger number of males in the class.

Some of the girls choose to take the role of observer letting the boys work on the computer as they watch (6th grade class).

Two six grade girls choose to sit out while their class is working on making polygons. When asked how they feel, one girl exclaims, "I don't get time on it (the computer) to practice." The other says, "I can't do something I don't understand and the teacher expects us to know" (6th grade class).

Two girls are trying to draw squares. They first move the turtle forward and turn RT 90. They move the turtle forward and then turn LT 90. They think for a while and finally turn the turtle RT 180 (5th grade class).

Third week: Teacher gives youngsters a prepared program of a rabbit design to copy called "Floppy Bunny." This is used to teach the children the Save Pic. procedure and to help the youngsters learn their class passwords and how to set up individual files. A few children recognize that the bunny is composed of several simple procedures which when combined form the total bunny. Some children have difficulty copying the lines of the program correctly as they hunt and peck at the keyboard (6th grade class).

Teacher divides her class into two sections thereby permitting each youngster access to his/her own computer. The lesson is tightly structured. The children practice a number of control functions as the teacher directs. The focus of the lesson is on learning how to move the cursor more easily and correct typographical errors (5th grade class).

Children each have their own booklets to write down control functions and commands. Children write down programs for square, rectangle and triangle that the teacher puts on the board. The repeat command is introduced. Children are encouraged to try out each shape, and most get to try all three. One boy tries combining different program elements and then uses the Erase command to clear the screen of his design (4th grade class).

The teacher writes the repeat command on the board and tells the children to try it out. Children repeat procedures and poly. A number of youngsters make pretty starts and designs (a number by chance) and share their discoveries with other members of their class. The teacher encourages the children to write down their procedures in the booklets and then copy them into the Editor mode. One boy makes a house writing step-by-step procedures. A girl writes her initials in a similar trial-and-error fashion. Two children experiment making starburst designs by alternating numerical inputs with the repeat command (5th grade class).

Fourth week: Three machines are down. Children are given the assignment--Draw a house. Two different groups of boys draw elaborate house designs on paper--one with a two-car garage, one having several stories. Both pairs start with simple square bases then add the other structures, modifying as they go along. Children are permitted to choose their own partners to work with, and most pairs are of the same sex. Girls appear more comfortable with this arrangement (6th grade class).

One youngster (male) who is learning-disabled works by himself at the computer. He strikes random keys and then erases his results, smiling. He seems less interested than the others in making designs or shapes. He leans over to the next computer and interrupts a boy-girl team seated to his left. Eventually, the teacher removes him from the computer (6th grade class).

Three machines are still not working. Four girls volunteer not take their turns. The rest of the class works on an assigned task. The children are to write a program that will produce their teacher's first name in block letters. Each youngster has a sheet of graph paper and has made a copy of the letters on his/her papers. Two boys working together successfully complete their program, but they use long, repetitive step-by-step procedures. Two girls who are working together stop after a short while. They have encountered difficulty and are ready to give up until a teacher assists them. The participant observer suggests that they try to write the teacher's name in linear form instead of block letters. The girls find this is much easier for them and are successful (4-5 grade class).

Four machines are not booting up today. Teacher demonstrate the lesson to the class on one of the monitors while the class gathers around. A few youngsters seem very intent while a few others stand on the periphery chatting and not attending (5th grade class).

Half of the class is working on the machines, but there is no supervising teacher present. When children encounter difficulty, they go into the adjoining room to summon their teacher (6th grade class).

Girls ask, "What words am I supposed to type?" as they write their programs. "What do I call it?" Teacher and p-o reassure the girls that whatever they want to name their procedures is okay (6th grade class).

Considerable experimentation is going on. Children are trying the REPEAT command and watching the turtle "wrap" around the screen. Several boys try using large numbers to see what happens. Three girls sharing one computer do the same and are pleased to watch the turtle leave an imprint in the form of a checkered design. One boy is drawing an elaborate house on the screen. He creates it as he goes along but does not attempt to transfer the commands to the EDIT mode. He seems disappointed when he is informed that his efforts won't be saved (6th grade class).

Teacher writes on the board some formulas to make regular polygons (a rectangle, a triangle, etc.). The children try out the formulas but some seem genuinely confused and ask, "What am I supposed to do next?" Many children cannot predict the outcome of the formulas and are not certain what shape polygon their inputs will create (5th grade class).

Fourth grade girls come over to the P-O. "You are the lady who helped me make a diamond," says one of girls. "Do you think you really needed my help?" "Oh, yes." "Do you really think that the computer is smarter than you are?" "Yes," she replies, "That machine knows more. I'm dumb" (4th grade student).

Fifth week: Children are introduced to the REPEAT command using brackets and are encouraged by their teacher to make something. Experiment. One girl creates a diamond by making two triangles using the following command: REPEAT 3 [FD 50 RT 120] REPEAT 3 [FD 50 LT 120]. She is challenged to try and draw a diamond in a different direction. At first she is puzzled, and she needs some assistance and encouragement until she can orient the turtle correctly. Once she understands, her basic design becomes more complex. She makes three intersecting diamonds and then transfers her design to the EDIT mode (4th grade class).

The P-O demonstrates "variables" to the class. Children are asked to give different numerical inputs and are shown how their squares can be made larger or smaller. They are then shown a program called "Growsquares" which is a simple recursion program. The children are excited by what they see on the screen and try different

inputs and note the results (4-5 grade class).
Teacher introduces the concept of a circle as a series of small steps and small turns. She has some children walk forward a bit, turn a bit and continue this pattern until they return to where they started. This is then translated into the command: REPEAT 360 [FD 1 RT 1]. The children try this pattern out at their machines. One boy asks the participant-observer if there is a way to make a smaller circle. The child is shown another circle pattern: REPEAT 180 [FD 1 RT 2] and then encouraged to try different combinations on his own. After some experimentation, the child generates: REPEAT 90 [FD 1 RT 4] REPEAT 60 [FD 1 RT 6]. He recognizes and verbalizes the relationship of 360 degrees as a characteristic of all circles. After the session ends, the teacher expresses dissatisfaction with the P-O exclaiming that she prefers to teach this concept her own way (4th grade class).
Sixth week: Teacher assigns children to write a program which will make their initials in block letter form. The children first use graph paper and then try to translate their efforts to the screen. One girl produces her initials (AL) in an attractive manner, but her program is a long continual step-by-step process. She is encouraged by the P-O to try to write "A" first as a subprocedure and then do the same with "L."

One boy works on his name: SEAN. He can draw the E in two dimensions, but he is having difficulty with the S and finally draws it as follows: FD 50 LT 90 FD 50 LT 90 FD 50 RT 90 FD 50 RT 90 FD 50. The final product is one dimensional and contains no repeats or subprocedures (4-5 grade class).

Some fifth grade girls are asked about how they like working on the computers. "It's kind of boring," exclaims one. Another states that reading is her favorite subject. Another girl says, "I can program in BASIC. My mom knows how to program, too" (5th grade class).

Children are asked to draw a house and tree. One girl writes a fairly elaborate program consisting of subprocedures called House, Tree, Treetop, and Fulltree. Her design is first drawn on graph paper which shows top down planning and an analytic approach to solving a problem.

Teacher reviews Primitives and built-in commands with the children. She introduces them to program writing by teaching them:

```
To Rectangle  :Repeat 2 [FD 30 RT 90 FD 80 RT 90]
To Poly :Side  :Angle (variables)
Forward :Side
RT :Angle
Poly :Side :Angle
```

Two girls are frustrated as they sit waiting for their machine to boot up. Two others try TO POLY and produce a star. They want to make it appear lower on the screen. "How do we do that?" they ask. Two boys make a hexagon and start creating nested hexagon patterns. Most of the children seem to get their ideas from what is on the screen and modify from there. They do not seem to have any specific plan in mind as they begin working (6th grade class).

Seventh week: Teacher brings half of class to the computer room. The lesson is highly structured. Children are taught EDIT (ED) command and are asked to copy instructions off the board: TO SQUARE1: REPEAT 4 [RT 90 FD 50]. Each short program makes a square of a different sixe. Then the various squares are combined into a larger procedure called: TO SQUARE A SQUARE1 SQUARE2 SQUARE3 END. From this example the teacher introduces variables: SQUARE :SIZE REPEAT 4 [FD :SIZE RT 90] END. Children practice these procedures at their computers. A majority have difficulty copying the program correctly and are puzzled why it does not work. They add extra spaces or leave them out. The concept of variable is not well understood. Children finally produce several designs: a colored-in square; a progressive series of inverted Ls; a partially colored-in double square (5th grade class).

Two boys are working hard trying to fix their program of a house. The house consists of two stories, windows and a double garage. They try different approaches and then edit their program when they are satisfied. Their program consists of one major procedure TO HOUSE and a number of smaller procedures developed by visual approximation in the Immediate mode (6th grade class).

Children continue the assignment of writing their initials. Girls, in general, work in the Immediate or Drawing mode, relying upon visual approximation to get the correct angle or direction. Several boys are working in the EDIT mode. One boy is writing his initials, J.J., in the EDIT mode. His program is a step-by-step procedure which he repeats all over with the second J. The P-O suggests that there may be a way to shorten the program. After she demonstrates how one component can be used as a subprocedure, the child and his partner figure out how to write one program for J, then lift up the pen, reorient the turtle and repeat the program. The youngster is pleased with his efforts. He exclaims, "I like to draw and make designs. I have an Atari at home" (4-5 grade class).

One boy tries Slinky--a circle recursion program. He produces a series of inscribed circles instead of a continuous spiral. He does not seem unhappy with this unexpected result, but he cannot explain why his design came out differently than he anticipated (5th grade class).

Eighth week: Teacher wants youngsters to draw a picture that can be put on the hard disk and saved. The children are taught the necessary commands for their files and then encouraged to draw whatever they want. Two girls working together use the recursion program of GROWSQUARE and make a fan. Then they make a series of circles that resemble a snowman. Two other girls work on writing Hi! One boy working alone tries out Slinky--a recursion pattern of circles. Two girls draw a castle. They do not write subprocedures but instead work out a long, continuous program. Two boys create a cannon and have the turtle shoot up through it. A few other boys boot up the MAZE program. This ia a program that requires children to navigate the turtle through a maze without touching the boundaries. Several boys gather around the screen and each takes a turn trying to get the turtle to move through the maze (6th grade class).

Teacher gives the class a mimeographed handout dealing with recursion to work on. Children have little time to do anything else except follow the handout (4-5 grade class).

Ninth week: Teacher wants to save the children's recursion designs. KAT is not working properly. SAVE.A.PICT does not work. Children sit waiting at their machines, disappointed but understanding.

They continue working on their designs. Both girls and boys are involved in drawing designs using recursion programs. Most seem pleased with results although few can predict what they will be ahead of time. Several youngsters share their "discoveries" with others who try them out on their machines (5th grade class).

A group of girls in fourth and fifth grade exchange impressions about the computer: L: "I didn't like it at first. I didn't like BASIC. It was boring, and I didn't like being told what to do. I like Logo. I get to draw things, and I don't have to type in as much." P: "I like to draw flowers, and I liked the bunny program. But I want time to do my program, too (4-5 grade class).

Children work on the Turtle Theorem program which helps them discover the rule of 360 degrees. Several children work by trial-and-error and approximation as they try to make enclosed six-sided figures. The relationship between number of sides and angle degrees needs to be seen visually by a number of children. Few youngsters take the time to analyze the numbers they are typing in. Some children recognize a pattern and use division to get numbers that will work, but it appears that the majority do not understand the underlying principle of enclosed figures. The teacher does not bring the class together at the end of the session to discuss what they did (5th grade class).

It is an unstructured session. A substitute teacher is present. Two boys are working on SETSHAPE, a program that allows them to change the turtle cursor into another form. They work on creating a car and then design on paper a road for the car to travel along. They plan out a two-lane highway and try to get the car to move along the road. They then discuss whether it is possible to make two cars, each moving in a different difrection. Their ideas are highly abstract, and they try a number of different approaches as they try to solve the program (6th grade class).

Tenth week: Two sixth grade boys are asked how they like working on the computer: E: "I enjoy instant graphics and all the games we played this year (the Dungeon game, Race car game). I like Logo. The graphics mode is easy. I like to hang around after school and play on the computer." C: "I like the way you program on BASIC, but I like Logo, too. I like the KAT program, and I enjoy moving the turtle around the screen"(6th grade class).

Six boys are gathered around one computer watching the results of a recursion program and commenting. One boy returns to his computer and tries to duplicate what he has seen on the screen but confuses the inputs to put inside parenthesis (6th grade class).

The teacher gives the children mimeograph handouts which she tells them to copy. Little explanation is given. Students work on a prepared program called "Puff, the Magic Dragon." On most machines only one child is stationed. Each youngster types in the program and one girl finishes the dragon first. Two boys have difficulty with typos and cannot proofread their mistakes. A number of chldren seem confused about how to edit and need to review the simple commands. Two youngsters try typing GOODBYE in the EDIT mode and cannot understand why the machine does not respond (6th grade class).

It is lunchtime. Six boys are crowded around a computer playing the 3-D game. The boys who are not playing the game are giving encouragement and suggestions to the ones who are. All of the boys have given up their recess period in favor of playing on the machines.

Eleventh week: Teacher introduces "Puff, the Magic Dragon" and suggests that the children try it if they like. One boy finds it too difficult to copy and plays with the keyboard instead. Another boy also finds it hard but keeps working. A girl quickly finishes the program and finds out when she displays the graphic that the dragon's tail is inverted. She asks the P-O for help and together they correct the program. Another girl completes her dragon but discovers when the tail is displayed that she has omitted a line of instructions. Several girls practice making squares. One turns her square into a simple house with a door and window, creating as she goes along. Another youngster practices a recursion design but does not use a recursion program.

The children do not seem too familiar with the CTL features of the machine. Although they can do simple editing, few understand subprocedures or what it means to build one procedure upon another (5th grade class).

Children are editing programs that they wrote a week earlier which has been stored in KAT. Six youngsters (4 girls, 2 boys) opt to do homework instead of working on the computer. Two boys modify their house--changing it into a village consisting of two houses with doors, windows, and TV aerials. One girl works on her American Flag design trying to make small stars fit inside. Another girl works on a recursion program of a star she calls SUNRACH (4-5 grade class).

Four girls work on the computers. One designs an ice cream cone with a cherry on top. Another makes stars and designs. A third tries SQUARAL, and the fourth works on Puff. They all agree to liking the computer and Logo (5th grade class).

Twelfth week: Teacher introduces class to DYNATRACK, a graphics game written in Logo. The object is to try to maneuver the turtle around an inner circle. The teacher relates this to space travel and principles of physics. Two boys are successful at manipulating the turtle. One girl stops working and takes out a book. When asked why, she states, "This is boring and a waste of time. The teacher talks too much, and I'd just rather work than do computer."

A group of boys gather around the teacher and ask him several questions about how that particular program was written and why it works (6th grade class).

Teacher suggests that each child be the creator of a program. "Do some problem-solving. Figure out a design or picture by yourself. Experiment." Two girls are writing a program they call CRAYON. The design is composed of an elongated rectangle topped by a triangle. They write the program as one continuous procedure using the immediate mode first and then transfer their efforts to the EDIT mode. The P-O suggets that the girls might try to modify their program by writing two separate procedures. The girls decide to write a program first for the rectangle. They are successful with this part but find it difficult to orient the turtle correctly to make the tip of the crayon. After three attempts, the girls erase the entire procedure and give up (6th grade class).

One girl works on a bird's body. She seems to know what she wants to create but has difficulty getting the angles just right. She tries a variety of approaches and finally writes a subprocedure which satisfies her.

Two girls draw a boat with a semi-circular base and a triangular sail. They first write a procedure for the boat's bottom, and then they begin to work on a second procedure for the sail (6th grade class).

Findings

From these anecdotal reports a number of patterns emerge. The majority of children enjoyed being on the computer and found Logo fun. There were a few, though, who found Logo hard or boring. While most children eagerly looked forward to computer time, others used this time for reading or working on mathematics homework.

Both girls and boys seemed to enjoy working on the computer with a partner of the same sex. Some children preferred to work alone as it gave them more time to complete an activity. Boy-girl pairs often were dominated by the boy while the girl took the role of observer.

During free time and lunch, boys often came into the computer room to play a game or work out a program. Boys usually came in groups of three, four, or more. Girls tended to shy away from the computer during this time, preferring to chat with a friend or play games on the playground. A girl would be more likely to enter the computer room if a female teacher were present and at least one other girl was working on the machines. Having a friend present helped.

The children's understanding of the different procedures and functions varied. Most children quickly mastered working in the Immediate (Graphics) mode and had little difficulty moving the turtle forward, backward, or turning it left or right 90°. Moving the turtle along a diagonal proved more difficult for some and many children relied upon visual approximation (trial-and-error) rather than taking the time to logically solve the problem.

Writing programs and editing them proved difficult for most youngsters. In order to help the children master the CTRL functions, charts were placed around the room and most children wrote the list of CTRL functions in their notebooks. Few children had difficulty learning to move the cursor or learning the edit functions, but not knowing how to type proved a limitation for many. Often mistakes were made because a space was omitted or the letter O was confused with the number 0. The hunt-and-peck method slowed down many children and made the copying of long procedures tiresome and boring. Several became frustrated and gave up. Others preferred to start again rather than try to find their error and debug their program.

Many youngsters continued to add more CTRL functions to their vocabularies as they spend more time on the computer and became more proficient with the Logo language. In general, most children learned simple formulas and could easily modify them, but only a few youngsters were successful at creating original programs and designs. Using graph paper helped the children plan what they wanted to do, but it was the rare child who stayed with his/her original idea and was successful at executing it as it had been planned on paper.

Powerful mathematical ideas such as the Turtle Theorem (rule of 360° for enclosed polygons) were poorly understood by the majority of the children. Polygons often were drawn by trial-and-error with few children able to verbalize the underlying principles. Through their drawing and experimenting some children came to recognize a straight line as 180 degree and a right angle as 90 degrees, and they used this knowledge to orient the turtle and correct their errors. This worked well when the turtle was visible, but when the turtle could not be seen, many children had problems with orientation.

The principle of recursion was not well understood by most children although a number enjoyed experimenting with programs that used recursion. Children like changing numerical inputs but were usually surprised at the results on the screen. Many designs were the result of chance which pleased the children nonetheless.

The majority of children did little overt planning nor did they seem to have an idea in mind. They discovered what worked as they went along using what they saw on the screen to help them decide what to do next. Sometimes they were inspired by what another child produced. Sometimes a serendipitous input turned into a beautiful design. Occasionally, curiosity and exploration led to new understanding of mathematic principles (e.g., making different size circles).

Several children started with a specific plan in mind but few took the time to analyze their pictures before executing them, and even fewer children divided their problems into smaller components and worked on individual sections. Most children relied upon a step-by-step approach using the screen as a sketch pad. They watched their pictures take form on the screen and corrected as they went along. Most did not transfer their efforts to the EDIT mode until they felt certain that their pictures would turn out "right".

A few youngsters collaborated and developed long-range projects (e.g., the highway, the village). The lack of a reliable storage and printout system, however, made it difficult for most children to keep their excitement and interest in one project over a period of time. Mechanical breakdowns also interfered and caused many children to lose interest. Most youngsters worked on something new each time although in one case, where the teacher assigned the project and graded the results (writing one's initials), the children worked for two weeks trying to develop and edit their programs.

Many children found it difficult to interface subprocedures. This caused some children to give up and erase entire programs or change goals midstream. A number of children needed and requested teacher assistance, some just for reassurance or a desire to share, others because of general confusion. Some children wanted to be told what to do, and many wanted to be shown.

Results of Parent Survey

A survey was sent to each student's family and returned by 88 (55%0 of the children in the study. Eleven youngsters, (or a little under 13%) owned a home computer. Three children (4%) had taken programming classes outside of school. Among their parents, 17 (20%) fathers and 12 (14%) mothers knew how to program a computer. Of this group, the majority (66%) were familiar with BASIC. Five parents (17% of 29) were familiar with Logo. The other languages parents mentioned knowing were PASCAL and FORTRAN. The parents with only one exception (87 or 99%) stated that they werer eager for their children to learn programming. When asked if they felt that their child was eager to learn porgramming, 83 (94%) responded affirmatively (see Appendix D).

The questionnaires were sent out during the first two weeks of the experiment. By the time the parents filled out and returned the forms, the children had been given a brief orientation to Logo as well as some beginning BASIC. Therefore, when asked if their child was familiar with BASIC, 40 parents responded YES and an even greater number (47 or 53%) said their children were familiar with Logo.

Parent Training Session

More than half of the parents (51 or 58%) volunteered to attend a parent training session in Logo. Two sessions were held with 25 parents attending the first session and 15 attending the second. About a third of the parent group was composed of fathers. Notes given to the parents are included in Appendix D.

Teachers' Comments

Every Wednesday after school the teachers and the researcher met to discuss the weekly lesson and any concerns the teachers had. This was a time to air impressions, exchange ideas, discuss approaches that worked and those that didn't, and provide support for one another. The teachers made a number of comments during the first few weeks of the program. Their concerns were as follows:

> Sixth grade teacher: I wish there was someone running the computer to program full time. It's so hard to keep up with learning how to program and all my other classroom responsibilities.

Sixth grade teacher: It's okay to learn with my class. It doesn't seem to bug the kids if you don't know. Nobody is putting down one another. The only frustration is when the machines won't boot up properly.

Fifth grade teacher: I'm having problems using Logo on the hard disk system. The DOS command doesn't always work.

Fourth-fifth grade teacher: I like to take a child through a procedure showing him a step-by-step approach.

Fourth grade teacher: I find it helpful for the children to keep their notes and a list of the commands in a booklet. I like to use class time to go over the commands and then bring the children to the computer room.

Several weeks into the program the teachers' concerns focused on curriculum, plans for the coming year, and the day-to-day operation of the hard disk/printer system:

Fourth grade teacher: The kids all are progressing at different rates. What will happen next year? How do we integrate new students?

Sixth grade teacher: Our fan has finally arrived, and now we can put the hard disk into operation. This should help us save class procedures and permit us to start printing out programs.

Fifth grade teacher: What about word processing? Could we get a printer?

Sixth grade teacher: I'm finding it takes a whole period to teacher a procedure, expecially if all the kids are doing different things on the computer. I only get through one lesson, and I can't go on and do another.

Fifth grade teacher: How can we tie in real units such as math or reading?

Sixth grade teacher: Many of my kids prefer BASIC. Do you think learning Logo is confusing for them?

This teacher is reassured by another. Once you learn one language, it is easy to bounce back and forth from one to another.

Fifth grade teacher: Do you think we ought to group the children next year?

Another teacher (sixth grade) disagrees. The fourth grade teacher thinks strands are necessary, especially for new students. Each strand would cover a different type of program such as BASIC, Logo, word processing. CAI would also be included.

Sixth grade teacher: I know I want someone to write a curriculum for us to follow next year. We need some structure.

Fifth grade teacher: Our current set-up doesn't lend itself to flexibility.

Fourth-fifth grade teacher: We can use more and better softward.

Several weeks into the porgram the two male sixth grade met with the researcher and discussed their impressions of Logo and how their children were responding to the program. Both teachers commented that girls seemed less "conceptual." They noted that boys try to modify the programs whereas girls just copy what is given:

> Many boys take apart existing programs. They analyze them and try to figure out how they work.

Both teachers felt that boys seem more interested in the mechanics of the system:

> They want to know how the hard disk works and how the printer hooks up. They are also more aware of the money that can be earned from computers.

Another striking difference these teachers observed was in the kinds of questions the children asked:

> Boys always seem to take the initiative. They ask, "Can I try? What will happen if...? How can I do that or make that?" Girls, on the other hand, are much more passive. They tend to wait to be shown and want more reassurance. They are not comfortable with debugging or figuring out how something works. They don't seem to mind being shown.

As the term came to a close, the teachers began to make plans for the following year. They were informed that the administration had decided to continue funding only fifth and sixth grades for the magnet computer program next year; hence, a number of teachers found themselves in the awkward position of realizing that their Logo training would not be needed. This news put a demper on the final teachers' meeting. A few teachers felt that their hard work had been in vain and others were angry or disappointed that their efforts had gone unrecognized. The focus of this last meeting was on what had worked, what needed to be imporved, and what the nexct step should be if the Logo program were continued.

All teachers: We need at least two more computers. Our classes are too large and not everyone can work on the machines at our scheduled times.

Sixth grade teacher: Perhaps we can get a grant for computer assistance. We can use more software. A few printers would allow each child to do a separate project. Maybe we can look into getting a music synthesizer and paddles.

Fourth-fifth grade teacher: What was good about this project is that we all got to share with one another. We learned from each other, and we could go to each other.

Sixth grade teacher: We really need to develop a better scope and sequence. This year we all overlapped and did the same things. Perhaps next year we can sequence better.

Fourth grade teacher: We need to pace the children better.

Fifth grade teacher: We need more variation and a variety of software packages.

Fifth grade teacher: Some children struggled with Logo. A number could not understand how to make simple polygons such as a triangle.

Fourth grade teacher: I think the younger ones worked better alone. Sometimes when two worked together, one would get frustrated. I found it easier to bring in only half of my class at a time. This gave them more time to complete a project and gave me a better opportunity to watch them at work.

Fifth grade teacher: I think an hour session is just about right. That would give us enough time for file management and to introduce the lesson.

Findings of the Survey

At the beginning of the experiment the participating teachers were asked to complete a survey on Computer Awareness (see Appendix K). Five of the seven participating teachers (71%) returned the survey. All of the teachers who responded said they felt comfortable with the following computer procedures: DOS, AROS, and BOOTING. Only one of the five teachers (the computer resource teacher) understood such procedures as HARD DISK and HARD DISK SHUT DOWN. Four of the five teachers (80%) felt comfortable with BASIC. Two of the five (40%0 said they knew a little about Logo. Requests for inservices included:

a) Printer and access to printer

b) Hard Disk capabilities and procedures

c) Booting procedures

d) Logo

Four of the five teachers listed the following needs in software:

> All areas of the curriculum including mathematics, language, English, science and social sciences which reinforce and extend concepts taught at each grade level.

Three of the five teachers had taken some inservices in programming. None of the five owned his/her own computer. Three commented upon needing more inservices and curriculum development, "(We need) time to experiment and apply knowledge gained through other people." One teacher requested that the school hire a full-time resource specialist to run the computer program, "It's too hard to run a classroom and a magnet program, too," and two asked for district funding to attend Computer Users in Education workshops.

Results of the Teacher Questionnaires

At the end of the training period the teachers were asked to complete a feedback questionnaire (Appendix I) asking them how they felt about the Logo project. Six of the seven teachers (86%) returned their forms.

All the teachers felt they gained an understanding of the Logo language. All felt that their students developed some Logo skills, but a majority of the teachers had reservations about the amount of learning that had occurred. Three teachers reported that they saw different levels of expertise emerge: "(Not) all students understand the concepts or can use building blocks to write a program."

All the teachers rated Logo as an easier language for children to learn than BASIC but recognized that for some it still proved difficult. One teacher commented that his students found it difficult to keep diaries, and he suggested that each student be given a printed handout of the CTRL functions to keep.

All of the teachers felt that the graphic orientation of Logo was motivating for their students:

> The turtle concept is easy for students to identify.
>
> Children can easily see results.
>
> Graphics allows children to transform words into forms and actions.

One teacher, however, added the following reservation: "There were still a few students who disliked working with the computers and felt too frustrated."

Some dissatisfaction was expressed when the teachers were asked if they felt that the materials they were given were explained adequately and their questions were sufficiently answered. Half of the teachers felt materials were not well organized or sequential:

> Teachers need to see materials in a packet, review them, practice themselves, and then teach.
>
> (We need) better sequential presentation and concept

development and more ideas on projects.

One teacher commented that inadequate time was set aside for inservices. Two teachers who took additional classes in Logo at the County TEC Center felt that the booklet prepared by the center and the inservices given were extremely helpful.

A majority of the teachers (four out of six or 67%) felt that the trial period for teaching Logo was sufficient. The first two weeks was an orientation period in which Instant Logo was used. This was followed by a ten week program of Terrapin Logo.

When asked "What was left out of the training?" five of the six teachers were very specific in listing their needs and noting their concerns:

(We needed) time to work on the computers.

It is assinine to try and learn what you are supposed to be teaching the same day.

Background--(we need) work up lessons to Logo.

Ideas on building with blocks or parts/synthesis.

(We need) a comprehensive scope and sequence with specific activities. File management training is also needed.

The teachers commented that the most effective parts of the project were as follows:

(The) cooperation and assistance among instructors and students.

Some kids finally "seeing" angles of 90 degrees, etc.

> The challenge to the staff and subsequent growth.
>
> Good inservices with sufficient computers nearby for practice. This environment is best for computer inservice.
>
> Printing out Logo figures for kids to actually take home and keep.

Five out of the six teachers (83%) said they would continue to use Logo in their classrooms. One teacher saw Logo's applicability in mathematics and social studies. Another saw it as useful for projects. Two teachers planned to continue their study of Logo, hoping to master more commands and primitives for future instruction and to develop a more thorough curriculum plan which emphasized top-down planning. One teacher planned to continue using Logo in the same way as he had. The only dissenting voice came from a fifth grade teacher who had been reassigned to fourth grade for the following year. Her response, "As a fourth grade teacher, I'll probably not use it," seemed motivated in part by the administration's decision to discontinue the computer magnet funding for fourth grade.

Two of the six teachers added these further ideas and comments:

> (We need) a well-defined and labeled library of software computer worktime for on-site staff.
>
> District/parents/board need to make a financial commitment to this excellent program. (There is a) need for more computers (and an) updating of the

networking system.

I have asked for lessons to be given before each actual lesson is to be taught on the computer.

Results of Children's Questionnaire

All of the children (174) who took part in the project were asked three questions upon the completion of their Logo training:

What did you like best about computers this year?

What did you like about Logo?

Was there anything that you did not like about Logo?

Out of the 174 children, 173 answered the first question, 170 completed the second question, and 174 completed the last for a response rate of 99%.

<u>What Children Liked Best About Computers</u>

A comparison of comments made by girls and boys about their computer experience shows remarkable similarities (note Table 20). A little more than 40% of both sexes chose Logo as the computer activity they liked the best (40 out of 172 boys, 31 out of 75 girls). Third youngsters (17%) reported that they liked learning new skills and that they felt working on the computer was educational. An equal percentage of boys and girls (14%) stated playing games on the computer was the activity they most preferred. Ten percent of both sexes (17 youngsters) listed BASIC as their favorite computer activity and another 10% stated that programming was what they most liked to do. (It was not clear whether programming meant BASIC, Logo, or a combination of the two). Additional comments included: I liked typing (2%), computer was fun (2%), I liked working by myself (1%), I liked my teacher, and I liked my math class. Two youngsters (one of each sex) said that there was "nothing" that they liked about computers.

Table 35

What I Liked about Computers This Year

Comments	Sex: Boys n = 98	Sex: Girls n = 76	Total n = 174
Logo	41%	41%	41%
Educational	19%	14%	17%
Games	14%	13%	14%
BASIC	10%	9%	10%
Programming	10%	9%	10%
Typing	1%	4%	2%
Fun	2%	3%	2%
Working by self	0%	3%	1%
Other Comments	1%	1%	1%
Nothing	1%	1%	1%

1% of the girls comments are missing or .5% of the total

What Children Liked About Logo

The children listed a number of features about Logo that they enjoyed (note Table 21). Out of 170 children a third (32%) listed drawing or working in the graphics mode as the feature they liked most. Specific functions such as the REPEAT command and EDIT were favored by 31 children (15%) with more boys (21 out of 95 or 21%) than girls (10 out of 75 or 13%) giving this response. Twenty-three youngsters (13%) simply stated that Logo was fun to do. Nine of the boys and four of the girls enjoyed making shapes (7%) and nine youngsters (5%) enjoyed working on specific prepared programs (e.g., Bunny; Puff, the Magic Dragon; Growsquares). Six of the girls (8%) said they liked the Turtle best, whereas only two boys (2%) gave this as a response. Five youngsters (three boys and two girls) stated they liked everything about Logo while 10 youngsters (eight boys and two girls) stated that they did not like anything about Logo.

Two responses were unique to one or the other sex. Five boys (5%) stated they liked Logo for its educational value. Five girls (7%) said they liked the idea of controlling the computer (see Table 36). In addition, there were a number of comments that did not lend themselves to categorization (five).

Table 36

What Boys and Girls Liked about Logo

Comments	Sex		
	Boys n = 98	Girls n = 76	Total n = 174
Graphics/Drawing	30%	36%	32%
Specific Functions of Logo (REPEAT, EDIT, commands)	21%	13%	18%
Fun to Do	10%	17%	13%
Making Shapes	9%	5%	7%
Specific Programs (Turtle Games; Growsquare; Bunny)	5%	5%	5%
The Turtle	2%	8%	5%
Everything	3%	3%	3%
Educational	5%	0%	3%
Controlling the Computer	0%	7%	3%
Other Comments	3%	2%	3%

Missing data included 3% of the boys and 1% of the girls for a total of 2%.

It should be noted that 8% of the boys and 3% of the girls for a total of 6% of the children said they liked nothing.

<u>What Children Did Not Like About Logo</u>

In answer to the question, "Was there anything that you did not like about Logo?" a majority of the youngsters (65%) responded "Nothing" (63 boys or 64% and 45 girls or 59%). Negative remarks included finding Logo boring (9%), not liking the assigned lesson (6%), not enjoying long procedures or the time it took to execute them (5%), and not liking the mechanics involved (5%). These remarks were evenly distributed between the sexes (note Table 22).

Two distinct differences emerged between boys' and girls' view of Logo. First, five boys (5%) stated that they did not like anything about Logo whereas no girl gave this response. Second, a significant number of girls (11 or 14% as opposed to 2 boys) commented that Logo was hard and confusing and that they did not like making mistakes. This latter sex difference was significant: ^{2} (i, N = 13) = 9.57 (see Table 37).

The Brookline Logo Project Tasks

Ninety-eight (56%) of the children in the experimental group completed the Brookline Project tasks pre and post:

Grade	Boys	Girls	Total
4	34	30	64
5	9	6	15
6	8	11	19

Table 37

Comparison of What Boys and Girls Did Not Like About Logo

Comments	Sex: Boys (n = 98)	Girls (n = 76)	Total
Nothing	64%	59%	62%
Logo was Boring	9%	8%	9%
Logo was Hard, Confusing/ I made Mistakes	2%	14%	7%
Didn't Like the Assigned Lesson	5%	7%	6%
Didn't Like the Mechanics	7%	4%	5%
Didn't Like the Long Procedures	4%	5%	5%
Other Comments	3%	3%	3%

5 boys commented that they did not like "everything" about Logo (5% of the number of boys). No girls gave this comment.

Chi-Square was significant for the response "Logo was hard, confusing, or I made mistakes." χ^2 (1, n = 13) = 9.57, $p < .002$

There were 51 boys, 47 girls or a total of 98 youngsters who participated. The Brookline tasks consisted of line estimation, angle estimation, sequencing and route planning.

Data Analysis

The task of line estimation required each child to determine the length of five different line segments after being given an example which served as the standard. The difference between each line's actual length and estimated length was calculated. The median of these five calculations was used as the child's line estimation score. A perfect score was zero.

The Brookline task of angle estimation required that each child determine the number of degrees in four different angles after being given an example which served as the standard. As above, differences were calculated, and the median difference score served as the angle estimation score. Again, a perfect score equalled zero.

Logo sequences consisted of a series of forward and backward commands. Each child was required to determine how far the turtle has travelled. For each correct sequence the child received one point. Scores ranged from zero to four points.

Route planning required that each child correctly draw and describe a path taken from point A to point B. Full credit (one point) was earned if the child correctly stated the number of blocks travelled and the direction of turns taken. For each error, one-fourth point was subtracted.

To examine whether or not each sex improved in ability to perform these tasks after a 12-week training period in Logo, difference scores were compared by means of the Wilcoxon matched-pairs signed-rank test, an appropriate nonparametric test for paired observations. To determine whether or not there was a difference between the way each sex performed, boys and girls pre and post scores were compared by means of the Mann-Whitney U-test, an unpaired samples test appropriate to use with equal dispersions. The Ansari-Bradley test determined if the sample dispersions were equal.

Results of the Brookline Tasks

On all four pretests boys perfromed slightly better than girls, but these differences were not statistically significant. After Logo training, significant differences were shown between the girls' and boys' groups on the sequencing and route planning tasks with girls improving on the sequencing task and boys improving on route planning. No significant differences were shown on tasks of line and angle estimation, although the girls' scores improved somewhat onthe task of line estimation.

Line Estimation

Lower scores reflectged more accurate estimations of line length (less deviation from the standard example). On the pretest, boys performed this task better than girls. The null hypothesis of equal dispersions was rejected when pretest scores were compared (Ansari-Bradley test: adjusting medians $z = 2.76$, $p < .01$). However, dispersions were found to be equal on the posttests, allowing the Mann-Whitney U-test to be performed ($z = .77$, $p > .05$).

Boys' posttest scores were not significantly different from pretest scores (Wilcoxon matched-pairs signed-ranks test, sample of difference median = 1.5, Calculated: 526, CV = 396, N = 48, $p > .05$). Neither were the girls' pre and posttest scores (Wilcoxon matched-pairs signed-ranks test, Median = 11.5, Calculated: 329, CV = 327, N = 44, $p > .05$). Although the girls' posttest scores improved, making them more similar to the boys' posttest scores, there was insufficient evidence to reject the null hypothesis (Mann-Whitney U-test for unpaired samples with equal dispersions, $z = .772$, $p = .44$) (see Table 38).

Table 38

Pre-Post Comparisons of Line Estimation by Sex

		Median	
Sex	n	Pretest	Posttest
Boys	51	20	20.5
Girls	47	35	20

For both groups there were three pairs of scores that stayed the same with the sample of difference median for boys 1.5 and for girls 11.5

Angle Estimation

Boys performed better than girls on the pretest, with lower scores reflecting better estimations of (less deviation from) angle size). The pre and post difference scores for the boys' group and the girls' group were compared by means of the Mann-Whitney U-test(z = 2.03, p > .05); and since the comparison was not significant, there was insufficient evidence to reject the null hypothesis.

There were no statistically significant differences between pre and posttest scores on angle estimation for either boys (Wilcoxon matched-pairs signed-ranks test: Median = 2.5, Calculated: 547.5, CV = 396, N = 48, p > .05) or girls (Wilcoxon matched-pairs signed-ranks test: Median = 3, Calculated: 441.5, CV = 343, N = 45, p > .05) (see Table 39).

For the boys' group there were three pairs of pre-post scores that stayed the same with the sample of difference median = 2.5. For the girls' group there were two pairs that stayed the same and the sample of difference median = 3.

Most children had little difficulty estimating angle sizes of less than 90°. Angles between 90° and 180° proved more difficult to estimate. Most difficult of all was determining angles between 180 and 270 degrees.

Table 39

Pre-Post Comparisons of Angle Estimation by Sex

		Median	
Sex	n	Pretest	Posttest
Boys	51	30	25
Girls	47	45	30

Sequencing

Boys performed better than girls on the sequencing pretest with a higher median score of correct sequences (three as compared to two for girls). Difference scores for the boys' group and the girls' group were compared to each other and found to be significantly different at the $p < .02$ level (Mann-Whitney U-test with equal dispersions $z = -2.188$) despite the fact that on its own, neither group demonstrated a significant change. For the girls, 21 pairs of scores stayed the same (Wilcoxon matched-pairs signed-ranks test: Median = -1, Calculated: 134, $N = 26$, $CV = 110$, $p > .05$), and the difference between the two samples was not statistically significant. For the boys, 19 pairs of scores stayed the same (Wilcoxon matched-pairs signed-ranks test: Median = -1, Calculated: 253, $CV = 159$, $N = 32$, $p > .05$) with the difference between the samples also non-significant (see Table 40).

Table 40

Pre-Post Comparisons of Sequencing Task by Sex

		Median	
Sex	*n*	Pretest	Posttest
Boys	51	3	3
Girls	47	2	3

Twenty-one girls and 19 boys showed no change in pre-post test scores. The sample of differences median for both groups was -1.

A number of children found the sequencing task confusing. When asked to determine how far the turtle had travelled, some children misinterpreted the tasks and tried to see "patterns" in the sequence, responding to the following sequence with FD 50 instead of FD 20:

FD 30 BK 20 FD 40 BK 30----→

Route Planning

As in the three previous tasks, boys performed better than girls on the pretest with a median score of .75 as compared to a median score of .50 for the girls. However, the difference was not statistically significant. After Logo training there were significant differences shown between the two groups (Mann-Whitney U-test: Calculated: 1511.5 $z = -2.30$ $p < .05$) (see Table 41).

Table 41

Pre-Post Comparisons of Route Planning by Sex

		Median	
Sex	n	Pretest	Posttest
Boys	51	.75	.75
Girls	47	.50	.50

Fifteen boys and 11 girls had pre-post scores that stayed the same. The sample of difference medians for both groups was -.25.

No child had problems drawing a line from point A to point B on the route planning task, but difficulty was shown in verbally describing the route taken. More boys oriented themselves as if they were actually taking the route; and, therefore, showed few difficulties in giving directions. In contrast, many girls had difficulty placing themselves in this position and chose instead to describe the route as though a person was moving towards them as they remained stationary. This resulted in a confusion of right and left.

Implications of all findings in Chapter IV, Sections I and II, as well as suggestions for implementation and areas for further research are discussed in Chapter V.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The influence of the Logo environment upon a youngster's attitude toward mathematics, locus of control and problem solving skills was examined experimentally to determine whether Logo strengthens proble-solving skills, promotes confidence in and improves attitudes toward learning mathematices, while conversely, reducing "math anxiety," especially among girls. Youngsters in grades 4, 5, 6 were the subjects of this experiment which examined the following questions:

1. Can studying Logo help children in grades 4, 5, 6 modify their internal-external beliefs of themselves as learners and improve their attitudes toward the learning of mathematics?

2. Can the study of Logo help youngsters improve their problem-solving strategies?

Studies by Papert (1980) and others suggest that youngsters who have had the opportunity to discover mathematical principles for themselves gain confidence in their ability to perform tasks in mathematics and view themselves as more successful learners. Logo was developed as a self-discovery method of learning mathematics based upon Piagetian principles. Anecdotal reports by teachers

Logo suggest gains in confidence and self-esteem are shown in students who have studied Logo (Milner, 1973; Fire Dog as quoted in Clements, 1984). However, this has never been tasted experimentally in a large group.

Design of the Study

The study, conducted in 1983 in two public elementary schools in a single school district located in a moderate sized city in north San Diego county, employed both an experimental design and an ethnographic approach. Two major hypotheses and a number of subhypotheses were tested. Additionally, data from classroom observations, teacher interviews, parent surveys, and teacher questionnaires were analyzed to obtain qualitative findings regarding the process and perceived outcomes of the program.

The intact nonequivalent control group design was employed for the purposes of this study. A modified form of cluster sampling was used at the experimental site, with six out of nine classes chosen to participate (two from each grade level). One of the fourth grade teachers asked to be excused from the study, and a combination class (4-5) was substituted. Additionally, another teacher volunteered to take part in the study and was included for administrative reasons. All teachers at the experimental site attended weekly training sessions in Logo from March 18 until June 10 and were given weekly lesson outlines. There were 174 children who were trained in Logo at the experimental site.

At the control site, four out of eight classes were randomly chosen to participate in the study, with classes from each grade level and combination class included in the sample. The final sample numbered 98 students.

Students from both sites were given two instruments to complete at the beginning and conclusion of the study. They were Dutton's, "A Study of Attitude toward Arithmetic," and Crandall et al.'s, "Intellectual Achievement Responsibility Questionnaire." Students in the experimental group received at least one hour a week of Logo instruction over a 12-week period with the first two weeks devoted to Instant Logo and computer Logo games. Students at the control site received no computer training. Both groups of students followed the same mathematics curriculum as prescribed by the district. At the beginning and completion of Logo instruction a test-retest of 98 students at the experimental site on the Brookline Logo Project Tasks was performed. In addition, weekly observations of the students were made as they studied Logo, and teachers were interviewed periodically. At the conclusion of the study the children were asked how they felt about computers and learning Logo. All of the participating teachers at the experimental site took part in the final interview, and six of the seven completed questionnaires asking them how they felt about the program.

Data were analyzed by applying chi-square, a variety of nonparametric statistical tests (McNemar, Mann-Whitney, Wilcoxon matched-pairs signed-ranks test) and multifactor analyses of variance. All analyses were computer assisted.

Findings

Testing the Hypotheses

Hypothesis 1 stated that there would be no significant differences shown in attitudes toward mathematics between girls and boys in grades 4, 5, 6 who study Logo and control group students who do not study Logo. The hypothesis was rejected at the $p < .01$ level. Analysis of the data indicated that there were significant differences between the groups by sex in test-retest scores. The results of the study showed that after a 12-week period of studying Logo, boys' attitude acores toward arithmetic improved significantly while girls' scores declined. No significant changes in attitude scores were shown among a group of control group students.

An analysis of children's favorite subjects found that more boys in the experimental group changed to a positive opinion about mathematics than did girls in the experimental group or children of either sex in the control group. This difference was not statistically significant. The null hypothesis was, therefore, not rejected.

Hypothesis 2 stated that there would be no significant differences shown in total IAR locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo. The hypothesis was not rejected. However, an analysis by sex revealed that there were significant differences between girls and boys in both the control and experimental groups on their pretest total IAR scores, with the control group boys scoring higher than the control group girls and the experimental group girls scoring higher than the experimental group boys ($p < .04$). In test-retest analysis, boys and girls in the experimental group increased their IAR scores ($p < .01$ and $p < .05$, respectively) as did girls in the control group ($p < .01$). Boys in the control group showed no significant change in test-retest scores. Differences by age were observed between groups; but all 10-year olds in the control group scored higher than the same age children in the experimental group ($p < .01$). Differences between boys and girls by grade were shown in both groups. Fourth grade boys scored higher than fourth grade girls, while the reverse occurred in the fifth and sixth grades ($p < .05$).

Subhypothesis 2.1 stated that there would be no significant differences shown in positive IAR locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo. The hypothesis was not rejected. However, an analysis by sex paralleled the total IAR results. Similar differences between the sexes by grade level were suggested ($p < .08$), and significant interactions were shown overall between groups by sex ($p < .02$) and groups by age ($p < .05$).

Hypothesis 2.2 stated that there would be no significant differences shown in negative IAR locus of control measures between students in grades 4, 5, 6 who study Logo and control group students in grades 4, 5, 6 who do not study Logo. The hypothesis was not rejected. However, an analysis by grade level revealed a significant interaction between groups on test-retest measures ($p < .01$). Grades 5 and 6 in the experimental group and grade 4 in the control group showed significantly higher scores ($p < .01$). A significant difference in test-retest negative IAR measures was shown between sexes with girls in both groups scoring higher than boys on overall negative IAR measures. Significant differences by age were observed between the groups ($p < .05$). Nine, 11 and 12-year olds in the control group and 10-year olds in the experimental group achieved higher negative IAR scores. Significant differences in boys' and girls' scores were observed in the experimental classes. In five out of seven classes girls had higher negative IAR scores than boys ($p < .03$). Within the control group test-retest differences by sex were not shown. Two classes, however, showed significant increases in test-retest scores ($p < .05$).

Negative locus of control was also examined by having children give reasons for "getting a poor grade." The majority of boys and girls in both groups gave internally oriented responses ("I didn't work hard enough" or "I'm not good at this subject") as reasons for getting a poor grade. An interesting difference was observed between the sexes on the retest, however. A significant number of boys in both groups changed their responses ascribing failure to a lack of effort ("I didn't work hard enough"). Girls did not show significant changes in their responses.

Addressing the Ethnographic Questions

Questions concerning problem-solving were examined using an ethnographic approach which included students' self-reports, observations, classroom interactions and informal interviews with teachers and students. Using this approach the following questions were addressed:

1. Will students who have had Logo training show improvement in their ability to perform tasks of estimation, sequencing and route planning on the Brookline Logo worksheets?

2. Will students trained in Logo demonstrate improved logical thinking and problem-solving skills?

3. Will children who have had experience with Logo demonstrate increased persistence, motivation and ability to sustain interest in a project?

4. Will differences be shown between boys and girls in their approaches to problem-solving and the strategies they use in programming tasks?

Analysis of the test-retest data of the Brookline tasks revealed significant differences between the girls' and boys' groups on the sequencing and route planning tasks with girls improving on the sequencing task ($p < .02$) and boys improving on route planning ($p < .05$). No significant differences were shown on tasks of line and angle estimation, although the girls' scores improved somewhat on the task of line estimation. It should be noted that on all four pretests boys performed slightly better than girls, but these differences were not statistically significant.

Anecdotal reports and observations of youngsters as they worked revealed that the majority of children enjoyed being on the computer and found Logo fun. The time spend on the computer, however, was not equally distributed between the sexes. During free time, groups of boys often came into the computer room to play a game or work out a program. Girls were less frequently observed in the computer room during these times.

Children's understanding of the different computer procedures and functions varied. Difficulty was shown in moving the turtle cursor along a diagonal or in orienting the turtle's heading. Most children relied upon visual approximation.

Writing programs and editing proved difficult for most youngsters. Not knowing the keyboard made typing commands difficult and often, frustrating. Many children preferred to erase the screen and begin again rather than correct errors.

The majority of children did little overt planning. Not many children started with a specific idea of what they wanted to accomplish. More on-task behavior was observed when the children were given a specific assignment. Most children learned a few simple formulas (e.g., square, circle) and could easily modify the size of shapes by varying numerical inputs, but only a few youngsters were successful at creating original programs and designs. Few seemed to understand powerful mathematical ideas, such as recursion. it was difficult for most youngsters to verbalize the underlying mathematical principles behind a procedure.

Children usually discovered what worked as they went along. Most relied upon a step-by-step approach using the screen as a sketch pad. Withou specific guidance an analytic strategy composed of simple procedures which could be built upon, proved too difficult for most children. Most youngsters needed help in trying to interface subprocedures and were confused when the turtle appeared on the screen in a different place than they had anticipated. The majority of children were content with just producing a recognizable drawing.

Teachers observed that children were progressing at different rates, with different levels of expertise emerging. Some children struggled badly. A number could not understand how to make simple polygons such as a triangle. Not all students understood the concepts or were comfortable using building blocks to write a program. Teachers felt that, in general, their students had developed some skills of Logo, but a majority of the teachers had reservations about how much learning actually took place. Boys were described as being more curious and interested than girls in the mechanics of the system and computer programming. "Many boys take apart existing programs...try to figure out how they work." Boys were seen as being assertive ("They always take the initiative") whereas girls were viewed in passive terms ("They wait to be shown and need much more reassurance"). Some teachers felt that when children worked together they became more frustrated. Teachers thought that it might be better to expand the lesson period to an hour and have fewer children work in the computer room at one time.

Other Findings

Questionnaires and Surveys

The analyses of questionnaires and surveys completed by students, parents, and teachers resulted in the following additional findings:

1. Children from both groups expressed the same likes and dislikes about arithmetic. Their favorite topics were fractions, multiplication, and addition. The topics they least liked were division, subtraction and word problems.

2. Children made more comments about what they did not like about arithmetic than what they liked about arithmetic, supporting Dutton's (1951) findings. The majority of the reasons given for liking or disliking

arithmetic focused upon the child's interest in the subject or the way the specific tasks were taught or perceived. Arithmetic was described by those who liked it as fun, challenging, interesting, or practical. It was described by those who disliked it as boring and hard.

3. Children in the experimental group made more critical remarks about teachers and teaching methods, whereas in the control group the opposite occurred. This suggests a greater self-confidence and self-assurance in the experimental group.

4. The "fear of failure" was cited by a small number of children in both groups as a reason for not liking arithmetic. On retesting a decrease in this type of comment was shown in the experimental group.

5. Over 99% of the parents surveyed stated that they were eager for their children to learn programming.

6. Almost 95% of the parents surveyed felt that their children were eager to learn programming.

7. Teachers at the experimental site felt comfortable with standard machine operations that they had practiced (DOS, AROS, BOOTING). They felt less secure with new procedures and requested additional inservice training in order to feel comfortable with more complex filing and operating systems (such as the hard disk and the printer).

8. All of the teachers felt that they had gained an understanding of the Logo language after the 12-week period. A majority (67%0 felt that the trial period for teaching

Logo was sufficient.

9. The teachers felt that Logo materials and lesson plans needed to be better organized into a comprehensive scope and sequence with specific group activities outlined.

10. Teachers felt it important to have time set aside for them to practice computer skills and that inservices were necessary.

11. Improved assistance and cooperation among instructors and students were cited as one benefit of this project.

12. Eighty-three percent of the teachers (five out of six) who responded to the teacher questionnaire stated that they would continue to use Logo in their classrooms.

13. Ninety-nine percent of the children stated that they liked working on the computer.

14. Ninety-four percent of the children stated that they liked Logo.

15. An equal percent of boys and girls (40%) chose Logo as the computer activity they most preferred.

16. The Logo feature youngsters most liked was being able to draw pictures and designs on the screen (35%). All the teachers felt that the graphic orientation of Logo was motivating for their students.

17. Less than 40% of the children cited drawbacks to Logo. This included finding Logo at times boring and not enjoying the lessons. A few youngsters did not like the

mechanics involved or the time it took to execute a procedure.

18. A significantly greater number of girls than boys commented that Logo was hard and confusing and that they did not like making mistakes ($p < .01$).

19. A number oc children tried to find number "patterns" when doing the Brookline sequencing tasks (e.g., FD 20 BK 19 FD 30 BK 20--→ FD ?). Instead of computing the distance travelled by the turtle as FD 20 steps, they gave FD 40 steps as their answr, a logical response if one focused only on number pattern: 20, 10, 30, 20... . This suggests that many youngsters use a global style of problem solving and peform mathematical problems in a "rote" manner. When the form of the problem looks familiar to previously learned problems, children tend to imitate the pattern.

20. On the Brookline task requiring children to draw and then describe the steps needed to go from point A to point B, girls, especially, had difficulty giving directions. They confused right and left in their descriptions and gave directions as if they were watching someone walk towards them rather than being the person actually taking the route. This confusion in directionality supports findings of Maccoby and Jacklin (1974) that boys have better developed spatial orientation than girls.

21. Teachers' style of teaching did not appear to alter findings significantly as shown in test results,

despite the fact that they used a variety of instructional methods to present the lesson.

Conclusions

Attitude toward Arithmetic

Previous studies have demonstrated that the middle school years (grades four through eight) are crucial in the development of students' attitudes toward mathematics. The link between achievement expectancies and performance in mathematics has been shown by a number of researchers, with girls often found to have lower expectancies (Dweck & Brush, 1976; Parsons, Ruble, Hodges & Small, 1976) and less positive attitudes than boys (Fennema & Sherman, 1977). Papert (1980) notes how powerfully self-reinforcing negative self-images can be, "If people believe firmly enough that they cannot do math, they will usually succeed in preventing themselves from doing whatever they recognize as math" (Mindstorms, p. 42). He suggests that one way of intervening is to place children in an environment that encourages self-discovery--a "Mathland" where mathematics is naturally spoken and children can explore relationships for themselves without fear of punishment for errors. Logo, according to Papert, is such an environment.

The children in this experiment were introduced to Logo over a 12-week period to see if Logo could modify their attitudes as "emotionalized feelings for or against something (p.84). He developed his scale by asking students to write down their feelings toward arithmetic. He found that negative comments outnumbered positive comments and seemed to be more emotionally charged than positive ones. The seven most frequently mentioned reasons for not liking arithmetic included lack of understanding, teaching dissociated from life, pages of word problems, boring drills, poor teaching, lack of interest, and fear of making mistakes. Students' reasons for liking arithmetic included proficiency in it, good teachers who explained the work and made it meaningful, and appreciation of arithmetic as a vital subject in the curriculum. In other words, Dutton concluded, "a good teacher, a challenging experience, and numerous practical or meaningful applications help youngsters develop favorable attitudes toward the subject" (p .89).

Aiken (1970) and others have labeled grades four through eight as crucial in developing attitudes toward mathematics. However, as students progress in school, studies show that their attitudes toward mathematics decline especially in the later grades (Antonnen, 1969).

The results of this study showed that Logo could serve a role in reversing this decline among boys but not among girls. Boys in the experimental group showed significant increases in their attitudes toward arithmetic scores. Girls, on the other hand, showed a decline in their attitude scores. Children in the control group showed non-significant decreases in their test-retest attitude scores.

It may be argued that the positive effects observed were not specifically related to the Logo experience. Boys as a group spent more free time on the computer, and as a result of their experiments with programming and games may have come to value mathematics simply because it proved useful for pormoting success with the computer.

Locus of Control

Locus of control measures for both boys and girls improved after Logo training. However, increases in scores were also shown for girls in the control group, suggesting that some of the gain in scores was due to maturation or to factors other than Logo training. Crandall, Katkowsky, and Crandall (1965) note that both age and experience contribute to children developing self-responsibility for their actions, although normative data on more than 900 subjects indicate that self-responsibility may already be established by third grade. Boys in the control group showed little change in their test-retest scores, but as a group they started with the highest IAR scores.

The IAR assesses the extent to which a child feels responsible for his/her successes and failures, specifically in academic intellectual tasks and situations. Crandall, Katkowsky, and Preston (1962) found that boys who took responsibility for their intellectual performance spent more time in intellectual free play activities than did boys who externalized responsibilities for their performance. It is interesting to note that more boys than girls in the experimental group worked on computers during free time (lunch and after-school). McGhee and Crandall (1968) found that both the I+ and I- subscales of the IAR predicted girls' grades and achievement test scores, while boys' scores were predicted more consistently by I- subscale scores (i.e., "belief in their responsibility for failure"). The exception to this was in fourth grade where the I- measures were a better predictor of grades for girls, while I+ measures were a better predictor of boys' grades. It is, therefore, of interest that fourth grade boys in both groups scored higher than fourth grade girls on I+ measures. On I- measures, fourth grade boys who studied Logo outperformed girls on test-retest measures although in the control group, both girls and boys in the fourth grade showed significant gains in I- test-retest measures. Girls in the fifth and sixth grade in both experimental and control groups outperformed boys on IAR measures, concurring with Crandall's (1965) findings that older girls give more self-responsive answers than do older boys.

Messer (1972) found that boys who took credit for their academic successes and girls who accepted blame for their failures were most likely to have higher grades and higher achievement test scores than children with different profiles. This study did not examine achievement test scores to see if such a relationship exists.

In the experimental group, boys of all grades showed test-retest gains in both positive and negative IAR measures. Girls in fifth and sixth grades showed test-retest gains in both measures, whereas girls in fourth grade showed modest gains in positive IAR subscores but a significant decline in negative IAR subscores. This contradicts Crandall et al.'s (1965) finding that girls assume a greater level of responsibility for negative events between third and fourth grade, which was based on a rise in I- scores in his study. It should be noted that Crandall (1965) found test-retest correlations after a two-month interval to be .69 for total IAR scores, .66 for I+, and .74 for I- with no significant sex differences shown.

Problem-Solving

Currently, efforts are being made in our schools toward developing computer curricula that will provide children with the ability to converse comfortably in a computer language. All languages consist of the expression and communication of thoughts and ideas through gesture, symbol, or sound. A computer language uses a special set of symbols, numerals, and rules (patterns, one might say) for the transmission of information. Computer literacy, therefore, may be defined as having competency in the use of such a "vocabulary-of-patterns" (Peters & Waterman, 1982).

All languages devlop gradually over a period of time through a combination of formal education and practical experience. Fromal education provides us with the basic tooks, the necessary foundation and building blocks, to understand the forms, structures, rules and logic behind a language (e.g., syntax and semantics). Practical experience, on the other hand, gives us the opportunity to experiment and try new combinations, to imitate and practice, and to ultimately reshape the theoretical into a workable, personal model.

Administrators and teachers often believe that by providing children with the formal tools of a computer language, i.e., the rules of the language as well as basic instruction in the technical skills needed to operate the machines, they are doing enough to promote computer literacy. They tend, in general, to overlook the need for practical experience which translates into the opportunity to practice a language in an environment that is supportive and non threatening.

Infants learn to speak only after years of listening, watching, and practicing what they see and hear. Eventually, they internalize the rules of the language and begin to expand their vocabularies. However, not all infants develop a language at the same rate, nor with the same degree of complexity. Some obviously develop richer vocabulary patterns than others and are more creative in their ability to utilize the language.

H. A. Simon, in his research on chess players (as quoted in Peters & Waterman, 1982), discovered that "while the class A chess player has a vocabulary of around 2,000 patterns, the chess master has a vocabulary of around 50,000 patterns." According to Simon, when confronted with a chess problem, chess masters do not rely upon "decision-tree" thinking, but begin instead to use their extensive memory patterns. They ask themselves, "Have I seen this one before? In what context? What worked before?" Certain board configurations seem to trigger memory patterns which in turn help generate a number of possible solutions. They then follow George Polya's (1945) model of problem-solving, going through a mental checklist of heuristic questions such as: Can this problem be related to a problem I already know how to solve? Can this problem be divided into simpler problems?" Such an approach represents the marriage of formal education and practical experience. This integration of the formal and practical, internalized into memory patterns, can thus be used intuitively and, ultimately, creatively.

Sex Differences

A closer examination of current practices both in the schools and at home suggests that despite our belief that we are providing equal opportunities for girls and boys in the formal aspects of computer training, a real difference exists in the amount of time allotted for practice. In other words, despite there being no sex difference in computer aptitude, children differ in their interest and willingness to spend time practicing computer skills. It is reasonable to suggest that the youngster who spends more time experimenting and asks more questions would eventually develop a richer "computer vocabulary" than the child who just does what he/she is told.

Based on the results of this study, it appears that boys and girls do not get equal opportunity to develop a "vocabulary of computer patterns" because of differences in interest and motivation. The observations gathered from this study would suggest that girls, in general, do not spend the same amount of "recreational or free" time as boys at the computer. Boys will often give up lunch time or recess to "get on" the machines, whereas girls are much more reticent to do so. The girls studied were willing to work on assigned computer tasks, and often performed these tasks competently, but interest in general was not so strong that the girl would willingly give up recess or lunch in order to have a computer to herself. Kiesler, Sproull and Eccles (1983) found that girls liked to use the computer, but not if they had to fight with boys to get a turn. Social pressures and differences in boys' and girls' patterns of social interaction also play a role. One 10-year old girl noted the following reasons for not choosing the computer as a "free-time" activity:

> I get nervous when groups of girls are around. Girls, I think, tease and kick you out of groups more than boys. I get nervous because I might make a dumb mistake and then my friends will tease me. Also, the boys are up to the computer room before most of the girls. I hate most boys, and they take all the computers.

Ironically, according to Papert turtle geometry (Logo) was designed to be something children could make sense out of in order to help them develop the following "mathetic strategy: In order to learn something, first make sense of it" (Mindstorms, p. 63). Logo employs "syntonic learning," i.e., it was designed to make use of the child's sense and knowledge about him/herself. Papert says that a youngster's learning is dependent not upon the content of knowledge but his/her relationship to it (Mindstorms, p. 65). This relationship, however, does not consider the influence of societal role models and differences in social expectations.

The results of this study indicate that interest in Logo does not seem to differ by sex. An equal number of girls and boys said they liked Logo and enjoyed their computer experiences. The differences came instead in the children's interpretations of their experience. A significant number of girls stated that they found Logo hard to understand and that they were afraid of making mistakes. Despite the fact that Logo encourages "debugging" many girls erased entire procedures and found it easier to start again than correct their errors. Perhaps, again, this represents "fear of failure" at work.

"Logoland" in the Curriculum

Papert would have us believe that Logo is a "remedy for developing a new relationship with numbers" (Mindstorms, p. 151). It appears, however, that the attitude of the learner towards the process of learning remains important. The school "ethic" teaches that errors are bad. Girls appear to be more acutely aware of this than boys. Logo's "debugging" philosophy suggets that errors benefit us because they encourage us to study what went wrong and to learn from our mistakes. Yet, as Papert points out, in a mathematics class a child's reaction to a wrong answer is usually to try to forget the mistake as soon as possible. Although in the Logo environment the child is not criticized for an error in drawing, the fact that many children resist using "debugging" suggests that the environmental message that "errors are bad" is extremely powerful to overcome, perhaps more so for girls than for boys.

Thus, the question of whether a "Logoland" existed for this study may be argued. Opportunity for self-discovery and time for experimentation tended to be limited during scheduled computer classes. Computer class was viewed as a separate part of the curriculum and not integrated with math lessons. Differences in philosophy (re: role of the teacher and process versus product) also tended to negate Papert's intent.

The Teacher's Role

Logo is touted as a computer language which takes advantage of a child's own interests rather than programmed activities. However, this requires teachers who are secure and comfortable in using a self-discovery approach to learning, teachers who understand the value of a youngster having plenty of hands-on practice time in front of the computer with an opportunity to work and learn at his/her own speed.

Teachers cannot be faulted, however, for their uneasiness. Most do not yet know where computers fit into their prescribed curricula. Should time on computers be evaluated in the same way as are other subjects? Does that means assigning a grade to a child's efforts or having a child complete a series of graded tasks? Papert would suggest otherwise, yet all of the teachers interviewed for this study felt that what Logo lacked most was an outline or guide which teachers could easily follow.

Papert states, "Our education culture gives mathematics learners scarce resources for making sense of what they are learning" (Mindstorms, p. 47). He feels that our children are forced to follow the very worst model for learning mathematics. This is a model of rote learning, where material is treated as meaningless and is dissociated from the child's experience. He proposes that learning to communicate with a computer may actually change the way other learning takes place, especially the learning of mathematics. "Children will learn mathematics as a living language as they communicate with computers that are 'mathematics-speaking.'" According to this model, a child learns mathematics through space, movement and repetitive patterns, and no particular computer activities need be set aside as time for "learning mathematics." Papert compares this approach of learning mathematics to "what living in France is to learning French;" in other words, an environment which permits the merging of formal training and practical experience.

The paradox is that currently, in many of our schools, computers have not found an integrated place in the classroom or in the curriculum. The language most computers speak depends upon the software available to the teacher and the teacher's training in the use of the program. What it means to be computer literate has not been easily translated into everyday classroom goals. Instead of computers reforming the way learning takes place, traditional schools are using computers to reinforce the skills and support the kinds of teaching they feel most comfortable using. The teachers in this study were interested in software that could be incorporated directly into their lessons, software that would reinforce skills and give the children opportunities to practice them. The observations made in this study show that most of the teachers applied the same "standards" and pedagogy to Logo that they use for teaching other subjects. Many children were not certain why they were in the computer room although they enjoyed the idea of working on the machines. The connection between mathematics and Logo was clear to only a few. Rarely did a teacher have a child try to experience the turtle's movements by trying them out for him/herself. While the children often proceeded without preplanning, their serendipitous discoveries were rarely discussed. Instead, teachers emphasized the child's competence in using CTRL functions and comfort in "booting up" the machines. One teacher even graded the child's efforts at producing a design, focusing on what was drawn on the screen instead of the program that produced it. In such a setting Logo becomes dissociated from mathematics and from life in general. Indeed, it would be reasonable to question whether Logo was being taught at all.

Alfred Bork (1984) reported that he and his staff have visited many schools using Logo, yet what they have seen is far removed from the intent of Logo:

> There is little good curriculum material. The teacher goes to a workshop and learns how to draw triangles, and gets the kids to do it by rote and thinks it is

marvelous. The kids enjoy using up time and nothing much happens (p. 4).

Whether "nothing much happens" is arguable. Certainly the results of this study suggest that there were benefits from studying Logo, even if the curriculum was at times removed from the intent of Logo. The group that gained the most from the Logo experience was the boys. Boys were more willing to try out new approaches and experiment on the machines. They tended to ask more questions and practice more during their free time. Their attitudes toward arithmetic improved significantly and their willingness to take responsibility for intellectual performance grew. It is possibile that this pattern of sex differences was related to the way the computer was being used, and the way its use was organized and supported in each of the classrooms.

Societal expectations must also be considered. To many children, parents, and teachers computers are viewed as a part of the mathematics and science domain. This alone may prejudice girls against the study of programming. It is also possible that the activities offered in the Logo classes may not be viewed in the same way by girls as by boys. A common way to introduce children to Logo is to begin with the drawing of angular shapes (square and other regular polygones). Yet such activities may be of more interest to boys than girls. The results of the Brookline tasks showed that boys had an easier time with angle estimation and directionality than did girls. Therefore, beginning Logo activities may actually be easier for boys than girls. Clinical observations of children's doodles show that boys usually draw rockets and cars (angular objects) while girls usually draw people, flowers, and designs. It is possible that girls may actually benefit from starting the study of Logo with learning how to make circular shapes, thus allowing them to draw what is most interesting to them.

The differences in social organization patterns favored by boys and girls aged 9-12 years old must also be considered. To a girl, working alone in the computer room during free time may carry a social stigma (the suggestion of not being popular). On the other hand, working with others opens the possibility of having one's mistakes exposed and being embarrassed. Society, on the other hand, seems to give a different message to boys. Boys tend to view computers as something to control and master. Therefore, working alone shows initiative and working in groups is a way of showing off one's achievements and successes.

The question still must be raised as to why boys as a group gained more than girls from their Logo experience. Boys were more willing to try out new approaches and experiment on the machines. They tended to ask more questions and practice more during their free time. Their attitudes toward arithmetic improved significantly, and their willingness to take responsibility for intellectual performance grew. It is possible that this pattern of sex differences was related to the way the computer was being used, and the way its use was organized and supported in each of the classrooms.

It is likely that the problem of differences between the sexes in mathematics achievement is extremely complex and cannot be ameliorated merely by the introduction of new technology. Logo offers much promise but may not be powerful enough to overcome deeply rooted societal beliefs and current educational practices. Discovery learning requires time and patience, a luxury many schools cannot afford in their already crowded curricula. Differences in the way girls and boys view success and failure may lead to differences in their interpretation of their experiences with Logo. Girls may not view the mathematical emphasis of Logo as personally useful to them if they do not feel mathematics is a useful subject. They may need to be encouraged to use Logo for subjects which they enjoy more, such as reading or art, in order to order to appreciate its practical applications. They may need to have Logo presented in a more "social" context, one that encourages the verbal sharing of their experiences. They may also benefit from collaborative enterprises which support girls' preferred ways of relating to each other (Hawkins, 1984). In sum, it seems obvious that computers need to be used in ways which more effectively match individual children's interests and goals if they are to make the kinds of impact that Papert envisions.

Recommendations

Based on the findings of this study, the researcher makes the following recommendations:

1. Continued research needs to be done on Logo in the classroom. It is possible that this study's findings were due to a number of factors including the Hawthorne effect than to Logo per se. Longitudinal studies should prove helpful in this regard.

2. More and better teacher training in computers and mathematics is needed. Many teachers are given the responsibility of teaching computer languages to their students yet receive little training for this assignment.

3. Teachers need to be shown the many ways computers can be used in the classroom in order for both sexes to benefit. Computer activities should be integrated into the curriculum not only in math and science but in the humanities and the arts. Children's different social needs and intersts should be acknowledged in planning classroom computer activities.

4. A comprehensive Logo curriculum with scope and sequence is needed. Children find it relatively easy to learn the semantics and syntax of Logo but find it difficult to write programs that use building blocks without instructional guidance.

5. Computer hardware is not enough for a district to provide. Teachers need time to learn and practice new skills. They need opportunity to share their classroom experiences with colleagues and to find out what works best.

6. Teachers also need additional support from a district in the form of workshops, inservices and periodic sessions with an on-site "expert" who can help with curriculum and the operation of the machine and printer. This "expert" (most likely a classroom teacher) should have "release time" in order to better serve in this role of coordinator.

7. Problem-solving skills may need to be taught directly. Students may require teacher guidance to develop understanding of the complex and sophisticated ideas involved in programming. The mathematical content of Logo activities should be emphasized and related to the mathematical curriculum the children follow in their classrooms.

8. Teachers need to be encouraged not to fear the new technology. The application of "good teaching skills" (skills which have been shown effective for other subjects) to the teaching of programming should be encouraged and rewarded.

9. Better designed software which is of interest to girls as well as boys is needed. Such software should encourage the kinds of social interactions that boys and girls find most comfortable.

10. Additional opportunities are needed for youngsters, especially girls, to practice computer skills. Special times or days designed "for girls only" may prove beneficial.

11. Girls should be encouraged to experiment with and modify different programs in ways that will help them gain a sense of control. They should be encouraged to ask questions and try new approaches.

12. Different kinds of software should be available to youngsters in order to better match the goals and interests of individual children.

13. Logo alone does not appeal to every child. Word processing, music editors, CAI, BASIC and Logo programming should all be part of a well-rounded computer program.

Suggestions for Further Research

This researcher was interested in finding out if Logo is an effective learning tool that can promote positive attitudes toward mathematics, strengthen self-esteem and improve problem-solving strategies. The results suggested that the study of Logo is beneficial; however, its benefits may not be equally distributed between the sexes. Further research may wish to explore these differences further:

1. What is the best way to organize a child's computer experience recognizing that there are maturational, social, and sexual differences that affect the interpretation of this experience?

2. Will children benefit more from a set Logo

curriculum with scope and sequence than from an open discovery-learning approach? Which approach better helps youngsters develop a stronger vocabulary of patterns and helps them to internalize mathematical relationships?

3. Are there ways to promote computers in the classroom so that children have equivalent achievement expectations?

4. Will girls be more willing to spend free time at the computer if the environment is perceived as supportive of their interests (offer activities that emphasize what they enjoy)?

5. What kinds of software do girls find most attractive? Are there software that appeals equally to both sexes?

6. Are there software in mathematics and science that can enable girls to view these subjects as more useful to them?

7. Will girls benefit more from computers if instructional grouping is for girls only? Or if additional practice sessions are set aside for girls only? Or if activities encourage cooperation rather than competition?

8. Are there special teaching strategies which can promote sexual equality in science, mathematics and computer classrooms?

9. Can teachers be taught to change their teaching style when working with Logo? And conversely, can the discovery-learning style of Logo help teachers to modify

their teaching of other subjects?

10. Are there cultural differences in children's response to Logo?

11. Is the computer experience cost-effective? Is a modest change of attitude worth the cost of equipment and the time of teachers?

12. Does the computer in the classroom lose its novelty after a while and become only as effective a teaching tool as the teacher who uses it?

APPENDICES

PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.

These consist of pages:

The IAR Questionnaire Pages 219-223

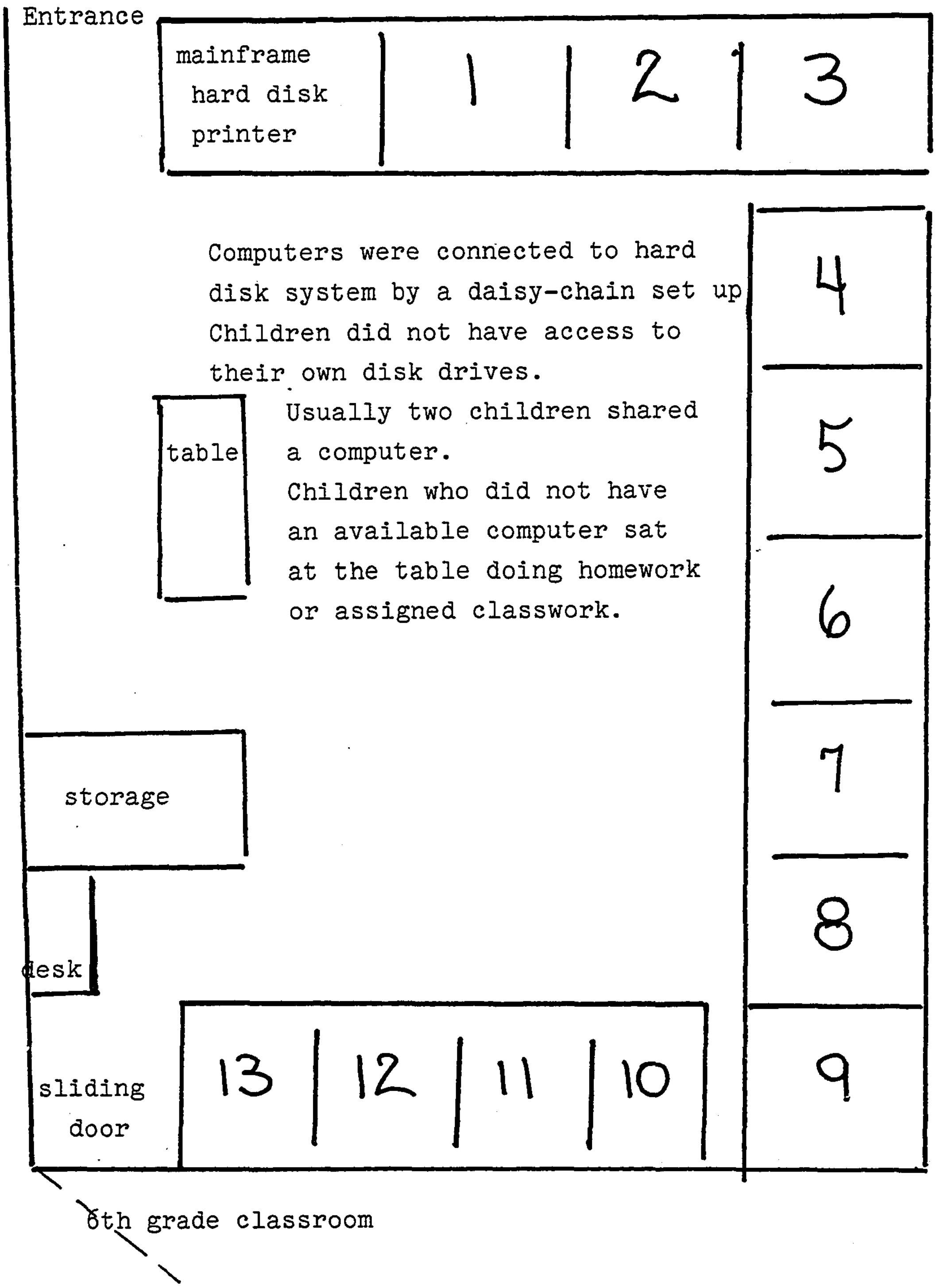
A Study of Attitude Toward Arithmetic Pages 224-226

Examples of Teacher Lessons Pages 232-240

Brookline Logo Project Pages 244-247

Appendix C

Design of the Computer Laboratory



Appendix D

Home Survey

March 14, 1983

Dear Parents,

We will be teaching all our fourth, fifth and sixth grade children Logo on our Apple II computers over the next few weeks. In order that we may beeter serve your child, we would appreciate your filling out the following questionnaire. Thank you.

Child's Name______________________Grade____Teacher__________

We own a home computer	YES	NO
My youngster has taken courses outside of school in computer programming	YES	NO
My child is familiar with BASIC	YES	NO
My child is familiar with LOGO	YES	NO
My child is eager to learn programming	YES	NO
I would like my child to learn how to program	YES	NO

* * * * * * * * * * *

We would appreciate your answering the following questions in order to help us prepare for our parent education classes. Thank you.

I can program a computer (Mother)	YES	NO
I can program a computer (Father)	YES	NO

If yes, circle the languages you know:

BASIC Logo PASCAL Other__________________

* * * * * * * * * * *

I would be interested in attending classes for parents on problem-solving and the computer YES NO

If YES, I would be available for classes during MARCH-MAY:

_______________evenings 7 to 9 Circle Day: M Tu W Th

_______________after school 3 to 5 Circle Day: M Tu W Th

Note to Parents:

What Is Logo?

Logo is a procedural computer language developed at M.I.I. by Seymour Papert and others, based upon the developmental learning principles espoused by Jean Piaget.

Some of the features of Logo that make it both a fun computer language and a language that allows children to discover mathematical and scientific principles are as follows:

1. Logo is computer "friendly"--its messages are in English (not syntax error) and are self-explanatory.

2. Logo is immediate--commands are carried out as they are given (not complicated loops).

3. Logo is based on the idea that the child tells the computer what to do (not the other way around as in CAI.

4. Logo provides an environment that wants the student to experiment and try things out. It supports discovery learning.

5. Logo involves the student in problem-solving. It puts the student in an environment where s/he needs to learn basic geometric principles and see relationships.

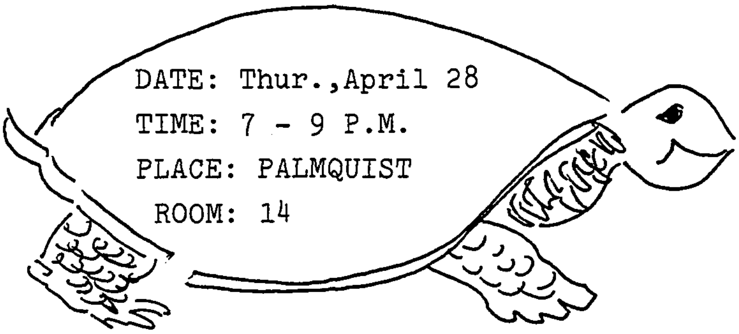
6. Logo helps the student deal constructively with mistakes. Mistakes are part of learning. Logo de-emphasizes mistakes and allows children to debug (correct) them and just go on.

7. The procedural aspect of Logo allows children to see relationships--build up programs one at a time, modify them, add to them, use them in other programs. Such an approach helps children recognize the importance of breaking a task down into manageable components and then task out each section at a time. This is an important problem-solving skill.

A FUNDAMENTAL AIM OF EDUCATION IS THAT THE LEARNER GROW IN KNOWLEDGE AND UNDERSTANDING, AND IN DOING SO BECOME INCREASINGLY INDEPENDENT AND RESPONSIBLE FOR HIS OR HER OWN LEARNING.

Announcement of Parent Meeting

TURTLE GEOMETRY - A DEVELOPMENTAL APPROACH
TO COMPUTER LITERACY



Dear Parents,

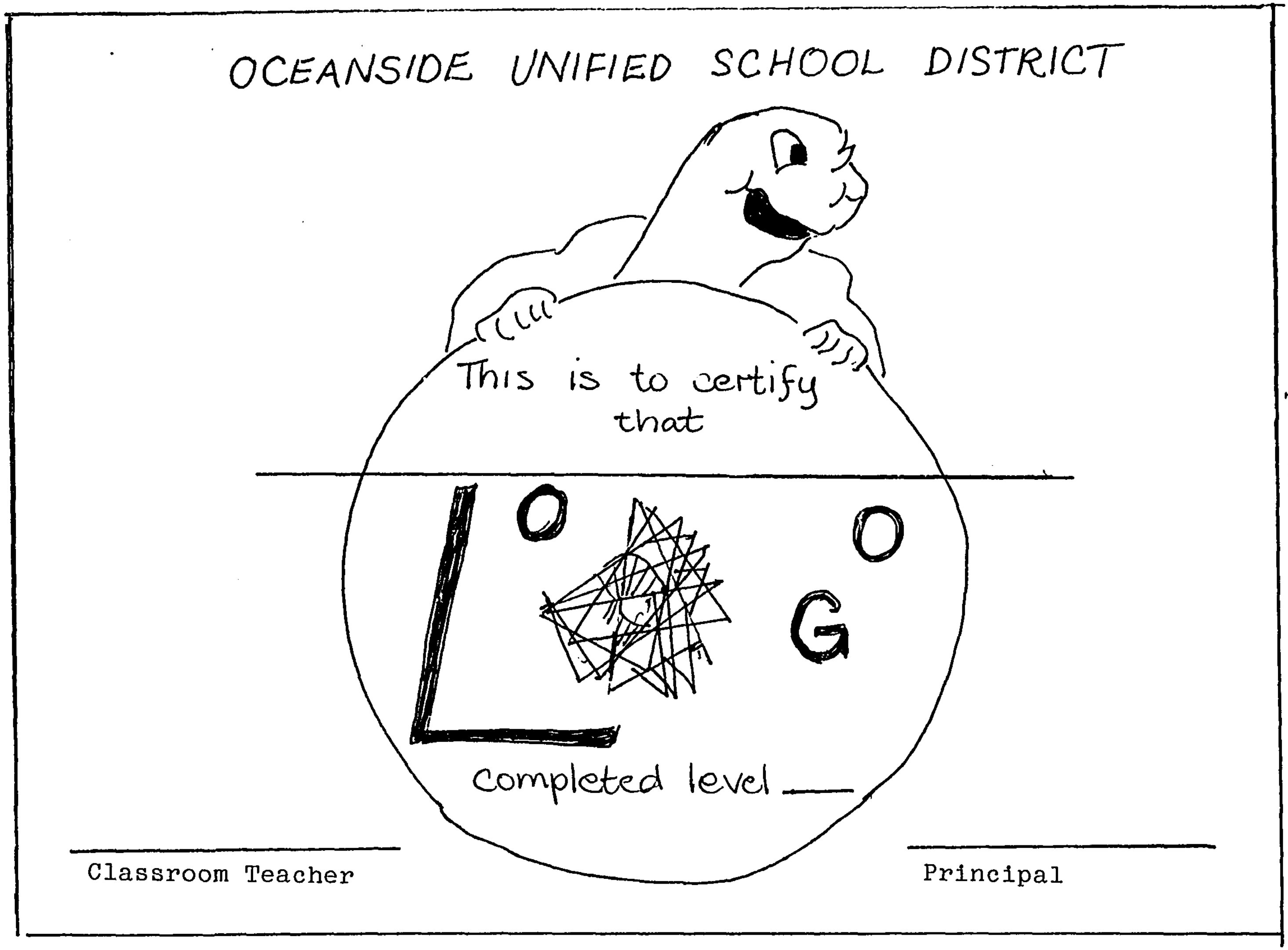
We will be oppering a (2) hour introductory workshop on April 28, to all parents interested in learning more about Logo - the computer programming we are using in our classes. Mr. Bob Rowe, our computer specialist and Mrs. Barbara W. LeWinter, math consultant, will conduct the session.

Please fill out the form below and return it to your child's teacher if you are interested in attending this workshop. Thank you.

_____ Yes, I am planning on attending the Logo workshop on Thursday, April 28, 1983 at 7:00 P.M.

Parent's Name________________________ Child's Name__________

Child's Teacher______________________ Room Number__________



Certificate of Course Completion

Appendix F

Classroom Schedules

TIME	MON.	TUES.	WED.	THURS.	FRI.
8:30	6H				
9:05	6H				5C
9:40	6H				5C
10:15		5W		5W	
10:50			5C	5W	
	L	U	N	C	H
12:55		4C	6D	4C	
1:30		4C	6D	4-5W	6R
2:05	4-5W		6R		6R

Teacher Meetings

Dates	Teachers Present
3/14	6H, 6R, 6D, 5W, 4-5W, 5C, 4C
3/21	6H, 6R, 5W, 4-5W, 5C, 4C
4/4	6H, 6R, 6D, 5W, 4-5W, 5C, 4C
4/11	6H, 6D, 5W
4/18	6H, 6R, 6D, 5W, 4-5W, 5C, 4C
5/2	6H, 6R, 6D, 5W, 4-5W, 5C
5/16	6H, 6R, 6D, 5C, 4C
6/1	6R, 6D, 4-5W, 4C
6/11	6H, 6R, 6D, 5W, 4-5W, 5C, 4C

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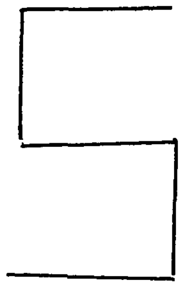
Brookline Logo Project Pages 244-247

Classroom Observations

DATE	OBSERVATION		
Week 1	4C	5W	6R
Week 2	4-5 W	6H	6D
Week 3	6R	5C	4C
Week 4	6H	6R	4-5W
Week 5	4C	4-5W	
Week 6	4-5W	5W	5D
Week 7	5C	6D	4-5W
Week 8	6R	4-5W	6D
Week 9	5W	4-5W	6H
Week 10	6R	6D	
Week 11	5W	4-5W	5C
Week 12	6R	6D	

Appendix G

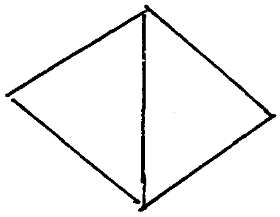
Examples of Student Work



PU RT 90 PD FD 50 LT 90

FD 50 LT 90 FD 50 RT 90

FD 50 RT 90 FD 50 HT



PU RT 90 PD

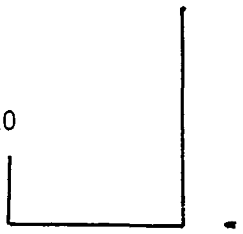
REPEAT 3 [FD 40 LT 120]

REPEAT 3 [FD 40 RT 120]

BK 20 RT 90 FD 50 LT 90

FD 60 PU BK 60 RT 90 FD 10

PD FD 3 HT



Appendix I

LOGO PILOT PROJECT

Teacher Feedback Questionnaire

1. Did you feel that you gained an understanding of the LOGO computer language?__________

2. Did your students develop adequate skills to use LOGO?__________

3. Did you feel that LOGO was easy for your students to learn?__________

   Comments:__________

4. Do you feel that the graphic orientation of LOGO was motivating for your students?__________

   Comments:__________

5. Did you feel that the materials were explained adequately and that your questions were sufficiently answered?__________

   Comments:__________

6. Was 12 weeks a sufficient trial period?__________

7. What did you feel was left out of the training?__________

8. What did you feel were the most effective parts of the project?__________

9. Will you continue to use LOGO in your classroom? If so, how?__________

10. Further ideas and/or comments:__________

Thank you.

Appendix J

Student Feedback Questionnaire

What did you like best about computers this year?

What did you like about LOGO?

Was there anything you did not like about LOGO?

Note: This questionnaire was included on page 2 (back side) of the IAR posttest given to the experimental group.

Appendix K

Teacher Survey on Computer Awareness

I am comfortable with the following computer procedures:

DOS (i.e., Catalog)	YES	NO
AROS (Networking)	YES	NO
BOOTING	YES	NO
RE-BOOTING	YES	NO
STOPPING	YES	NO
HARD DISK	YES	NO
HARD DISK SHUTDOWN	YES	NO

I am comforable with the following computer languages:

BASIC (Applesoft)	YES	NO
LOGO	YES	NO

OTHER____

I would like more inservice on the following topics:

____

____

____

My needs in software are in the following areas:

____

____

____

I have taken programming courses in addition to our school inservices.	YES	NO
I own my own computer.	YES	NO

Additional comments, suggestions and the like:____________

____

Name (Optional)____________________ Years teaching_____

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