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The selection of Logo problem-solving strategies by young minority children as influenced by turtle position and cognitive style

Howard, Janice Renee, Ph.D.

The University of North Carolina at Greensboro, 1991

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THE SELECTION OF LOGO PROBLEM-SOLVING STRATEGIES BY YOUNG MINORITY CHILDREN AS INFLUENCED BY TURTLE POSITION AND COGNITIVE STYLE

by

Janice R. Howard

A Dissertation Submitted to
the Faculty of the Graduate School at
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Approved by

Dissertation Advisor

APPROVAL PAGE

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JANICE R. HOWARD, Ph.D. The Selection of Logo Problem-Solving Strategies by Young Minority Children as Influenced by Turtle Position and Cognitive Style. (1991)
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The purpose of this study was to examine problem-solving strategies between cognitive styles for minority preschool children in a Logo computer curriculum with analytic and relational instructions. Sixteen Black four-year-olds enrolled in a model child development center located in a public housing development served as subjects. Subjects were classified as field dependent/independent according to scores on the Preschool Embedded Figures Test. Cognitive style was the independent variable. Dependent variables were number of surplus grids for analytic instructions and number of total grids and solution paths for relational instructions. Treatment consisted of 48 tasks presented in a random order to examine performance in quadrants, in corners, and from side perspectives. It was hypothesized that field independent (FI) children would perform significantly better on analytic tasks, while field dependent (FD) children would perform significantly better on relational tasks. It also was hypothesized that field independent children would perform equally well on tasks across all treatment phases, while field dependent children would demonstrate more success in upper quadrants, lower left and right corners, and from left side perspectives. Data were analyzed using a series of repeated measures analyses of variance and regression analyses measuring individual subject performance over time.

Results from the repeated measures ANOVA's revealed a significant effect for cognitive style for surplus grids on

analytic tasks in quadrants, with FI children being more efficient in the upper left quadrant than FD children. There was a significant main effect for corner on number of solution paths. Tukey's post hoc comparison revealed a significant difference between the lower left corner (mean = 2.41) and the upper left corner (mean = 3.00). Both FI and FD children completed more solution paths in the upper left corner and completed fewest solution paths in the lower left corner. Findings also revealed that FI children performed significantly better from all side perspectives than FD children on number of surplus grids on analytic tasks. There was also a significant side perspective effect for solution paths on relational instructions. Tukey's post hoc comparison indicated that both FI and FD children completed more solution paths from the bottom side perspective (mean = 3.22) and fewest solution paths from the right side perspective (mean = 2.59).

It was concluded that FI children were better at generating problem solutions than FD children when the directional flow of the problem was moving from right-to-left. Both FI and FD children demonstrated more success when problem solutions matched the child's perspective or necessitated a left-to-right directional flow, while both groups demonstrated less success when the turtle was at the top of the screen, requiring the children to take an opposite, turtle-centric perspective.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

BACKGROUND

Microcomputers are gaining wider acceptance in the education of young children with emphasis shifting from the computer as a 'subject' to be taught to the computer as a 'tool' for teaching many subjects. Computer-assisted instruction (CAI) has been the preferred type of software used by teachers to teach young children concepts such as numbers, shapes, and the alphabet. However, CAI has been criticized for limiting the responses of children by offering them the alternative of only two choices, or only one right answer, instead of allowing creative expression of their own problem-solving processes.

As an alternative to CAI, open-ended or discovery-based software allows children to 'learn by doing.' Logo, the procedural programming language developed by Seymour Papert at MIT, is perhaps the most popular and the most controversial software reported on in the microcomputer literature. Logo is based on the Piagetian premise that children construct their own knowledge, and the microworld provides a powerful mindset in which children are able to engage in discovery-based learning by developing their own direction. Logo uses commands (e.g., right turn, left turn, forward, back) to program the turtle to move from the HOME position (i.e., center of screen pointing north) to the desired location on the screen. Children engage in 'syntonic' learning within a context that has personal meaning by using their own body position as a guide for programming the turtle.

Some researchers believe that young children should not be exposed to computer curricula because it is not age-appropriate (Brady & Hill, 1984; Barnes & Hill, 1983), and that computer programming is best taught at the high school and college levels. Barnes & Hill (1983) stated that microcomputers as part of the educational curriculum are not appropriate for children in the preoperational stage, because children do not develop the abilities to decenter, reverse, and explore cause-effect relationships until they reach the concrete operations stage. However, Barnes & Hill failed to acknowledge the abilities of preschoolers to use cognitive skills such as symbolic representation with microcomputers. It is true that microcomputers should never replace physical learning experiences with real objects; however, the question is not whether or not microcomputers should be an addition to the curriculum, but rather how learning is approached and the context in which it occurs that is important (Cuffaro, 1984). Children as young as three- and four-years-old are able to learn simple Logo commands to program the onscreen turtle (Shade & Watson, 1987; Clements, 1986; Miller & Emihovich, 1986). Preschool children can benefit from learning microcomputer skills (i.e., simple one-key commands, planning, and spatial relations) if these skills are presented and taught at an age-appropriate level.

According to Piaget, preschool children are operating at a preoperational level of thinking, in which they are beginning to be less egocentric. Preoperational children can begin to take the perspective of others in thinking about a problem, and they are beginning to use more symbols and intuition in their mental representations. Researchers have begun to examine spatial development in programming abilities of young children (Fay & Mayer, 1987; Campbell, Fein, Scholnick, Schwartz, & Frank, 1986). Fay & Mayer (1987) studied spatial development in grades 4, 5, 6, and 8 and concluded that children younger than sixth grade were more likely to demonstrate confusion regarding direction (i.e., right and left) and angles (i.e., 45 and 90 degrees) due to preconceptions about spatial reference that conflict with Logo concepts. These children also lacked adequate knowledge of Logo semantics. In a study with kindergarten children, Campbell et al. (1986) postulated that children use a rectangular grid system in which they operate initially on the screen (e.g., treating all turns as right angle turns). When their spatial development becomes more advanced, children appear to operate within a concentric circle system by treating the current cursor position as the HOME position. It seems logical that children with more advanced spatial development are better able to solve programming problems within the Logo microworld. But how do young children operate with Logo to change or facilitate spatial abilities when they are functioning at less advanced stages of programming?

Papert (1980) stated that there is more operating within the microworld than the computer itself. In Mindstorms, Papert (1980) stated that Logo makes 'formal operations,' as defined by Piaget (i.e., abstract thinking), more concrete for children. Children are able to program the turtle commands (i.e., an abstract perception of commands that they believe will result in the desired move) and then witness the concrete execution of these commands to determine if their abstract perceptions are accurate. Papert believes that Logo can teach procedural thinking, problem decomposition, and debugging skills that the student is able to transfer to other problem-solving domains. However, Papert has been criticized for making such claims because the power to produce these skills does not appear to be inherent within Logo itself. Pea and Kurland (1984) reported that structure must be included in Logo lessons as well as teacher guidance in order to teach higher-order thinking skills.

Researchers have examined factors such as teaching style, structure versus no structure in lessons, teacher mediation, and comprehension monitoring (Miller & Emihovich, 1986; Emihovich & Miller, in press; Gallini, 1987; Myrick, Proia, Hatfield, & Watson, 1988). Miller & Emihovich (1986) stressed the importance of teacher mediation in computer programming instruction, in which the teacher acts as a tutor to provide guidance to the student by bridging background knowledge with new skills provided by Logo. Teacher mediation and scaffolding, defined as transferring the reasoning and logical next step in solving the problem back to the child, are very important steps in the process of teaching. Comprehension monitoring also has been found to be beneficial in teaching Logo programming and debugging skills (Miller & Emihovich, 1986; Gallini, 1987; Easton, 1989). Comprehension monitoring is defined as engaging children in 'thinking about their own thinking' as a metacognitive strategy to enhance development of problem-solving skills. Gallini (1987) reported that children who were exposed to Logo training were better able to engage in reflective thinking about their own cognitive processes than were children exposed to CAI training.

The study of programming in Logo with young children has led researchers to be divided among two camps: 1) those who believe that learning Logo requires knowledge of programming (i.e., syntax, semantics, executing strings of commands), and 2) those who believe that the Logo environment or 'microworld' provides a powerful mental framework in which the child 'learns by doing.' There is considerable debate regarding the transfer of cognitive skills (i.e., top-down thinking, problem decomposition, planning, debugging), with approximately 40% of the studies providing support for Papert's claims of enhanced cognitive skills (Clements & Gullo, 1984; Clements, 1986; Clements, 1987b; Mayer & Fay, 1987; Klahr & Carver, 1988; Watson, Lange, & Brinkley, in press), and 60% of the literature failing to find support for transfer of planning skills to other areas (Pea & Kurland, 1984; Kurland & Pea, 1985; Vaidya, 1985; Dalbey & Linn, 1985.

A recent third view has been proposed which shifts emphasis from generalized cognitive gains to more specific issues such as individual differences, instructional methods, and precursors of learning (Krendl & Lieberman, 1988; Mayer & Fay, 1987; Watson & Busch, 1989). The rationale behind this view is based on the premise that the child is bringing with him into the Logo environment important characteristics that directly influence learning (e.g., stylistic differences such as field independent/ field dependent, cultural biases, and problem-solving approaches such as convergent/ divergent thinking). A logical assumption would be to explore these individual differences in an attempt to explain the great degree of variability in Logo research.

Researchers have examined cognitive style as a predictor of programming success. Cognitive style guides an individual's thinking, understanding, remembering, judging, and problem-solving (Witkin, Moore, Goodenough, & Cox, 1977). Field independence/dependence is a component of cognitive style that determines how an individual perceives and processes information. Field independent (FI) individuals are analytic, able to perceive figure from background, and pay attention to detail. They are able to overcome the influence of an embedded context. Field dependent (FD) individuals are global thinkers who perceive the context in its entirety and conform to contextual cues.

In research on programming skills, FI students consistently have been found to be more efficient than FD students in problem-solving strategies (Canino & Cicchelli, 1988; Howard, Sheets, Ingels, Wheatley-Heckman, & Watson, 1988; Cavaiani, 1989; Watson, Lange, & Brinkley, in press). Canino & Cicchelli (1988) reported cognitive style to be responsive to instructional method, with FI students performing better than FD students in discovery-based methods (i.e., less structure) versus algorithmic methods (i.e., more structure). Cavaiani (1989) found college students using a global (FD) cognitive style to be at a disadvantage in program comprehension and debugging. Watson, Lange, & Brinkley (in press) focused on field independent and field dependent styles in four- and five-year-olds to examine spatial route efficiency in Logo (i.e., the most efficient route for a solution path for the turtle onscreen). Watson et al. found field dependent subjects took significantly longer times and made more errors than did field independent subjects, who learned Logo better in a transfer task. Cathcart (1990) reported Logo programming experience to have an effect on cognitive style in a study of fifth-graders, who demonstrated an increase in divergent thinking and field independence after only 14 weeks of training when compared to a control group. It is unclear if cognitive style determines performance across settings, or if problem-solving ability is specific to the demands of the context (Globerson & Zelniker, 1989, p. 71-85). The construct of cognitive style is discussed in detail in the review of literature.

Statement of the Problem

Recent research has examined specific strategies used by FI/FD children who are learning to program in Logo, such as pointing, using grid systems and quadrants (Brinkley & Watson, 1990; Gallini, 1987; Campbell et al., 1986). Pointing strategies involve syntonic learning where the child uses his/her own body position as a guide for directing the turtle (Brinkley & Watson, 1990). Grid systems are used initially by novice programmers and consist of spatial representations on the screen using forward/back movements and right angle turns, eventually progressing to viewing the screen as a series of concentric circles and using oblique angles (Campbell et al., 1986). Quadrants are created by dividing the screen into four equal sections (i.e., upper right, upper left, lower right, and lower left). It has been demonstrated that children learn forward and right commands earlier (Campbell et al., 1986; Easton, 1989). Children learn to point the turtle in the desired direction as the initial step in problem-solving (Watson & Busch, 1989; Brinkley & Watson, 1990), and recent research has reported that young children solved Logo problems more effectively in the upper quadrants of the screen when the cursor was in the HOME position pointing north (Brinkley & Watson, 1990; Easton, 1989).

Studies indicate that young children are able to take alternative perspectives if the task is age-appropriate and if the children are able to communicate the alternative viewpoint (Borke, 1983; Watson, Lange, & Brinkley, 1991). Classic perspective-taking is defined by Piaget & Inhelder (1956) as taking the perspective of another. Fay & Mayer (1987) proposed that children take the turtle's perspective (i.e., turtle-centric) regardless of its positioning on screen. Watson, Lange, & Brinkley (1991) applied this concept to Logo by examining perceptual role-taking behavior from turtle-centric, quadrant, and side-of-screen perspectives. This study examined performance of 4- and 5-year-olds from each of the four on screen perspectives (i.e., top, right, left, and bottom,) using the most spatially efficient routes. Results revealed that solutions from the left perspective (i.e., directional flow of the problem from left-to-right) took significantly less time for field dependent subjects to complete than the right, top, or bottom perspectives which were not significantly different from each other. Field independent subjects were not significantly different in any of the four perspectives.

The above study suggests ease of problem-solving from left-to-right for field dependent subjects, who are categorized as being more wholistic, global thinkers and who tend to view the entire screen equally. Perhaps these subjects are more likely to be influenced by past experiences (e.g., reading a book or crossing the street) and rely on this experience as a guide to problem solutions. Alternatively, field independent subjects are more analytic and are able to separate figure from ground, thus paying more attention to various details on the screen and making it easier to take the various perspectives of the turtle from each of the four sides with equal ease.

The present study includes cognitive style as a variable to determine whether FI or FD individuals from a minority population solve Logo problems equally in all four quadrants (i.e., upper right, upper left, lower left, and lower right), from each of the four corners (i.e., upper right, upper left, lower left, and lower right), and from each of the four side perspectives (i.e., right, top, left, and bottom) as determined by analytic versus relational instructions. If cultural differences influence learning in young children, then what are the implications for cognitive style differences within cultures? The purpose of this study is not to compare performance across cultures, but to examine differences between FI/FD individuals within a given minority sample. This study is limited to examining the effects of the cognitive style dimension of field independence and field dependence. Field dependent individuals rely upon the external environment, whereas field independent individuals tend to 'work on' the environment. Analytic task instructions ask the child to approach the problem using a convergent, linear style of thinking that is used predominantly by field independent individuals. These instructions require the child to be somewhat 'reflective' in thinking about the problem and in considering the relevant details of the task in order to find the most efficient route or solution path on the screen. Therefore, analytic instructions are better suited for the cognitive style of the field independent child. Alternatively, relational task instructions command the child to consider all aspects of the screen equally, using a more divergent or creative approach in finding as many solution paths as possible to solve the problem. Theoretically, relational instructions are better suited for the cognitive style of the field dependent individual.

This research will address the specific strategies which FI/FD children may use to solve Logo programming problems:

1) Do FI/FD children perform equally in all four quadrants with analytic versus relational instructions?

2) Do FI/FD children use the entire computer screen as a quadrant itself when the turtle is positioned in a particular corner to bias problem-solving strategies toward upper, lower, left, or right corners with analytic versus relational instructions?

3) Does taking the turtle-centric perspective from each of the four side perspectives make a difference in ease of problem-solving flow (i.e., left to right, right to left, top to bottom, and bottom to top) for FI/FD subjects with analytic versus relational instructions?

Hypotheses

Based on the problem statements the following hypotheses were presented. Hypotheses are stated in research form.

H1 There would be a significant effect for cognitive style (FI versus FD) and significant cognitive style by quadrant (upper right, upper left, lower right, and lower left) interaction for both analytic and relational tasks. Quadrants are formed when one horizontal and one vertical line intersect in the center of the screen.

(a) Field independent subjects would perform significantly better than field dependent subjects in all four quadrants on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects would demonstrate equal performance in all four quadrants on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better in the two upper quadrants than the two lower quadrants on analytic tasks as measured by number of surplus grids.

(d) Field dependent subjects would perform significantly better than field independent subjects in all four quadrants on relational tasks as measured by number of total grids and solution paths.

(e) Field independent subjects would demonstrate equal performance in all four quadrants on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better in the upper quadrants for relational tasks as measured by number of total grids and solution paths.

H2 There would be a significant effect for cognitive style (FI versus FD) and significant cognitive style by corner (upper right, upper left, lower left, and lower right) interactions for both analytic and relational instructions. Corner is defined as the point where two sides of the screen come together.

(a) Field independent subjects would perform significantly better than field dependent subjects in all four corners on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects would demonstrate equal performance in all four corners on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better in the lower left corner for analytic tasks, necessitating an upward problem flow from left-to-right, as measured by number of surplus grids.

(d) Field dependent subjects would perform significantly better than field independent subjects in all four corners on relational tasks as measured by number of total grids and solution paths.

(e) Field independent subjects would demonstrate equal performance in all four corners on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better in the lower left and lower right corners for relational tasks, necessitating an upward problem flow, as measured by number of total grids and solution paths.

H3 There would be a significant effect for cognitive style (FI versus FD) and significant cognitive style by side perspective (right side, top side, left side, and bottom side) interactions for analytic and relational instructions. The screen consist of four sides.

(a) Field independent subjects would perform significantly better than field dependent subjects from all four side perspectives on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects would demonstrate equal performance from all four side perspectives on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better on perspectives from the left side of the screen on analytic tasks as measured by number of surplus grids.

(d) Field dependent subjects would perform significantly better than field independent subjects from each of the four side perspectives on relational tasks as measured by number of total grids and solution paths.

(e) Field independent subjects would demonstrate equal performance from all four side perspectives on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better from the left side perspective on relational tasks when compared to right, top, and bottom sides as measured by number of total grids and solution paths.

Importance of Study

Cognitive style is a determinant of how individuals perceive and process information (Witkin, Moore, Goodenough, & Cox, 1977; Saracho, 1984, 1989). Although cognitive style is somewhat modifiable (Kagan & Kogan, 1970), it is believed to be a relatively stable characteristic over time and across situations (Witkin & Goodenough, 1981). Very little has been written about cross-cultural differences in cognitive style as it influences learning in young children. Hale-Benson (1982) described a Black learning style based on her knowledge of how African families reared their young. Carbo, Dunn, & Dunn (1986) reported a global, holistic, simultaneous, field dependent style used by many young children in their approach to learning which seemed to parallel the learning style described by Hale-Benson (1982).

Lee (1986) advocated using the 'preferred learning style' of Black children instead of trying to modify it in the educational setting. She reported inequity in the classroom due to the differences in learning styles of traditional or analytic thinkers versus relational thinkers. Microcomputers are used more often as integral tools to teach analytic or convergent thinkers, whereas they are used as 'tutors' to remediate skills of relational thinkers whose primary style of learning does not revolve around spoken or written language. Black children tend to employ a relational style of learning, which emphasizes audio and visual stimuli, and which is believed to be a direct result of cultural influences such as music, dance, and other art forms. Although Lee herself did not provide empirical support for her argument, preliminary findings by Pea & Sheingold (cited in Lee, 1986) reported that microcomputers aid children in building symbolic aspects of knowledge gained from other kinds of experiences (e.g., cultural). Lee also stated that using microcomputers allowed students to express creativity through audio and visual stimulation and advocated an 'educational match' between teachers and students in terms of relational versus analytic styles in the classroom, particularly with microcomputer technology.

This study was designed to determine if field independent/dependent individuals perform more successfully with programming tasks given instructions suited to their cognitive style (i.e., analytic versus relational). According to Cavaiani (1989), analytic problem-solvers employ a structured approach in decision making and are able to locate errors in programs automatically. Global or relational problem-solvers need to make modifications and to receive feedback to verify their decisions because they reason by analogy. Given this reasoning, it was hypothesized that analytic (FI) individuals would solve the tasks more efficiently (i.e., fewer surplus grids due to a more structured approach) when given analytic instructions, while relational (FD) individuals would use more total grids (i.e., more feedback from errors) to solve the programming tasks. Alternately, relational (FD) individuals should be more successful than analytic (FI) individuals with relational instructions by generating more solution paths.

This study was designed to provide information regarding strategies used in quadrants versus the whole screen in terms of perspective-taking. Will holistic thinkers treat the whole screen as a quadrant, and will analytic thinkers focus on only part of the screen and remain within the 'quadrant' system? These strategies were analyzed by comparing the numbers of surplus grids, total grids, and solution paths for FI/FD thinkers with relational and analytic instructions.

Assumptions.

The major assumption being made in this study is that the instructions for the card sets (i.e., 8 cards in each phase) will be distinctly different from each other to distinguish between relational and analytic styles of problem solving. It is assumed that these card sets represent each quadrant equally, as well as each corner and each perspective equally. It also is assumed that the time limits of this study for training and problem-solving are adequate for the results.

Limitations.

A major limitation of this study is the small sample size (N = 16). A series of repeated measures analyses of variance will be employed to help control for effects of small sample size. This study has attempted to control for order effects by randomly assigning subjects to instructions (i.e., analytic versus relational) and to phase (i.e., 1, 2, or 3) for each trial. The results of this study are generalizable to similar populations of low income minority four-year-olds attending a child development center.

Definition of Terms

Card Set. A card set consists of a set of 8 problems, programmed using Logo Plus, that appears on the screen one at a time. There are 3 card sets, one for each phase. Each card presents a task requiring the student to program the commands to make the turtle move from the current position to the desired location on the screen. Each card set was used once with analytic instructions and once with relational instructions.

Cognitive Style. A cognitive style is a personal style of information processing that characterizes how an individual thinks, remembers, judges, and solves problems.

Field Dependent. Field dependence is a component of cognitive style that is characterized by global perception of the entire perceptual field. FD individuals conform to contextual cues.

Field Independent. Field independence is a component of cognitive style that is characterized by an analytical style of thinking with attention to detail. FI individuals discriminate figure from ground and are able to overcome the influence of an embedded context.

Grid System. The computer was programmed to use a 14 X 20 block invisible grid system to measure distances moved for each onscreen problem card.

HOME Position. The turtle is in the HOME position when it is in the center of the microcomputer screen pointing north.

Logo. Logo is a programming language developed by Seymour Papert and associates at MIT. This discovery-based software employs turtle geometry created by programming the turtle with commands such as right turn, left turn, big step, little step, forward, and back.

Phase. The study consists of problems from 3 phases. Phase 1 uses problems in each of the four quadrants. Phase 2 uses problems in each of the four corners. Phase 3 uses problems from each of the four side perspectives.

Problem-solving Strategy. Each child selects a strategy to begin to find the solution path to the designated point on the screen (e.g., pointing the turtle, moving forward, turning right).

Problem-solving Task. Each card in a card set contains a task that the student must solve on the microcomputer screen using the eight directional key commands, as well as big steps and little steps, to get from Point A to Point B.

Quadrant. The microcomputer screen can be divided into four equal quadrants by one horizontal and one vertical line drawn through the center of the microcomputer screen.

Solution Path. The solution path is defined as the directional path the student should follow by giving the turtle the appropriate commands to reach the target.

Surplus Grids. The number of grids in a given solution path is defined as the number of grids in excess of the shortest path.

Total Number of Grids. This term is defined as the total number of designated blocks used in creating a solution path(s) for each problem card. The computer will keep a record of the number of grids employed in each problem solution. One big step equals 3 grids and one little step equals one grid.

Turtle. The turtle is the triangular cursor in Logo software. It is manipulated by the student, who uses it as a means of syntonic learning or as an 'object to think with.'

Turtle-Perspective. The child takes the turtle's perspective (turtle-centric) by placing himself mentally in the turtle's position onscreen and solving problems from that perspective.

CHAPTER II

REVIEW OF THE LITERATURE

In Mindstorms it was proposed that computer programming in Logo could accelerate children's cognitive development by allowing them to master abstract ideas that otherwise would be too advanced for their developmental level (Papert, 1980). The decade of the eighties produced many inconsistent findings in Logo research. As a result, attention was turned to factors that may mediate the outcome of computer programming instruction, which include cognitive style, teaching style, and explicit instruction. This review of literature attempts to categorize and summarize some of these findings.

Cognitive Style

As stated earlier, cognitive style guides an individual's thinking, understanding, remembering, judging, and problem-solving (Witkin, Moore, Goodenough, & Cox, 1977). Cognitive style consists of many components (e.g., field independence/dependence, reflectivity/impulsivity, convergence/divergence, conformity/creativity); however, only the component field independence/dependence will be discussed. Field independence (FI) is defined as an analytical approach to perception, in which items are experienced as discrete from their backgrounds and in which the influences of embedded contexts are overcome. Alternatively, field dependence (FD) is defined as a global type of perception in which the context is perceived in its entirety with conformity to contextual cues (Saracho, 1983a).

Age. Field independence/dependence appears to be influenced to some degree by maturation. Young children are relatively more field dependent because the ability to separate an object from the context develops with age (Kogan, 1983). As individuals get older, they tend to become more FI (Witkin, 1949). Adults in their middle years are more FI than younger and older persons. The period between ages 10 and 24 is marked by significant changes (e.g., puberty, less dependence on family, college, occupation, possible marriage), and yet the psychological dimension of FI/FD remains fairly stable and is considered to be a powerful continuity in development according to Witkin and colleagues. Evidence suggests that young children are more FD, but as they mature they become more FI and peak in adulthood, followed by a decline for older ages in FI characteristics toward FD (Kagan & Kogan, 1970). Schwartz and Karp (1967) provided convergent evidence that geriatic populations were highly field dependent. Witkin, Goodenough, & Karp (1967) found in a cross-sectional and longitudinal study of persons ranging from 8 - 24 years old that field dependence decreased up to age 17 and changed very little thereafter, providing evidence for stability of the field dependence/independence (FDI) dimension from their fourteen-year-study. FDI has been shown to be a stable characteristic over extended periods of time from middle childhood through young adulthood. However, it is less certain that the FDI dimension is a stable one in the preschool population.

Kagan & Kogan (1970) clearly stated that the stability of the FDI dimension is interindividual, not intraindividual. That is, an individual's position is maintained relative to others, although he may be progressively increasing in degree of FI. Witkin's research focused on a group of children who had already undergone fundamental cognitive changes (i.e., ages 8 and up). Can a cognitive style theory account for developmental changes? Although the course of development is marked by continuities as well as discontinuities, a comprehensive developmental theory should be able to incorporate Witkin's stability of the FDI dimension as well as cognitive changes discussed by Piaget (i.e., the transformation from preoperational to concrete to formal operations). Kogan (1976) built a case for the coherence of the FDI dimension in preschool children based on the correlation between the Embedded Figures Test (EFT) and the Rod-and-Frame Test (RFT). However, Witkin & Goodenough (1981) suggested that each measure may be tapping distinctive, but related psychological processes. The EFT utilizes one's restructuring ability within a spatial domain, whereas the RFT assesses visual versus vestibular sensitivity to perception of the upright position. Kogan (1976) also stated that research on adolescent samples suggests that there may be two distinct components, which then raises the question of degree of structural continuity across the years of earlier and later childhood. Kogan (1983) ventured the hypothesis that the splitting of FI/FD into two concepts is a 'postchildhood phenomemon.'

Birth Order. A few studies have examined the effect of birth order on creativity or divergent thinking. Runco and Bahleda (1987) conducted a study using a very large sample (N = 234) and found 'only' children to have the highest divergent thinking test scores, followed by eldest, youngest, and then middle children. Also, children with more siblings had higher scores than children with one sibling. Some studies have proposed that first-born children are more conforming and therefore less creative (Eisenman, 1964), while others have indicated that birth-order is unrelated to creativity and that first-borns are distributed equally in high, medium, and low creativity groups (Datta, 1968; Wilks and Thompson, 1979). One concludes that results are mixed at best; perhaps other factors such as parental cognitive style, family income, and ethnicity need to be examined.

Gender Differences. Some slight gender differences have been reported with regard to cognitive style. Witkin, Moore, Friedman, & Owen's study (cited in Saracho, 1989) reported males to be slightly, but consistently more FI than females. However, Sherman (1967) criticized results from Witkin's Rod-and-Frame Test (RFT), as well as from the Embedded Figures Test (EFT), stating that the reported sex differences are merely artifacts due to sex differences in space perception and do not support the idea that females are less analytical than males. Within the preschool population, girls tend to perform at a higher FI level than boys. It has been suggested that the girls' biologically-based developmental maturity may be more advanced than the boys' level of maturity. Or perhaps the PEFT measure itself may reflect social content which favors females (Kogan, 1983). After the preschool years girls' passivity increases and boys' activity decreases, thereby shifting away from female to male superiority in FI. While the notion of sex differences in FI/FD has some support, it is noted also that differences exist within the sexes. These differences are attributed largely to socialization, although they can be confounded by age differences as well (Saracho, 1989). The indication that sex differences generalize across several cognitive domains suggests that maturational factors play a role; however, psychosocial determinants cannot be ruled out (Kogan, 1983). Witkin (1976) concluded that socialization factors were undoubtedly important regarding individual differences in FI/FD, and that researchers need to determine the role that genetic factors play as they interact with social factors.

Cultural Differences. Many studies have examined cultural differences regarding field independence/dependence (Ramirez & Price-Williams, 1974; Saracho, 1983b; Berry, 1986). Berry (1986) stated that in general more field dependent individuals are found in 'traditionally tight' agricultural groups as opposed to looser social structures, while more field independent individuals are found in

'Westernized' societies than in traditional ones (i.e., prior to imigration). Minorities are reported to be more field dependent in general (Dunn, Gemake, Jalili, Zenhausern, Quin, & Spiridakis, 1990; Griggs & Dunn, 1989). Dunn et al. (1990) revealed in a comparison of African-American, Chinese-American, Greek-American, and Mexican-American fourth, fifth, and sixth graders that all four groups were field dependent as measured by the Group Embedded Figures Test (GEFT). Ramirez and Price-Williams (1974) also found fourth-grade Mexican-American and Afro-American students from middle and low socioeconomic backgrounds to be more field dependent than their Caucasian peers and credited socialization and cultural values as likely contributors to this cognitive style. Ramirez, Castaneda, and Herold (1974) cautioned however about generalizing cognitive styles to various cultures when their findings revealed a great degree of variability within the Mexican-American community that appeared to be related to family values (e.g., social conformity versus independent values). A prosocial orientation taken by the family is believed to relate to field dependence in young Mexican-American children. Saracho (1983b) also reported variability in FI/FD and concluded that cultural differences based upon socialization practices had been oversimplified when she found FI in Mexican-American children as young as five-years-old. She stressed the need to examine individual differences in other cultures before attempting to determine their cognitive style.

Cognitive Style and Computer Programming.

As stated previously, the FI/FD component of cognitive style may influence development of cognitive skills in computer programming. Lee (1986) advocated matching educational curricula, including teaching styles, with individual learning styles in the classroom. She described the preferred style of learning by Black children, which consists of a relational style that emphasizes audio and visual properties. This style is believed to be a direct result of cultural influences such as music, dance, and other types of performing arts. Lee reported inequity in the classroom regarding microcomputer use among analytical and relational thinkers, as did Fullilove (1985), who reported that Black students are not provided the access to computers that White students receive. Microcomputers more often are used to teach analytical thinkers, whereas relational thinkers use them as tutors to 'remediate' their skills. Lee (1986) stated that microcomputers allowed students to express creativity through audio and visual stimulation, and she cited preliminary findings by Pea & Sheingold that reported that microcomputers aid children in constructing symbolic knowledge gained from other real-world experiences. Therefore, relational thinkers certainly should benefit from microcomputer instruction as well as analytical thinkers. Regarding implications for education, Berry (1986) recommended that cultural diversity in the classroom be viewed as a resource instead of as a deficit to be overcome.

Studies have reported consistently the finding that field independent students perform significantly better than field dependent subjects on computer programming tasks (Witkin, Moore, Goodenough, & Cox, 1977; Canino & Cicchelli, 1988; Cavaiani, 1989; Watson, Lange, & Brinkley, in press; Cathcart, 1990). The FI students approach the tasks in an analytical, structured approach that appears to be more efficient in solving the problem, and they are able to locate errors in programs more quickly (Cavaiani, 1989). The FD students reason by analogy, require more feedback regarding their attempts at solving the problem, and seem to lack initial strategies to tackle the problem. Watson, Lange, & Brinkley (in press) found that field dependent subjects took longer times and made more errors on programming tasks than did field independent subjects, who learned Logo better in a transfer task involving programming a robot turtle on a floor map.

Type of Training. Although cognitive style appears to be a relatively stable dimension, it is somewhat modifiable (Kagan & Kogan, 1970). Canino & Cicchelli (1988) reported cognitive style to be responsive to instructional method with a group of university students in Puerto Rico, with FI students performing better than FD students in discovery-based methods (i.e., less structure) versus algorithmic methods (i.e., more structure). Cathcart (1990) also reported Logo programming experience to have an effect on cognitive style. In a study of fifth-graders, increases in field independence as well as divergent thinking were observed after only 14 weeks of instruction. Type of training and specific instruction are reported as being very influential in type of cognitive skills demonstrated by students, including transfer of problem-solving skills from one domain to another similar domain.

Again, these studies report findings with school-age children, and results are mixed regarding the 'trainability' of the FDI dimension. Morell (1976) tried to improve performance of 11-, 14-, and 18-year-olds on the RFT by giving feedback during training trials in one session. He found no significant training effects when compared to a control group and concluded that FDI was not trainable in middle childhood through adolescence. Alternatively, some researchers believe that individuals can learn to function and react in more efficient ways which are different from their cognitive style (Ramirez & Castaneda, 1974; Saracho & Spodek, 1981). The most effective technique for teaching alternate ways of processing information is to increase the individual's repertoire beyound the range of the dominant cognitive style (Saracho, 1983a; Globerson, 1989).

Hemispheric Differences. Hemispheric lateralization is yet another component of cognitive style and is defined as left/right brain orientation. It is clear that individuals differ in regards to hemispheric orientation, with some individuals being more verbal/analytical thinkers (i.e., left brain), while others are more oriented toward creativity/

spatial relations (i.e., right brain). It is unclear, however, if hemispheric lateralization is related to differences in computer programming ability. Gasen & Morecroft (1990) conducted one of the few studies examining lateralization on programming ability using adult college students in an introductory COBOL class. Gasen & Morecroft concluded that laterality preference does not appear to be significantly related to performance on programming tasks. The Laterality Preference Schedule (LPS) indicated that individuals with left hemispheric dominance performed slightly better on cognitive tasks such as following procedures and deciphering language commands.

A growing concensus among researchers based upon recent findings (Sergent & Bindra, 1981; Sergent, 1982; Gasen & Morecroft, 1990) is that perhaps too much emphasis has been placed upon individuals regarding lateralization differences, instead of examining differences between hemispheric lateralization itself. Sergent (1982) proposed that spatial ability is not a function of right hemispheric lateralization, but is instead dependent upon the spatial frequency of presented visual stimuli. High spatial frequency is processed more effectively in the left hemisphere, and low spatial frequency is processed more effectively in the right hemisphere. Thus, it may be the temporal aspects of visual perception (i.e., quality of the stimulus input, duration, stage of processing), as well as the preferential sensitivity of the two hemispheres, that result in findings of 'hemispheric differences.'

Neuropsychological analyses of cognitive styles have been described in several studies (Waber, 1989; Globerson, 1989). A two-stage mechanism of brain structure and function is proposed by Waber (1989) which links behavioral phenomena and cognitive style. The first stage involves attentional processes (i.e., timing and organization) controlled by the fronal lobes. Individual variation in these attentional processes affects the quality of perceived sensory information, which introduces biases at the second stage of processing where higher cognitive functions associated with right/left hemispheric preferences result in a bias toward an analytic or gestalt approach. Within this framework cognitive style can be understood by the interaction of control processes of the frontal lobes and analytic processes associated with the two hemispheres. Waber's explanation of field dependence in the young child stems from the poorly developed control processes which biases the system toward a more global approach of processing information. These processess become more efficient with development and take a more analytical approach as the child matures.

A second account of cognitive style is provided in the form of functional performance-based stylistic differences by Globerson (1989). She provided empirical evidence that refuted structural differences in mental capacity between field dependent and field independent children, and also demonstrated that under appropriate learning conditions the performance gap between FI and FD children could be nearly eliminated. That is not to say that on different tasks different stylistic children may mobilize varying amounts of mental effort or capacity. These findings corroborate Witkin's view that cognitive style differences are different from developmental differences. Globerson concluded that under style appropriate learning conditions, and when the task's information-processing demand is appropriate developmentally, learning and transfer are greatly enhanced. FDI was assessed with the WISC-R Block Design Test. Training (i.e., metacognitive processing and self-awareness) had an effect only on the 8-year-olds in the study. The 6-year-olds were cognitively too immature in their mental effort capacity to handle the complex tasks. This finding also supports Witkin's view that FDI stability is not measured easily prior to age eight.

Globerson stressed that she did not attempt nor succeed to change the cognitive style of the field dependent subjects; instead, she changed the children's cognitive functioning in a restricted domain of tasks. Therefore, both FI and FD children were able to learn different strategy usage, and Globerson concluded that cognitive style is not developmental in nature, but instead, is a performance variable. She demonstrated that both stylistic groups have the same developmental competence/ mental effort capacity, both can mobilize the same mental effort capacity to the task situation, and the low performers can learn to function at a normative level. Lower performance of FD children is explained by certain task situations with perceptual misleadings to which FD children are sensitive, but this misperception can be overcome in order to reach a higher level of competence.

SES Differences. Cognitive style preferences also seem to be related to socioeconomic backgrounds. Waber, Carlson, Mann, Merola, & Moylan (1984) found that lower SES children were more likely to be categorized as field dependent than were higher SES children. Higher SES fifth- and seventh-graders showed a clear bias toward right visual field-left hemisphere orientation, whereas lower SES fifth and seventh graders showed a more even distribution toward the preferred right or left hemisphere orientation. The direction of the bias is consistent with the association of left hemisphere processes with field independent style and right hemisphere processes with field dependent style. There does appear to be an association between hemispheric processes and cognitive style, as well as SES-related differences; however, the functional relation between them remains to be determined (i.e., environmental versus heriditary).

Conclusions. Witkins's FDI dimension has stimulated much research regarding the components of cognitive style; however, the mixed findings have left researchers with a less than clear picture of the boundaries of this construct. The FDI dimension is not confined to perception but is related to cognition, intelligence, personality, and social behavior as well (Kagan & Kogan, 1970; Saracho, 1983a). Spatial decontextualization is only part of the construct with its many underlying dimensions. The EFT and RFT measures are multidimensional themselves, but do share some variance. It is this shared variance which needs to be explained. As Kogan (1983) so aptly stated, the present FDI construct is at a 'conceptual crisis point.' Waber (1989) concurred that the concept of cognitive style as a unitary trait is not useful to researchers and that examining the phenomena in terms of contributing processes would be more fruitful in terms of conducting research on learning differences and computer programming.

Pedagogical Factors of Programming

Age. Johanson (1988) raised the issue that perhaps research with Logo has been conducted at the wrong age. Most research has been conducted with students aged 6 - 8 years or older (i.e., those who have reached the concrete operations stage), in order to engage them in meta-cognitive strategies (i.e., thinking about their own thinking). However, by using younger children in research, Logo would be more likely to have an impact relative to the child's limited other experiences. For example, Clements (1986) reported more success with first graders than third graders in terms of gains in skills of classification and seriation.

If software is designed appropriately children as young as three can be introduced to computers (Shade & Watson, 1987). Tan (1985) reported that 3- and 4-year-olds are quite capable of matching symbols and remembering the locations of keys used. Young children actively engage in memory discrimination and symbolic representation, while at the same time learning social skills of cooperation and sharing. Clements (1987a) reported that preschool children should be able to benefit from using computer programs because they employ symbolic gestures and language in their play. The computer graphics are very appropriate for preliterate children.

Self-Concept. In addition to enhanced cognitive skills acquired through Logo, students also may experience increased locus of control in the learning process, as well as more self confidence and better self-concept (Gallini, 1987; Burton & Cook, 1987; Burns & Hagerman, 1989). Burton & Cook (1987) used first-graders to test Papert's notion of empowerment using an inventory measuring internal/external locus of control. Results indicated that the Logo group scored higher internal control on the 'luck' factor than did the control subjects, thereby perceiving luck as having a lesser effect on the attainment of goals and attributing more control to themselves. Burns & Hagerman (1989) also found increases of internal locus of control orientation in third grade children after four and a half months of Logo training. Student attraction to the microcomputer is well-documented in the literature, as it facilitates learning through user-friendliness, immediate feedback, self-paced instruction, and increased motivation to interact with the computer screen (Lepper, 1985). It appears that Logo enhances intrinsic motivation as well as mastery thinking in students.

Gender Differences. Consistent gender differences have not been found when children learn to program in Logo. Both males and females appear to show significant improvement in computer programming and in mathematical concepts as well. In a study conducted with preschoolers (Schaefer & Sprigle, 1988), females were found to use the computer terminology (e.g., disk drive, return key) more often than males. It has been documented that fewer females take advantage of computer learning opportunities than do males (Dalbey & Linn, 1985). However, Linn & Dalbey (1985) found females to outperform males in middle school introductory BASIC programming classes.

Preconceptions and Pitfalls. Children typically bring with them to the microworld certain 'rules' about spatial relations based upon their experience or cognitions, which are not always accurate. These preconceptions are challenged by Logo. Although Logo can be used successfully by children in primary grades and younger, certain graphics features of Logo may present difficulties when trying to solve problems onscreen. Fay and Mayer (1987) selected children from grades 4, 5, 6, and 8 to participate in Logo instruction. Findings revealed a tendency to confuse left and right commands, with younger children (i.e., Grades 4 and 5) demonstrating an egocentric perspective when compared to Grades 6 and 8.

Younger children also often confused the command 'turn' to mean 'turn and move,' an example of a mistaken preconception that did not analyze the commands into two separate actions.

To provide additional knowledge about preconceptions, Fay and Mayer (1987) conducted a supplemental study using a 'naive' adult population who received training in Logo. Interestingly, adults also demonstrated some preconceptions by confusing 'turn' and 'move' commands as labels. However, only 3 of the 27 adults in the sample tended to take an egocentric perspective. This finding is consistent with Piaget's prediction that the ability to take the turtle's perspective is not difficult for adults but may be difficult for children who are not yet capable of abstraction (i.e., formal operations thinking).

Perkins, Farady, Hancock, Hobbs, Simmons, Tuck, & Villa (1986) used a small group of eleven 8 to 12-year-olds from different ethnic backgrounds and found that a 'fragile' knowledge base often exists in novice programmers. This fragile knowledge base cannot presuppose possession of necessary skills for programming (e.g., organization, debugging) that may make programming Logo commands difficult. Abstraction was difficult for children because no 'mental models' were available to use as guides for visualizing the problem. The wrap-around feature often confuses young children who see the turtle disappear behind the screen and who lack the ability to conceptualize and predict where it will reappear (Cohen & Geva, 1989). It has been suggested that perhaps an optional 'NOWRAP' command be included for young children using Logo. The units of measurement or length of 'turtle steps' are too small for children to differentiate; therefore, the designation of 'big' steps and 'little' steps is used in some studies (Brinkley & Watson, 1990; Rembert, 1989; Easton, 1989). The shape of the triangle (i.e., turtle) makes it confusing when trying to determine the directional heading because the sides are almost the same length. Therefore, children must pay careful attention to determine the actual heading of the turtle. The concept of angles also presents problems for many children who are unable to calculate the distance between the two sides of the angles.

Children may demonstrate bias in their understanding of commands and in the sequence of commands in Logo (Campbell, Fein, Scholnick, Schwartz, & Frank, 1986). Turn commands may be difficult because young children (i.e., prior to the age of five) often do not know the difference between left and right. In a study conducted by Campbell et al. (1986) kindergarten children used forward (FD) commands more than back (BK) or left (LT), and they used right (RT) turns more than left (LT) turns. The forward and right commands may be easier to learn, or they may be learned initially as a first step to Logo mastery, which will be discussed in a later section on problem-solving strategies.

Prerequisite skills for Logo programming consist of concept of conservation and measurement of length, taking alternative perspectives as well as the turtle's frame of reference, and concept of angle rotation. Even though very young children (i.e., ages 3 to 5) may lack full or partial development of these skills, it is possible for them to demonstrate some success when programming in Logo. Such exposure to Logo should serve to facilitate the development of conservation and measurement skills.

Consequences of Programming

At the heart of the computer programming literature is the debate regarding transfer of cognitive skills when learning to program in Logo. Papert (1980) claimed in Mindstorms that the microcomputer provided the child with an "object to think with," and with this object the child constructed knowledge through experiences via the microcomputer. Based upon Piagetian principles of cognitive development, the microworld environment created by Logo "concretizes and personalizes" formal operations (i.e., abstract thinking) by making the operations real or concrete so that the child can witness them on the screen.

The most important concept underlying Logo according to Papert is "appropriation" (i.e., making knowledge gained via the computer one's own knowledge) (Reinhold, 1986). This concept is based on Piaget's constructivist view in which children create their own knowledge through learning experiences within their environment. Papert stated that the current educational system espouses the opposite approach by relaying knowledge from the teacher to the student. However, when students use problem-solving software such as Logo in the classroom, they are: 1) provided the benefits of crossing subject areas (e.g., sequencing, planning, hypothesis testing), 2) presented information in more than one mode, 3) required to take risks and synthesize information, 4) and encouraged to make trial-and-error approaches that are necessary and unavoidable. Schoenfeld (In Nickerson & Zodhiates, 1988, p. 3) stated that when students use Logo they are able to understand that deriving a workable solution to the problem requires attempts at revising, and in doing so students are able to become more proficient than their teachers, as opposed to engaging in passive memorization of others' mathematical solutions to problems. Schoenfeld (1988, p. 85) also stated that little is known about learning strategies and called for more research in this area.

Soloway (In Nickerson & Zodhiates, 1988, p. 129-135) stressed the need to understand the function of computers and software in order to use them effectively, and he stated that synthesis skills need to be taught and learned in order to enable switching between different programming languages. Students who learn programming in the context of a particular subject matter will encounter these same concepts again, which should facilitate the transfer of programming skills. Three problem-solving strategies which enhance transfer include: 1) "plan-a-little, do-a-little, repeat" strategy, 2) retrieval and reuse of relevant material, and 3) the generation of alternative solutions and evaluation of them. Students need to be taught these synthesis skills in an explicit manner.

Transfer Not Found. Logo's powerful ideas and bold claims have received criticism by some researchers (Pea & Kurland, 1984; Pea, Kurland, & Hawkins, cited in Pea & Sheingold, 1987). Pea's colleagues at Bank Street College conducted an in-depth two-year research project that taught Logo to elementary students (i.e., third through sixth grades) as a main part of an educational curriculum. Unfortunately, results at the end of the two years failed to find evidence of any transfer of planning skills on two different planning tasks (i.e., a far-transfer measure of classroom chore-scheduling tasks on a plexiglass map, followed by a near-transfer microworld planning task with more surface and structure similarity). Pea, Kurland, & Hawkins concluded that the Logo programming environment lacked pedagogical ability to result in generalizable cognitive gains and that the discovery-learning principle was not conducive to developing planning skills to be generalized to other tasks. Also cited of importance was the length of time students spent in class actually exposed to the Logo programming curriculum (i.e., approximately 30 hours), which is more time than most students spend in studies reporting positive successful transfer of cognitive skills (i.e., 5 to 20 hours). The teachers at Bank Street realized that structure is needed in Logo lessons, and they increased teacher guidance during the second year of their study. Their finding is not contradictory to claims made by Papert. Logo is not a treatment that can be administered without the necessary components of teacher involvement and age-appropriate presentation. Claims of cognitive enhancement are not inherent in Logo itself; however, higher-order thinking skills (e.g., problem-decomposition, debugging, hypothesis testing, and procedural thinking) can be facilitated through the use of Logo. Pea has admitted that perhaps the focus at Bank Street College was incorrect and that the curriculum should have stressed specific skills defined accordingly in the lesson plan (Johanson, 1988).

BASIC Research. Much of the literature regarding transfer of higher-order cognitive skills has utilized BASIC programming instruction as opposed to Logo. These studies by necessity employ older students (e.g., junior and senior high school, and college students), presumably who have reached Piaget's formal operations stage (Linn & Dalbey, 1985; Dalbey, Tournaire, & Linn, 1986; Dalbey & Linn, 1986; Cafolla, 1987-88). In Piaget's stage theory of cognitive development, formal operations skills necessary to learn programming develop after the age of eleven or twelve (e.g., propositional logic, seriation of abstract symbols, and assignment of variables). It has been estimated that only 50% of the population actually reach the formal operations stage of development, and empirical evidence supports this estimate (Cafolla, 1987-88; Santrock, 1990, p. 496). Cafolla

(1987-88) reported that achievement levels of cognitive development and verbal reasoning abilities were strong predictors of success in a community college course of BASIC programming. In light of such statistics, the possibility exists that perhaps some subjects do not possess the cognitive capabilities of engaging in transfer.

Linn & Dalbey (1985) found that access to computers and general ability were related to progress in BASIC programming for middle school students in typical classes, but not for students in exemplary or accelerated classes. Students in exemplary classes made more progress in comprehension, reformulation, and design of problem solutions than students in typical instruction. The major finding was that instruction greatly influenced outcomes in introductory programming classes; a secondary finding was that medium and high ability students made similar progress in exemplary classes emphasizing explicit instruction. Dalbey & Linn (1986) reported that students understood BASIC language commands, but rarely became competent at reformulating programs or designing complete solutions.

Instruction that makes explicit the skills for planning, testing, and reformulating in more than one formal system (e.g., learning other programming languages) may promote acquisition of general problem-solving ability (Linn, 1985). Mayer (1981) found concrete models of procedural processes to assist adult novice programmers, especially when the task required transferring knowledge to a new situation. Dalbey, Tournaire, & Linn (1986) failed to find evidence of transfer when problem specifications deviated from strategies learned in initial instruction using BASIC. Shaw (1986) also failed to find evidence of increased problem-solving abilities among fifth-grade students after seven weeks of instruction from trained teachers in either BASIC, Logo, or no instruction (i.e., control group). However, she employed as a pretest/ posttest measure a standardized test of reasoning skills (i.e., the New Jersey Test of Reasoning Skills), for which the control group scored sigificant gains on the posttest as did the Logo and BASIC groups, indicating that this measure is not an appropriate indicator of acquired computer programming skills. McCoy (1989-90) stated that courses in BASIC, Logo, and PASCAL must contain explicit instruction in procedural skills in order to realize the potential of transfer from programming instruction to general problem solving.

Curricular Instruction

The debate has continued over the last decade regarding the intended versus unintended consequences of Logo, as well as the presence or absence of higher-order cognitive skills due to transfer that may or may not have occurred. At any rate, researchers are beginning to examine the teaching strategies used as Logo is being 'taught', and data are pointing to the conclusion that explicit instructions result in the acquisition of specific skills that are transferred to other domains (Dalbey & Linn, 1985; Emihovich & Miller, in press; Clement, Kurland, Mawby, & Pea, 1986). Stated differently, should researchers be surprised when scores on standardized achievement tests do not reflect increases in metacognitive skills such as planning, analysis, and debugging? Also, are standardized tests designed to measure such metacognitive skills?

Dalbey & Linn (1985) revealed that researchers often have failed to determine how or why such transfer should occur, and that many courses do not provide students with sufficient instruction for transfer to occur. Before the extent of transfer of cognitive skills is assessed, most researchers do not determine even whether the skills were acquired during the treatment or training phase (Klahr & Carver, 1988). Amount of transfer is associated with amount of learning; therefore, if no learning actually occurred then one should not expect to find evidence of transfer from one setting to the next. Many studies (Krendl & Lieberman, 1988; Klahr & Carver, 1988; Reed, Ernst, & Banerji, 1974) support the claim that students learn specifically what they are taught; therefore, it seems likely that intended curriculum goals are a possible explanation for the variability in findings with Logo programming. Johanson (1988) concluded his argument by calling for more research in curricular and instructional development. Recent trends in research have included integrating educational and psychological theory into research, concept specification, and better research designs (Krendl & Lieberman, 1988).

The approach taken by researchers has shifted from searching for general cognitive outcomes to searching for specific skills taught by explicitly designed lessons. Kinzer, Littlefield, Delclos, & Bransford (1985) concluded that the stuctured method was more effective for teaching Logo, and also found that development of generalizable skills was related to the role of the teacher as s/he explained how to solve the problem. Klahr & Carver (1988) found that 8- to 11-year-olds learned specific debugging skills whenever these skills explicitly were included as cognitive objectives in part of an explicit Logo debugging curriculum. In a transfer task (i.e., arranging furniture) the amount of transfer was correlated with the degree of debugging skill acquisition after a 4-month period without any training. Past data also indicate that transfer of skills from one problem-solving domain to another is "surprisingly specific" (Reed et al., 1974). Reed et al. found transfer of problem-solving strategies of adults solving word problems only in the case of going from more difficult problems to similar easier ones.

In a small sample of middle school students (N = 7), Kurland & Pea (1985) found inability to explain recursive features even after approximately 50 hours of prior Logo training. Students were unable to perform mental models or abstract representations prior to running the program onscreen. Pea & Kurland concluded that self-guided discovery needs to be mediated with instruction. Vaidya (1985) also used little teacher guidance in a study of mostly minority preschool children from low income, urban backgrounds. No significant differences were found between high, medium, and low Logo-ability groups in terms of FI/FD, creativity, or mathematical aptitude. However, Vaidya used an extremely small sample (i.e., 5 or less per cell) and found prior experience with home video games to be a significant factor in Logo ability. Salomon & Perkins (1987) distinguished between 'low road' transfer (i.e., occurring as a result of thorough practice) and 'high road' transfer (i.e., occurring as a result of abstract generalization). Salomon & Perkins explained the mixed findings of transfer by crediting 'insufficient practice and little provocation of mindful abstraction' to studies failing to demonstrate transfer.

Success of Transfer. Although some studies have documented failure of transfer from programming domains to other domains, other research has demonstrated successful transfer of skills. Clements & Gullo (1984) tested two groups of six-year-olds randomly assigned to a CAI or Logo group, and results revealed that the children in the Logo group demonstrated some changes in cognitive style in terms of increased divergent thinking and increased reflectivity in problem-solving tasks ; however, no significant differences were found between the CAI and Logo groups in terms of cognitive development (i.e., skills such as classification and seriation). Clements (1986) conducted a study of longer duration (i.e., 22 weeks) comparing performances of six- and eight-year-olds randomly assigned to Logo, CAI, or control groups. Children in the Logo group demonstrated significantly higher scores on measures of operational competence (i.e., Piagetian tasks of classification such as object sorting, and seriation or ordering a series of objects by length) than did the control group. The CAI group demonstrated some gains as well but were not as efficient as the Logo group. The Logo programming group also showed significant increases in metacognitive skills (i.e., planning and evaluating one's work), as well as in creativity and in describing directions. No significant differences were found between Logo, CAI, and control groups on scores of reading and math achievement, thus lending further support to Logo's inability to enhance higher-order thinking skills measured on standardized tests. Lehrer (1986) supported Logo's claims of transfer with third-graders using reminders of how Logo knowledge would apply to math. The degree of reminders significantly affected transfer of knowledge from Logo to math. Connections between concepts and future application must be established in order to facilitate transfer of Logo concepts to other domains.

A third study by Clements (1987b) assessed long-term effects of learning Logo programming 18 months after training. Primary grade students demonstrated gains in metacomponential skills (i.e., deciding the nature of the problem, selecting an appropriate strategy). The Logo programming served to increase abilities in completing items that demanded application of metacognitive skills (i.e., analogies and sequences) through comprehension monitoring, as opposed to increasing domains of specific knowledge as measured by achievement tests. A mathematics achievement test was administered as a posttest to assess math knowledge. Clements (1987b) concluded that if Logo is to be used to teach mathematical concepts, then specific links between children's work in Logo and in mathematics classrooms must be made explicit through clear instruction. Otherwise, confusion may result in true understanding of concepts such as angle rotations that children may not infer correctly through their Logo experience. Findings from a study of high school students (Clement et al., 1986) also support the hypothesis that teaching specific skills results in transfer, and that transfer should not be expected spontaneously in other domains. Clement et al. proposed that one way transfer may occur is through analogical reasoning, which may be enhanced through learning computer progamming. Recognition of analogous problem situations may be dependent upon circumstances, such as organization, context, and degree of abstraction required.

Cognitive Changes. Mayer & Fay (1987) described a chain of cognitive events through which children progress according to their developmental level when learning to program in Logo. The three changes are: 1) changes in knowledge of specific features of the Logo language (i.e., syntax); 2) changes in the child's thinking within the domain of programming (i.e., semantics); and 3) changes in the child's thinking beyond the domain of programming (i.e., transfer). In only five sessions fourth-graders were able to improve measures of spatial cognition on a map posttest. Degelman, Free, Scarlato, Blackburn, & Golden (1986) provided kindergarten children with daily Logo training for five weeks, and found that these students performed significantly better on two problem-solving tasks involving rule-learning than did a matched control group. Gallini (1987) also found significantly higher posttest scores in the Logo group's ability to formulate directions (i.e., describing how a figure is constructed), while no significant differences were found between Logo and CAI groups in following directions (i.e., executing a set of step-by-step instructions). The turtle appeared to serve as a concrete model for constructing figures, whereas CAI did not. The fourth graders also demonstrated more self-confidence as the study progressed.

Kelly, Kelly, & Miller (1987) implemented a Logo study for one year with a large sample of fifth- and sixth-graders (N = 202) to assess gains in geography concepts such as relative position and direction. The Logo treatment group significantly outperformed the control group on relative direction tasks (i.e., determining north, south, east, and west headings). However, significant gains were not reported on tasks involving using a simple map and plotting coordinates. Kelly et al. suggested that further refinement of classroom instruction may change this outcome. Horton & Ryba (1986) implemented a Logo curriculum with a small group of junior high students (N = 8) and found a trend of superior performance (i.e., sample was too small for statistical analysis) on tasks such as writing directions, block design, matrices, and prediction tests, suggesting transfer of cognitive skills from a Logo setting to other problems. The control group outperformed the Logo group on the debugging task, possibly because the Logo experience taught the students to become more reflective in their error analysis, thereby slowing their performance.

In a final study, Thompson & Wang (1988) used a transfer test of plotting coordinates on a map with sixth-graders, after the experimental group received less than 3 hours of Logo instruction. Significant differences were found when compared to a control group, which indicated that transfer occurred as a result of discovery-oriented learning. Self-guided discovery learning is beneficial for the development of some skills (e.g., creativity, exploration), but data indicate that explicit instruction is needed for transfer of problem-solving skills (e.g., planning, debugging) to other domains.

Teaching Strategies. Miller and Emihovich (1986) have been the most prolific proponents of teaching strategies to be used with Logo instruction. Their model of teacher prompting is based on the tutorial principle by Wood, Bruner & Ross (1976). The teacher serves as a tutor to aid the student in hierarchical problem solving through a process called scaffolding. Scaffolding is defined as controlling the aspects of the problem that are too difficult for the child by presenting him with smaller steps within his ability. The student must comprehend the solution before he is able to solve the steps leading to it. Through scaffolding the tutor 'activates' the logical next step by making the problem solution recognizable to the child. A competent tutor provides guidance to help bridge the learner's background knowledge by presenting skills with new ideas in Logo programming.

Miller & Emihovich (1986) utilized comprehension monitoring, a metacognitive strategy in which children think about their own thinking, comprised of explicit instructional prompting or mediation by teachers. The teacher focused the student's thinking on relevant aspects of the programming problem and asked probing questions to make the child think about what they had learned and what step should be taken next. Probing questions included: 1) eliciting statements to recall previous material, 2) evaluative statements about what the turtle had just done, and 3) planning statements about the next step in the solution (Emihovich & Miller, 1988). This teaching strategy is based on Vygotsky's theory that self-regulatory behaviors develop as a result of collaborating with another individual. Miller & Emihovich (1986) trained preschool children in Logo for three weeks and employed teacher mediation whereby the teacher modeled self-regulatory processing for the child and transferred the responsibility back to the child through scaffolding.

Students in the Logo group demonstrated greater ability to detect errors in a block building transfer task than did students in the CAI control group. This study lends support to the hypothesis that preschool children can enhance comprehension monitoring skills through exposure to a Logo curriculum. Lehrer & Randle (1987) also found increases in comprehension monitoring using a group of predominantly minority first-grade students. The teachers employed scaffolding as well, whereby a scaffold is considered to be a construction of knowledge in process.

Emihovich & Miller (in press) conducted a study using minority first-grade students, mostly from low income backgrounds, along with majority students, from middle to upper class backgrounds, in each of the CAI control and Logo groups. Results revealed a significant main effect for race, with majority students performing better on posttest measures than minority students in CAI and control conditions. However, minority children outperformed the majority children in the Logo condition as measured by a mathematics posttest. In this case, Logo with teacher mediation proved successful for minority children. Emihovich & Miller stressed that access to or readiness for computer programming should not be contingent upon standardized test performance, using the example that minority students in their sample would not have 'qualified' but were able to demonstrate success given the opportunity to use Logo. Mediated verbal interaction is believed to be the crucial component in this learning process.

Logo instruction in the form of guided discovery can provide the learner with control over his own learning, making him reponsible for using feedback for future commands or strategies and facilitating independent cognitive skills. Alternatively, direct instruction in Logo minimizes student control of the learning process, yet provides the student with seemingly necessary explicit directions for solving future problems in other similar contexts. Dalbey & Linn (1985) suggested a combination of both teaching methods for students to become competent programmers, and also stressed the importance of designing instruction for a variety of learning styles. Pea, Soloway, & Spohrer (1987) also called for more specific instruction by teachers to convey that goals and plans are important intermediate steps between the problem statement and the solution. It is unfortunate but true that many teachers are poorly prepared to teach Logo. Leron (1985) stated that teaching Logo requires a highly skilled teacher who has been trained by a Logo expert, to incorporate the educational philosophy as well as the aspects of language and syntax. There needs to be a 'happy medium' between non-directed learning and controlled teaching. Bearden (1988) listed the key ingredients in teaching Logo: 1) promoting steps toward understanding, 2) challenging and encouraging students to engage in serious thinking, and 3) promoting creativity. If programming courses contain explicit instruction in procedural skills (e.g., planning, decomposition, metacognition, and debugging), then it is more likely that transfer from computer programming instruction to general problem-solving will occur (McCoy, 1989-90).

Problem-Solving Strategies

Since the focus of recent Logo research has shifted from searching for increases in general problem-solving knowledge to examining more specific skills, attention has turned toward the acquisition and order of skills employed by young children learning to program in Logo. Watson and colleagues have generated much research that has yielded some interesting findings in terms of predicting performance of preschool children who are learning Logo.

Sequence. Campbell et al. (1986) proposed a model in which children initially learn language commands and syntax of Logo, followed by use of a grid system with moves based on coordinates and development of spatial skills using a concentric circle system of angle rotations. Watson & Busch (1989) expanded the model to test pointing behavior as an initial step in Logo mastery and concluded that children develop pointing ability with the cursor as a prequisite skill. Brinkley & Watson (1990) tested more specific components of pointing behavior by including a cross-shaped and circular cursor in addition to the triangular cursor in their study. Results revealed that children demonstrated the most success (i.e., measured by fewer keystrokes in correcting errors) with the triangular cursor, thereby providing further support for pointing as an initial skill acquired for Logo mastery. Children also engaged in more right turns in problem solutions (i.e., they could keep turning right until the desired direction was achieved), and used more forward moves (i.e., going forward until turtle went off top of screen and reappeared at the bottom) (Brinkley & Watson, 1990; Rembert, 1989). Performance scores as measured by time, errors, trial, and keystrokes indicated more success in upper quadrants of the screen.

While children are engaging in Logo problem-solving strategies, it is useful to study the cognitive processes used to derive the solutions. Easton (1989) employed the comprehension monitoring questions used by Emihovich & Miller (1988) in a study of second- and fifth-graders classified by cognitive style (i.e., FI versus FD). Fifth-graders demonstrated more advanced levels of comprehension monitoring (i.e., generating hypotheses, planning ahead, evaluating outcomes) and tended to be more field independent. Since fifth-graders have more academic experience as well as advanced maturation this finding is not surprising. Similarly, the second-graders demonstrated a lesser degree of comprehension monitoring skills and tended to be more field dependent.

Watson, Lange, & Brinkley (in press) examined spatial route efficiency among FI/FD preschool children using barriers on the microcomputer screen. Results revealed that as the number of barriers increased, the field dependent children required longer times to solve the problem. Field independent children were more efficient (i.e., demonstrated quicker times, used fewer keystrokes, had fewer errors), and performed better on a transfer task using a finger maze. A second study by Watson, Lange, & Brinkley (1991) assessed perceptual role-taking behavior in 4- and 5-year-olds, and they concluded that preschool children are capable of taking the perspective of another if the task is age-appropriate. Field dependent children were able to solve problems with a left-to-right perspective more quickly than with the other perspectives (i.e., right, top, or bottom). Field independent children performed approximately equally from all four side perspectives. A possible explanation is that FI children possess the ability to separate out relevant details and impose structure and strategies in problem solution, whereas FD children view all information equally and may rely on past experience (e.g., reading a book) as a guide to problem solution.

Syntonic Commands. Most Logo studies have employed the regular Logo commands (i.e., comprised of two key presses for one command) for forward (FD), back (BK), left (LT), and right (RT), or at best have implemented the EZ Logo software in which one-key commands are used for forward (F), back (B), right (R), and left (L). As an easier solution to having preliterate children memorize letters for command keys, Allen & Watson (1991) devised a color-coding scheme in which command keys are labeled with a triangle (i.e., turtle) shape pointing in the appropriate direction. Forward, back, left, and right keys (i.e., also known as 90-degree turn keys) are labeled with green stickers pointed in the appropriate direction. All 45-degree turn keys are labeled with orange stickers pointed toward the four corners of the screen, respectively. The big step key has a large orange sticker and the little step key has a small green sticker. The authors named this procedure the 'syntonic command' method, based upon Papert's claims about turtle geometry. Papert (1980, p. 63) stated that turtle geometry is learnable because it is syntonic, which means that the turtle shares some personal properties with the child (e.g., position, goals, desires). Syntonic learning makes knowledge personal. Therefore, children are able to select the appropriate color command key based upon its directional heading once they know where they want the turtle to travel. The researchers deemed the syntonic command method more appropriate for preliterate and at risk populations.

As a brief synthesis of the research discussed, it is concluded that when young children are learning Logo several key factors contribute to skill acquisition and later transfer. These factors include, but are not limited to, cognitive style, teaching style, and degree of explicitness in instruction. Further analysis of the joint contribution of these components should enlighten researchers and serve to clarify some of the seemingly contradictory findings.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Of the original 20 children enrolled in the Project Uplift Child Development Center, three children moved out of town and one child was labeled "untestable" by the Developmental Evaluation Center; therefore complete data were collected for 16 subjects. All children were Black, four-year-olds from low socioeconomic backgrounds and were considered 'at risk' for developmental delays due to family income and environment. All children resided in Ray Warren Homes, a housing project operated by the Greensboro Housing Authority. The child development center follows the High Scope curriculum. Parents signed consent forms allowing children to participate in overall computer instruction as part of the curriculum, in which this study was included.

Subjects were pretested in the fall and posttested in the spring on the Preschool Embedded Figures Test (PEFT). Posttest scores were used for purposes of data analysis since they were deemed to be more representative of subjects' cognitive style classification at the time of this study. One child was absent the entire week of the posttesting; therefore, the pretest score was used so that this child's data could be included in the analyses. The children were categorized as either field dependent or field independent by a median split. The median and range of scores were comparable to data collected previously (Howard & Watson, 1991). Scores ranged from 10 - 21. Scores of 15 and below were classified as field dependent. Scores of 16 and above were classified as field independent. Seven children were categorized as field dependent and nine children were categorized as field independent. There were 4 field dependent and 6 field independent males and 3 field dependent females and 3 field independent females.

Design

The research design consisted of a quasi-experimental mixed factorial design with a series of repeated measures. Subjects were classified as field dependent/independent according to the (PEFT). Treatment levels consisted of Phase 1 tasks to be solved in the four quadrants of the computer screen, Phase 2 tasks to be solved in four corners of the computer screen, and Phase 3 tasks to be solved from the four side perspectives of the screen. Tasks from all treatment levels were presented in a different random order for each subject with both analytic and relational instruction.

Independent Variables. The field independent/dependent component of cognitive style was used to classify preschoolers according to their PEFT score. This classification served as the between-subject variable. Within-subject variables were the four quadrants (Phase 1), four corners (Phase 2), and four side perspectives (Phase 3). Separate analyses were conducted for analytic and relational instructions. Order of problem cards (1 - 8), number of phase (1 - 3), and type of instructions (analytic versus relational) were randomly assigned prior to data collection for each subject to avoid order effects.

Dependent Variables. The dependent variable for analytic instructions was the number of surplus grids (i.e., in excess of the shortest path) employed to construct a solution path. The computer determined the shortest route (i.e., fewest number of grids) to solve the problem successfully and this number was subtracted from the total number of grids in subject's solution path to yield a value for surplus grids. For relational instructions the dependent variables were the number of total grids used in all solution paths for a given task, as well as the number of solution paths (completed plus partial attempts). Allen & Watson (1991) determined the use of grids to be a more accurate indicator of problem solution attempts, as opposed to number of keystrokes, errors, and length of time for each problem.

Testing

PEFT. The Preschool Embedded Figures Test (PEFT) was used to determine the cognitive style (FI/FD) of each preschool child. The PEFT is a downward extension of the Children's Embedded Figures Test (CEFT), in which the presence of color is eliminated and the number of distracting forms are reduced (Coates, 1972). This test is a standardized test of perceptual discrimination that is developed for children between ages three and five and is administered individually. PEFT scores range from 0 - 24, with higher scores indicating field independence. Scoring is completed by dividing the group using a median split, with the top half of scores being classified as field independent and the bottom half of scores being classified as field dependent.

The PEFT was developed using 3- and 4-year-olds from various ethnic middle class backgrounds, and it was standardized on middle class 3 - 5-year-olds from private nursery schools. Reliability estimates range from .74 to .91 and are comparable to estimates obtained for EFT and CEFT scores for older age children. Test-retest correlations after five months ranged from .69 to .75. In terms of validity, the PEFT is correlated consistently with the Block Design scale of the WPPSI (Weschler Preschool and Primary Scale of Intelligence) for boys and girls (.55 to .67) (Coates, 1972). Busch, Nelson, Watson, Brinkley, & Howard (1990) reported estimates of internal consistency as .75 at pretest and .65 at posttest for a group of 37 predominantly white, middleclass preschool children attending a university preschool program. The test-retest correlation, also over a 5-month period, yielded a stability coefficient of .5. Ideally, both internal consistency and test-retest reliability values should be higher. For the present study internal consistency of the PEFT was assessed at pretest (Cronbach's alpha = .71) and again at posttest (Cronbach's alpha = .64). Test-retest reliability was also measured and the Pearson correlation revealed a coefficient of .66.

The median split as a classification procedure is somewhat controversial due to the 'arbitrary' cutoff depending upon the range of scores for a given sample. However, within the constraints of the PEFT as it relates to the Logo literature, the median split is an accepted procedure used commonly as a method for classifying FI/FD cognitive style within any given sample. It is not the intention of this study to make direct comparisons to any particular reference group or population. However, future replications with varied populations would provide more evidence for external validity of PEFT scores.

Equipment. The equipment used in this study included two Apple II GS microcomputers (1.25 megabytes) with two disk drives (3 1/2, 5 1/4), and two 12-inch diagonal color RGB Apple monitors. Logo Plus software, produced by Terrapin Software, was used. The microcomputers were arranged on low tables across from each other with 2 small chairs and were blocked off in one section of the classroom.

Experimenters. Three graduate students experienced in Logo instruction were used for all data collection. The experimenters provided verbal prompting and encouragement as needed to the subjects.

Procedure

Data Collection. Data collection was conducted an on individual basis Monday through Friday for three weeks between 9:00 - 11:30 am and 2:30 - 4:00 pm at the child development center. Two children were tested simultaneously.

Training. All subjects had received approximately 4 - 6 hours of introductory Logo instruction prior to this study with the same experimenters. Instruction included learning commands for 8 directions (i.e., forward, back, right, left, and headings for NE, NW, SE, SW) and two distance commands (i.e., big step, little step). Subjects practiced finding appropriate directional headings, turn commands, and distances to develop problem solutions on the screen for tasks requiring both analytical and relational solutions.

"Traditional" Logo commands (i.e., RT, LT, FD, BK) were not employed in this study. Instead, an alternate method of labeling keys with orange and green directional arrows was deemed more appropriate for this population. Command keys were reprogrammed by an experienced programmer for all turns (i.e., 45 and 90 degrees). Orange arrow keys represented right, left, forward, and back directions (i.e., all 90-degree turns). Green arrow keys represented northeast, northwest, southwest, and southeast directions (i.e., all 45-degree turns). The big step key was labeled with a large orange sticker and the little step key was labeled with a small green sticker (see Appendix A). A criterion of 50% was used to determine mastery of the orange and green keys at the end of the first two weeks of introductory training prior to this study. Each child was required to complete at least 6 out of 12 tasks successfully by using the correct command keys. All of the children met the criterion.

The NOWRAP procedure was programmed into the software due to reported difficulty children demonstrated with the recursive Logo command (Cohen & Geva, 1989; Cohen, 1990). Cohen (1990) cited confusion by second graders with the NOWRAP feature, as well as with numeric inputs to right and left commands after a seven-month-long study. Therefore, a barrier wall was produced around the perimeter of the screen for each task to prevent the turtle from disappearing at the top of the screen and reappearing at the bottom. Due to the design of the study, it was decided that the WRAP feature may actually confound results when the goal was to measure the most efficient route to the target. Each testing session in this study lasted approximately 20 minutes. Presentation of problem cards were selected according to each child's sequential random list. Each of the three phases contained 8 problem cards. Each child was presented with each of the 24 problem cards with analytical and relational instructions, for a total of 48 cards.

Phase I. Phase I utilized a series of spatial route problems represented equally in each of the four quadrants, with the turtle always beginning in the HOME position in the center of the screen facing north. Two tasks were represented in each quadrant (i.e., upper right, upper left, lower right, lower left), for a total of 8 cards. The eight cards were presented to the student with both analytic and relational instructions, for a total of 16 tasks.

Phase 2. Phase 2 utilized spatial route problems represented equally in each of the four corners of the screen, with the turtle being placed in the farthest point in each corner (i.e., upper right, upper left, lower right, lower left), always facing 'north' from that particular corner perspective. Two tasks were represented in each corner for a total of 8 cards. Students solved each card with both analytic and relational instructions for a total of 16 tasks.

Phase 3. Phase 3 utilized spatial route problems represented equally from each of the four sides of the screen (i.e., right, top, left, and bottom). Two tasks were represented from each side perspective for a total of 8 cards. Students solved each card with both analytic and relational instructions for a total of 16 tasks.

Instructions

Analytic. For problem cards requiring an analytical solution, students were read the following instructions: "For this problem I want you to find the shortest way for Tina Turtle to get from Point A to Point B. She is in a hurry and needs to get there as fast as she can" (see Appendix B). An analytical solution should be the most efficient spatial route (i.e., shortest distance), thereby utilizing fewer grids to solve the problem.

Relational. For problem cards requiring a relational solution, students were read the following instructions: "For this problem I want you to find as many ways as you can for Tina Turtle to go from Point A to Point B. She wants to learn as many ways as she can to get there" (see Appendix C). A relational solution should result in many completed solution paths (i.e., more ways to get from Point A to Point B), thereby using more grids.

Treatment. A set of 8 different cards were used for each phase (i.e., a total of 24 cards). Subjects were presented each card twice, once with analytic and once with relational instructions in random order, for a total of 48 tasks. Problem solutions required subjects to utilize 45 degree and 90 degree turns, as well as big steps and little steps (see Apppendix D).

Task cards were programmed into the Logo Plus software program to be accessed using a designated command. Subjects worked on one card at a time. Six cards were presented per testing session, for a total of 8 testing sessions. Each subject completed the 48 task cards.

Scoring of Exercises. Data from all problem-solving attempts for each problem card (i.e., number of grids used) were recorded and saved onto an individual disk for each student. Hard copies of each student's work were printed so that problem solutions (i.e., actual completed solution paths) could be analyzed and compared.

Data Analysis

To test the hypotheses that no significant differences existed between FI/FD, treatment phases, and instruction type for number of surplus grids, total grids, and solution paths, data were analyzed using a series of analyses of variance for repeated measures. The analysis tested for within-subject differences (treatment phases) as well as between-subject differences (cognitive style) and interaction effects for analytic and relational instructions. Main effects and interactions from the unweighted means analysis (Type III) were evaluated (Keppel, 1982). Tukey's post hoc comparison was performed to determine which means were significantly different for quadrant, corner, or side perspective on each dependent variable (surplus grids, total grids, and solution paths). A simple effects analysis was used to determine significant differences within an interaction.

Regression analyses were performed to measure individual subject success across all analytic versus relational tasks over time. Individual slope values for number of surplus grids, total grids, and solution paths were subjected to a *t*-test to test for significant differences between FI and FD subjects. The ANOVA procedures and regression analyses described above were sufficient to test the proposed hypotheses.

CHAPTER IV

RESULTS

Identical analyses were employed for each phase of the study: mixed, 2 x 4 within-subjects analyses of variance (Keppel, 1982). The between factor was cognitive style (field independence/dependence). The within factor at Phase 1 was quadrant (upper right, upper left, lower left, and lower right). At Phase 2, the within factor was corner (upper right, upper left, lower left, and lower right). Finally, the within factor for Phase 3 was side (right, top, left, and bottom).

At each phase, separate analyses were performed for analytic and relational instructional types since the two types of instructions required the children to perform distinctly different tasks. For analytic instructions children were asked to find the shortest route to the target. The dependent measure for tasks with analytic instructions was surplus grids (i.e., the number of grids in excess of the shortest path for that particular problem). For relational instructions children were asked to generate as many solution paths as possible. There were two dependent measures for tasks with relational instructions: total number of grids crossed and total number of solution paths (i.e., completed plus partial attempts) during the 2-minute time period.

In addition to the above analyses, three linear regression analyses were performed for each subject. Each of the three dependent measures (i.e., analytical: surplus grids; relational: total grids and solution paths) was regressed on time (24 trials) to detect improvement in performance across trials. The resulting slopes were then compared, using *t*-tests, for field independent versus field dependent children.

The subjects in this sample demonstrated success on tasks with analytic (i.e., finding shortest route) and relational instructions (i.e., finding many routes). All subjects completed solution paths by reaching the target goal on every analytic task. That is, there were no failures due to the subject not being able to complete the solution path. Subjects worked within a 2-minute time limit on all relational tasks, and all subjects were able to complete a minimum of one path on every relational task. Overall, FI and FD subjects were successful at programming the turtle to complete solution paths across all phases.

Results of the mixed-factor, within-subjects analyses will be presented separately for each phase. Then the *t*-tests results based on individual regression analyses will be presented.

Data Analysis - Phase 1

Hypothesis 1. It was hypothesized that there would be a significant main effect for cognitive style (FI versus FD) and significant cognitive style by quadrant (upper right, upper left, lower left, and lower right) interactions for both analytic and relational tasks.

Analytic Tasks

Three hypotheses were stated with regard to the analytic tasks:

(a) Field independent subjects would perform significantly better than field dependent subjects in all four quadrants on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects would demonstrate equal performance in all four quadrants on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better in the two upper quadrants than the two lower quadrants on analytic tasks as measured by number of surplus grids.

The children were given two analytic tasks within each of the four quadrants. Means were averaged across the two tasks within each quadrant. These means were then used in a mixed, 2 x 4 within-subjects analyses of variance. Cognitive style (FI/FD) was the between-subjects factor and quadrant (upper right, upper left, lower left, and lower right) was the within-subjects factor. One dependent measure was used for the analytic tasks: surplus grids.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) showed no main effects for cognitive style nor for quadrant (see Table 1). There was a significant interaction [$\underline{F}(1,42) = 2.99$, $\underline{p} = .0417$)]. Results of simple main effect analyses revealed no

Table 1

2 (Cognitive Style) x (4) Quadrant Mixed, Within-subjects Analysis of Variance for Phase 1 Analytic Instructions With Surplus Grids as Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	809.83	809.83	0.82	.3803
Subject (FI/FD)	14	13816.65	986.90		
Quadrant	3	167.45	55.82	0.16	.9249
FI/FD x Quadrant	3	3194.15	1064.72	2.99	.0417*
Quadrant x Subject(FI/FD)	42	14970.90	356.45		
Total	63	32881.48			

Note: The table represents the unweighted means analysis (Type III).

significant differences between quadrants for FI or for FD. Therefore, hypothesis 1(b) was supported, while hypothesis 1(c) was not. To determine if there were significant differences between FI/FD subjects for number of surplus grids in each quadrant, *t*-tests were performed. Results showed a significant difference between FI/FD in the upper left quadrant (p = .0321, unequal variances) (see Figure 1). FI subjects were more successful (i.e., had fewer surplus grids) (mean = 15.61) than FD subjects (mean = 45.36) in the upper left quadrant (see Table 2). Therefore, Hypothesis 1(a) was partially supported.

Figure 1. *T*-tests for FI/FD in Quadrants for Surplus Grids in Phase 1

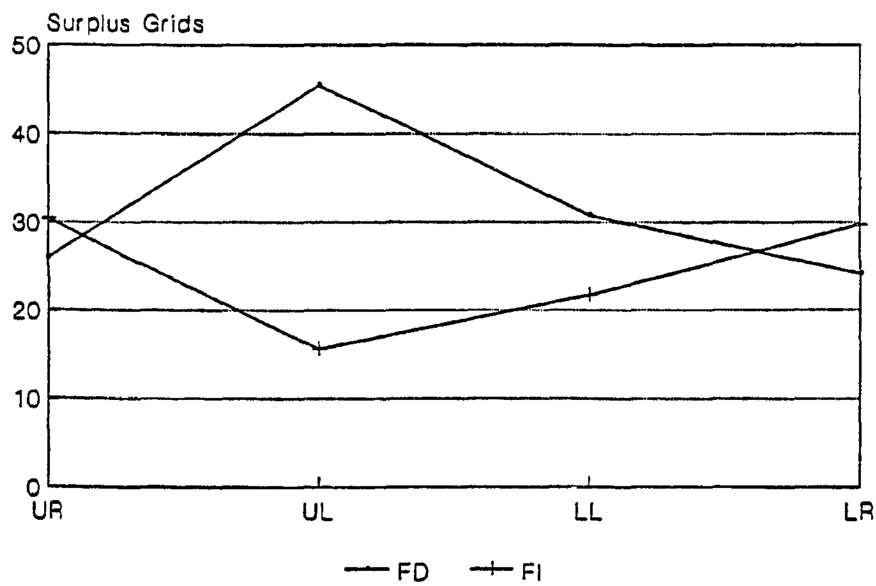

Table 2

Means and Standard Deviations for FI/FD for Surplus Grids in Quadrants for Phase 1 Analytic Instructions

Variable	N	Mean	SD
Field Independent			
Upper Right	9	30.39	19.92
Upper Left	9	15.61	12.06
Lower Left	9	21.72	24.37
Lower Right	9	29.67	23.60
Field Dependent			
Upper Right	7	25.93	22.19
Upper Left	7	45.36	28.18
Lower Left	7	30.71	26.99
Lower Right	7	24.07	22.93

Relational Tasks

Three hypotheses were stated with regard to the relational tasks:

(d) Field dependent subjects would perform significantly better than field independent subjects in all four quadrants on the relational tasks as measured by the total number of grids and solution paths.

(e) Field independent subjects would demonstrate equal performance in all four quadrants on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better in the two upper quadrants than the two lower quadrants on relational tasks as measured by number of total grids and solution paths.

The children were given two relational tasks within each of the four quadrants. Means were averaged across the two tasks within each quadrant. These means were then used in a mixed, 2 x 4 within-subjects analysis of variance. Cognitive style (FI/FD) was the between-subjects factor and quadrant (upper right, upper left, lower left, and lower right) was the within-subjects factor. Two dependent measures were used for the relational tasks: number of total grids and number of solution paths.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) showed no significant main effects or interactions for cognitive style and quadrant on number of total grids (see Table 3). FD subjects performed no differently than FI on number of total grids in each quadrant for relational tasks. The unweighted means analysis (Type III sums of squares in SAS GLM procedure) showed no significant interactions for cognitive style and quadrant on number of solution paths (see Table 4). FI subjects performed no differently than FD subjects on solution paths in all four quadrants on relational tasks. There was a near significant trend for quadrant effect [$F(1,3)=2.22$, $p=.0996$]. Examination of cell means revealed a near significant difference between the upper right quadrant (mean = 3.41) and the upper left quadrant (mean = 2.91), with FI and FD subjects completing more solution paths in the upper right quadrant (see Table 5). Hypothesis 1(d) was not supported.

Examination of cell means revealed that FI performance on number of grids and solution paths was not significantly different among all four quadrants (see Table 5). Therefore, hypothesis 1(e) was supported. Examination of cell means revealed that field dependent subjects performed equally in all four quadrants on number of total grids and solution paths (see Table 5). Hypothesis 1(f) was not supported.

Phase 2

Hypothesis 2. It was hypothesized that there would be a significant main effect for cognitive style (FI/FD) and significant cognitive style by corner (upper right, upper left, lower left, lower right) interactions for both the analytic and relational tasks.

Table 3

2 (Cognitive Style) x 4 (Quadrant) Mixed, Within-subjects Analysis of Variance for Phase 1 Relational Instructions With Total Grids as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	126.62	126.62	0.22	.6470
Subject (FI/FD)	14	8093.91	578.14		
Quadrant	3	1761.97	587.33	1.26	.3000
FIFD x Quadrant	3	1678.38	559.46	1.20	.3210
Quadrant x Subject(FI/FD)	42	19586.92	466.36		
Total	63	31186.09			

Note: The table represents the unweighted means analysis (Type III).

Table 4

2 (Cognitive Style) x 4 (Quadrant) Mixed, Within-subjects Analysis of Variance for Phase 1 Relational Instructions With Solution Paths as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	2.43	2.43	1.38	.2599
Subject (FI/FD)	14	24.68	1.76		
Quadrant	3	2.04	0.68	2.22	.0996
FI/FD x Quadrant	3	0.24	0.08	0.26	.8519
Quadrant x Subject (FI/FD)	42	12.84	0.31		
Total	63	42.36			

Note: The table represents the unweighted means analysis (Type III).

Table 5

Means and Standard Deviations for FI/FD for Grids and Solution Paths in Quadrants on Phase 1 Relational Instructions

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Grids						
Upper Right	9	75.78	33.89	7	56.00	19.92
Upper Left	9	62.50	20.43	7	68.57	21.20
Lower Left	9	70.89	13.97	7	75.79	28.03
Lower Right	9	79.39	16.02	7	76.86	17.07
Solution Paths						
Upper Right	9	3.67	1.15	7	3.07	0.53
Upper Left	9	3.06	1.04	7	2.71	0.70
Lower Left	9	3.33	0.79	7	3.07	0.45
Lower Right	9	3.44	0.88	7	3.07	0.45

Marginal Means	N	Mean	SD
Upper Right	16	3.41	0.95
Upper Left	16	2.91	0.90
Lower Left	16	3.22	0.66
Lower Right	16	3.28	0.73

Analytic Tasks

Three hypotheses were made with regard to the analytic tasks:

(a) Field independent subjects will perform significantly better than field dependent subjects in all four corners on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects will demonstrate equal performance in all four corners on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better in the lower left corner on analytic tasks as measured by number of surplus grids.

The children completed two analytic tasks within each of the four corners. Means were averaged across the two tasks within each corner. These means were then used in a mixed, 2 x 4 within-subjects analysis of variance. Cognitive style (FI/FD) was the between-subjects factor and corner (upper right, upper left, lower left, and lower right) was the within-subjects factor. One dependent measure was used for the analytic tasks: surplus grids.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) revealed no significant main effects or interactions for cognitive style and corners (see Table 6). FI subjects performed no differently than FD subjects in all four corners. Hypothesis 2(a) was not supported.

Table 6

2 (Cognitive Style) x 4 (Corner) Mixed, Within-subjects Analysis of Variance for Phase 2 Analytic Instructions With Surplus Grids as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	648.48	648.48	1.70	.2129
Subject (FI/FD)	14	5331.25	380.80		
Corner	3	171.21	57.07	0.19	.9035
FI/FD x Corner	3	846.29	282.10	0.93	.4333
Corner x Subject (FI/FD)	42	12702.04	302.43		
Total	63	19784.48			

Note: The table represents the unweighted means analysis (Type III).

Examination of cell means revealed that there were no significant differences among the four corners for the FI subjects on analytic tasks (see Table 7). Hypothesis 2(b) was supported. Field dependent subjects performed equally in all four corners as indicated by the cell means (see Table 7). Hypothesis 2(c) was not supported.

Relational Tasks

Three hypotheses were for relational tasks:

(d) Field dependent subjects would perform significantly better than field independent subjects in all four corners on relational tasks as measured by number of total grids and solution paths.

(e) Field independent subjects would demonstrate equal performance in all four corners on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better in lower left and lower right corners for relational tasks as measured by number of total grids and solution paths.

The children were given two relational tasks within each of the four corners. Means were averaged across the two tasks within each corner. These means were then used in a mixed, 2 x 4 within-subjects analysis of variance. Cognitive style (FI/FD) was the between-subjects factor and corner (upper right, upper left, lower left, and lower right) was the within-subjects factor.

Table 7

Means and Standard Deviations for FI/FD for Surplus Grids in Corners for Phase 2 Analytic Instructions

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Upper Right	9	22.56	19.28	7	27.86	19.61
Upper Left	9	14.39	9.29	7	33.07	23.09
Lower Right	9	25.39	14.84	7	25.50	17.38
Lower Left	9	27.50	17.75	7	29.09	21.48

Two dependent measures were used for the relational tasks: number of total grids and solution paths.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) revealed no significant main effects or interactions for cognitive style and corner on number of grids. FI subjects performed no differently than FD subjects on number of grids (see Table 8). Hypothesis 2(d) was not supported.

The unweighted means analysis (Type III) showed no significant interaction effect for cognitive style and corner for number of solution paths (see Table 9). However, there was a significant main effect for corner on solution paths [$F(1,3)=4.63$, $p=.0069$] (see Table 9). Tukey's post hoc comparison was calculated and results revealed a significant difference between the lower left corner (mean = 2.41) and the upper left corner (mean = 3.00) (see Table 10). There were no other significant differences between corners. Overall, all FI/FD subjects completed more solution paths on tasks in the upper left corner. Hypothesis 2(d) was not supported.

Examination of cell means revealed that FI subjects performed no differently in all four corners on number of total grids as well as solution paths (see Table 11). Hypothesis 2(e) was supported. Examination of cell means revealed that FD subjects performed no differently in all four corners on relational tasks on grids and solution paths (see Table 11). Hypothesis 2(f) was not supported.

Table 8

2 (Cognitive Style) 2 x 4 (Corner) Mixed, Within-subjects Analysis of Variance for Phase 2 Relational Instructions With Total Grids as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	917.15	917.15	0.98	.3382
Subject (FI/FD)	14	13059.84	932.85		
Corner	3	769.77	256.59	0.81	.4932
FI/FD x Corner	3	497.41	165.80	0.53	.6667
Corner x Subject (FI/FD)	42	13235.30	315.13		
Total	63	28445.86			

Note: The table represents the unweighted means analysis (Type III).

Table 9

2 (Cognitive Style) x 4 (Corner) Mixed, Within-subjects Analysis of Variance for Phase 2 Relational Instructions With Solution Paths as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	0.00	0.00	0.00	.9815
Subject (FI/FD)	14	13.96	1.00		
Corner	3	3.07	1.02	4.63	.0069*
FI/FD*Corner	3	0.07	0.02	0.10	.9596
Corner x Subject (FI/FD)	42	9.27	0.22		
Total	63	26.40			

Note: The table represents the unweighted means analysis (Type III).

Table 10

Means and Standard Deviations for Solution Paths in Corners for Phase 2 Relational Instructions

Variable	N	Mean	SD
Upper Left	16	3.00	0.66
Upper Right	16	2.81	0.63
Lower Right	16	2.63	0.59
Lower Left	16	2.41	0.61

Table 11

Means and Standard Deviations for FI/FD for Grids and Solution Paths in Corners for Phase 2 Relational Instructions

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Grids						
Upper Right	9	94.72	26.99	7	84.57	18.19
Upper Left	9	102.67	15.63	7	97.04	11.75
Lower Left	9	96.83	21.48	7	83.43	15.17
Lower Right	9	92.94	29.67	7	94.57	24.46
Solution Paths						
Upper Right	9	2.78	0.67	7	2.86	0.63
Upper Left	9	3.00	0.79	7	3.00	0.50
Lower Left	9	2.39	0.74	7	2.43	0.45
Lower Right	9	2.67	0.66	7	2.57	0.53

Phase 3

Hypothesis 3. It was hypothesized that there would be a significant main effect for cognitive style (FI/FD) and significant cognitive style by side perspectives (right, top, left, and bottom) interactions for both analytic and relational tasks.

Analytic Tasks

Three hypotheses were stated with regard to the analytic tasks:

(a) Field independent subjects would perform significantly better than field dependent subjects from all four side perspectives on analytic tasks as measured by number of surplus grids.

(b) Field independent subjects would demonstrate equal performance from all four side perspectives on analytic tasks as measured by number of surplus grids.

(c) Field dependent subjects would perform significantly better on perspectives from the left side of the screen on analytic tasks as measured by number of surplus grids.

The children completed two analytic tasks from each of the four side perspectives. Means were averaged across the two tasks within each side perspective. These means were then used in a mixed, 2 x 4 within-subjects analysis of variance. Cognitive style (FI/FD) was the between-subjects factor and side perspective (right, top, left, and bottom) was the within-subjects factor. One dependent measure was used for the analytic tasks: surplus grids.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) revealed a significant main effect for cognitive style [$F(1,14) = 6.67$, $p = .0217$] (see Table 12). Marginal means were 20.32 (FI) versus 35.23 (FD) (see Table 13). Overall, FI subjects performed significantly better (i.e., had more efficient spatial routes and fewer grids) than FD subjects. There were no significant interaction effects for cognitive style by side. Hypothesis 3(a) was supported.

Examination of cell means revealed that FI subjects performed no differently from all four side perspectives (see Table 13). Hypothesis 3(b) was supported. Examination of cell means revealed that FD subjects performed no differently from all four side perspectives on number of grids on analytic tasks (see Table 13). Therefore, hypothesis 3(c) was not supported.

Relational Tasks

Three hypotheses were stated with regard to the relational tasks:

(d) Field dependent subjects would perform significantly better than field independent subjects from each of the four side perspectives on relational tasks as measured by number of total grids and solution paths.

Table 12

2 (Cognitive Style) x 4 (Sides) Mixed, Within-subjects Analysis of Variance for Phase 3 Analytic Instructions With Surplus Grids as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	3502.62	3502.62	6.67	.0217*
Subject (FI/FD)	14	7355.32	525.38		
Side	3	2505.42	835.14	2.09	.1154
FI/FD x Side	3	2203.71	734.57	1.84	.1542
Side x Subject (FI/FD)	42	16745.94	398.71		
Total	63	32527.94			

Note: The table represents the unweighted means analysis (Type III).

Table 13

Means and Standard Deviations for FI/FD for Surplus Grids from Side Perspectives for Phase 3 Analytic Instructions

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Side						
Right	9	30.83	8.46	7	33.21	25.39
Top	9	27.27	18.43	7	32.07	10.16
Left	9	16.94	10.51	7	47.86	44.78
Bottom	9	6.22	4.58	7	27.79	23.24
Marginal Means	36	20.32	14.80	28	35.23	28.13

(e) Field independent subjects would demonstrate equal performance from all four side perspectives on relational tasks as measured by number of total grids and solution paths.

(f) Field dependent subjects would perform significantly better from the left side perspective on relational tasks as measured by number of total grids and solution paths.

The children completed two relational tasks from each of the four side perspectives. Means were averaged across the two tasks within each side perspective. These means were then used in a mixed, 2 x 4 within-subjects analysis of variance. Cognitive style (FI/FD) was the between-subjects factor and side perspective (right, top, left, and bottom) was the within-subjects factor. Two dependent measures were used for the relational tasks: number of total grids and solution paths.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) showed no significant main effects or interactions for cognitive style and side perspective on total number of grids (see Table 14). However, there was a near significant trend (p = .1064) for side perspective on number of total grids. Examination of cell means revealed a slight difference between the top side perspective (mean = 81.84) and the bottom side perspective (mean = 66.63) (see Table 15). Both FI and FD subjects used more total grids from the top side and fewest total grids from the bottom

Table 14

2 (Cognitive Style) x 4 (Side Perspective) Mixed, Within-subjects Analysis of Variance for Phase 3 Relational Instructions With Total Grids as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	0.89	0.89	0.00	.9778
Subject (FI/FD)	14	14092.93	1006.64		
Side	3	2497.51	832.50	2.16	.1064
FI/FD x Side	3	1489.32	496.44	1.29	.2900
Side x Subject (FI/FD)	42	16151.54	384.56		
Total	63	33854.98			

Note: The table represents the unweighted means analysis (Type III).

Table 15

Means and Standard Deviations for Total Grids from Side Perspectives for Phase 3 Relational Instructions

Variable	N	Mean	SD
Marginal Means			
Right	16	78.63	28.32
Top	16	81.84	22.20
Left	16	77.97	22.89
Bottom	16	66.63	17.23

side. However, hypothesis 3(d) was not supported at a level of statistical significance.

The unweighted means analysis (Type III sums of squares in SAS GLM procedure) revealed no interaction effect of cognitive style by side perspective for number of solution paths (see Table 16). There was a near significant trend for cognitive style on number of solution paths (p = .1027). Examination of marginal means revealed that FI children generated more solution paths (mean = 3.06) than FD children (mean = 2.64) from all four side perspectives (see Table 17). There was a significant side perspective effect for solution paths [$F(1,3)$ = 2.71, p =.0568] (see Table 16). Tukey's post hoc comparison (alpha = .05) was calculated to determine which sides were significantly different. Results showed a significant difference between bottom and right sides (see Table 17). There were no significant differences between the other sides. Overall, all FI/FD subjects completed more solution paths from the bottom side perspective (mean = 3.22) and fewer solution paths from the right side perspective (mean = 2.59). This part of hypothesis 3(d) also was not supported.

Examination of cell means for number of grids revealed no significant differences between side perspectives for FI subjects on relational tasks (see Table 18). Therefore, hypothesis 3(e) was supported. Examination of cell means revealed that FD subjects performed equally on all four side

Table 16

2 (Cognitive Style) x 4 (Side Perspective) Mixed, Within-subjects Analysis of Variance for Phase 3 Relational Instructions With Solution Paths as the Dependent Measure

Source	df	SS	MS	F	p value
FI/FD	1	2.68	2.68	3.05	.1027
Subject (FI/FD)	14	12.32	0.88		
Side	3	2.88	0.96	2.71	.0568*
FI/FD x Side	3	1.69	0.56	1.59	.2051
Side x Subject (FI/FD)	42	14.84	0.35		
Total	63	35.00			

Note: The table represents the unweighted means analysis (Type III).

Table 17

Means and Standard Deviations for Solution Paths from Side Perspectives for Phase 3 Relational Instructions

Variable	N	Means	SD
Marginal Means			
FI	9	3.06	0.84
FD	7	2.64	0.52
Side			
Right	16	2.59	0.84
Top	16	2.75	0.61
Left	16	2.94	0.60
Bottom	16	3.22	0.82

Table 18

Means and Standard Deviations for FI/FD for Grids and Solution Paths from Side Perspectives for Phase 3 Relational Instructions

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Grids						
Right	9	76.33	31.21	7	81.57	26.23
Top	9	76.11	19.49	7	89.21	24.76
Left	9	80.17	22.68	7	75.14	24.64
Bottom	9	72.06	16.66	7	59.64	16.47
Solution Paths						
Right	9	2.67	0.97	7	2.50	0.71
Top	9	2.78	0.62	7	2.71	0.64
Left	9	3.17	0.71	7	2.64	0.24
Bottom	9	3.61	0.82	7	2.7	0.49

perspectives as measured by number of solution paths (see Table 18). Hypothesis 3(f) was not supported.

Regression Analysis

Separate simple regression analyses were performed for analytic and relational instructions across time to assess improvement on both types of tasks over time. Individual regression analyses were performed for each subject using surplus grids as the dependent variable for analytic tasks (1 -24), and number of grids and solution paths as the dependent variables for relational tasks (1 - 24). Therefore, each subject had three regression slopes. The value for each slope was entered as a separate data set and *t*-tests were performed to test for significant differences between FI/FD on surplus grids, total grids, and number of solution paths.

It was expected that on analytic tasks subjects would become more efficient over time in finding the shortest route, thereby demonstrating a decreasing or negative slope from higher to lower numbers of surplus grids. For relational tasks it was expected that subjects would become more proficient at finding solution paths, demonstrating an increasing or positive slope from fewer to greater numbers of grids and solution paths. Three *t*-test procedures revealed no significant differences between FI and FD subjects on number of surplus grids, total grids, and solution paths for analytic and relational tasks (see Table 19).

Table 19

T-test Procedures Using Regression Slopes for FI/FD on Surplus Grids, Total Grids, and Solution Paths

Variable	Field Independent			Field Dependent		
	N	Mean	SD	N	Mean	SD
Surplus Grids	9	.1940	.2822	7	-.0036	.2248
Total Grids	9	.0746	.2066	7	.0935	.2970
Solution Paths	9	.1610	.1822	7	.0598	.2616

Visual inspection of regression plots showed that on approximately the first twelve tasks (analytic or relational) subjects were performing quite successfully, followed by a decline in performance on the last twelve tasks. This effect could have been due to boredom from having to perform tasks that were somewhat repetitive. Or the decline in performance could have resulted from the random or mixed exposure to both analytic and relational tasks, thereby confusing the child about finding the shortest path versus finding many solution paths.

CHAPTER V

DISCUSSION

General Findings

Perhaps the most important finding of this study is a non-statistical one. This study provided evidence that young minority children (i.e., Black four-year-olds) from disadvantaged backgrounds can learn to program successfully in Logo when the concepts and programming commands are presented at an age-appropriate level. This is very strong evidence considering the debate in computer programming literature that questions whether or not preschool children are capable of such an accomplishment given their stage of preoperational thinking. Vaidya (1985) provided Logo training for an 8-month period twice a week to a group of minority (i.e., predominantly Black) preschool children from low SES backgrounds. Vaidya provided little structure to the lessons and found no significant differences between high, medium, or low Logo-ability groups in FI/FD, creativity, or math ability. Of the small sample size, it was reported that five children learned Logo well, five learned with a great deal of encouragement, and four failed to learn Logo at all. This finding leads one to suspect the level of appropriateness of teaching methods for individual children. Fay & Mayer (1987) found that elementary students younger than grade 6 demonstrated confusion between right and left and between 45-degree and 90-degree angles despite hands-on experience (i.e., one lesson lasting approximately 30 - 45 minutes). Fay & Mayer stressed that research addressing the degree to which naive conceptions and confusions can be altered through experience at various ages is a worthy endeavor.

The present study demonstrated that children as young as four years old can learn to program the turtle in the desired direction if commands are presented with an age-appropriate format. Mayer & Fay (1987) proposed a 3-stage sequence of learning to program, in which learning language features (i.e., syntax) is a prerequisite for successful thinking about programming (i.e., semantics), and learning to think about programming is a prerequisite for thinking outside of programming (i.e., transfer). This chain of cognitive changes is facilitated by learning to program, according to Mayer & Fay. The present study provided an alternative method of allowing the children to learn syntax through single keystrokes programmed by the child, as well as to learn semantics by observing the turtle execute the programmed commands via single keystrokes (i.e., directional arrow keys and big/little step keys).

Evidence from this study also challenges findings by other researchers who failed to teach 4- and 5-year-olds to program successfully using simplified versions of Logo. Gregg (1978) used a floor turtle that could be operated by only three commands (i.e., 90-degree clockwise turns, 90-degree counter-clockwise turns, and forward). Children demonstrated difficulty in learning which button turned the turtle in the desired direction. Cuneo (1986) showed children the beginning and end states of Logo problems on the computer screen and asked children to program the all of the moves that the turtle had made using only four single-keystroke commands (i.e., F for forward, B for back, L for left, and R for right). Despite intensive feedback, children were not successful in generating the necessary two or three line programs. It would seem that the teaching methods were not age-appropriate for the 4- and 5-year-olds in these studies. Clements & Merriman (in Mayer, 1988) maintained that children are quite capable of learning to program in Logo if they are exposed to a rigorous computer training curriculum with age-appropriate teaching strategies. However, subjects in the present study were exposed to only 10 weeks of computer exposure (i.e., approximately 8 weeks of introductory training followed by 2 weeks of tasks in the treatment phases). This training represents approximately 10 hours of training, which is hardly considered 'intensive.' Children in this study were able to grasp the concepts presented in the microworld and successfully maneuver the turtle around the computer screen.

This study was designed specifically to assess the strategies that children were using to solve the tasks in the various quadrants, corners, and side perspectives. Although the study was limited to a small sample size, it was clear that these children were able to take the various perspectives (i.e, turtle's perspective) required to solve the problem on the screen. All children demonstrated successful completion of tasks using bottom-to-top, top-to-bottom, left-to-right, and right-to-left perspectives.

Hypotheses 1a., 1b., and 1c. Results showed a significant interaction between FI/FD subjects and quadrants (p = .0417) on analytic tasks. Although significant differences were predicted between FI/FD subjects in all four quadrants, significant differences were found in the upper left quadrant only. FI subjects used significantly fewer surplus grids (mean = 15.61) than did FD subjects (mean = 45.36) in the upper left quadrant. It is likely that the FD children experienced more difficulty in the upper left quadant because solution of these tasks required a general right-to-left upward motion to reach the target. The turtle was in HOME position, facing north at the beginning of both upper left quadrant tasks. Since FD children lacked strategies they may have relied on past experience for problem solution. It is probable that they did not have any past experience involving right-to-left spatial movement, which is the opposite of behavior such as reading (i.e., left-to-right). FI children were able to use strategies more efficiently in the upper left quadrant than FD children because they are better at focusing on relevant aspects of the problem. There were no significant main effects for cognitive style or quadrant; therefore only part of the hypothesis was supported.

There were no significant differences between quadrant performance for FI children as was predicted. They performed equally well in all four quadrants. FI children are able to separate out relevant aspects of the task and select a strategy for solving the problem. These children were able to take the turtle's perspective within any quadrant of the screen. Results showed that FD children also performed equally well in all four quadrants, which was not predicted. FD children were able to develop solution paths equally in all four quadrants as measured by the number of surplus grids. Although this finding is somewhat surprising, it may be explained by the eight weeks of introductory training in which children obtained experience solving problems from various locations on the screen. This explanation would support the proposition by Globerson (1989) which stated that children's behavioral repertoires could be increased in their weaker area without changing their cognitive style. Cathcart (1990) also found that fifth-graders demonstrated increases in divergent thinking as well as field independence after only 20 hours of training in Logo.

Hypotheses 1d., 1e., and 1f. Results revealed no significant main effects or interactions for cognitive style or quadrants with number of total grids or solution paths on relational tasks. There was a near significant trend (p = .0996) between the upper right quadrant (mean = 3.41) and the upper left quadrant (mean = 2.91). Both FI and FD children completed more solution paths in the upper right quadrant and fewer solution paths in the upper left quadrant. Success in the upper right quadrant can be explained by previous findings in the literature (Campbell et al., 1986; Easton, 1989) where children learn forward and right commands easier, thereby placing them in the upper right quadrant. One possible explanation may be that tasks in the upper left quadrant consisted of a right-to-left problem flow, whereas tasks in the upper right quadrant necessitated a left-to-right problem flow. Watson, Lange, & Brinkley (1991) found a left-to-right problem flow to be easier for FD children.

As was predicted, FI children performed equally well in all four quadrants on number of total grids and solution paths for relational tasks. FD children also performed equally well in all four quadrants on number of total grids and solution paths on relational tasks. Again, these children may have learned skills from the previous eight weeks of training related to the FI problem-solving style that they were able to use in the treatment tasks (e.g., focusing on relavent aspects of the problem).

Hypotheses 2a., 2b., and 2c. Results showed no significant main effects or interactions for corners or cognitive styles for surplus grids on analytic tasks. Again, it is possible that FD children learned problem-solving skills similar to the FI dimension of problem solving.

As was predicted, FI children performed equally well in all four corners on number of surplus grids for analytic tasks. These children were able to take the turtle's perspective in each corner (i.e., initially pointing north) and program a solution path to reach the target goal. Counter to the predictions made for FD children, results showed that these children also were able to perform equally well from each of the four corners.

Hypotheses 2d., 2e., and 2f. Analyses revealed no significant main effects or interactions for cognitive style or corners for total number of grids on relational tasks. Both FI and FD students performed equally well on treatment tasks regarding total number of grids crossed for a given task. Results showed no significant interaction for cognitive style and corners on number of solution paths for relational tasks. However, there was a significant main effect for corner performance (p = .0069). Overall, FI and FD children completed more solution paths in the upper left corner (mean = 3.00) and completed fewest solution paths in the lower left corner (mean = 2.41) for relational tasks. Interestingly, tasks in the far upper left corner necessitated a left-to-right and/or top-down perspective to be taken in order to find a solution path. Again, this finding may be explained by the tendency to begin the strategy in the top left corner as in reading. This finding is not surprising, especially for FD children who have more difficulty selecting a strategy and may rely on past experience to derive a solution. This evidence contradicts data by Campbell et al., (1986) that found that the target location on the screen as well as the heading of the turtle did not influence preschool children's directional fluency. However, Campbell et al. allowed children to use a magnet board which permitted physical experimentation with a cursor off of the screen as they attempted to use Instant Logo. It seems clear that this concrete teaching method in conjuntion with Logo enhanced the children's ability to use directional commands successfully.

FI children performed equally in all four corners as predicted on number of grids and solution paths on relational tasks. FD children also performed equally in all four corners on number of grids and solution paths on relational tasks. Again, a plausible explanation may be the possibility that FD children may have gained problem-solving skills similar to the FI style (e.g., experiencing items as discrete from their backgrounds) that they were able to use successfully in the treatment tasks.

Hypotheses 3a., 3b., and 3c. Analyses revealed no significant differences between cognitive style and side perspective on surplus grids; however, there was a significant difference between FI and FD children on surplus grids on analytic tasks (p = .0217). Overall, FI children performed better from all side perspectives than did FD children. Marginal means were 20.32 for FI versus 35.23 for FD. This finding is supported by previous evidence that states that FI children are better at taking the turtle's perspective from all sides of the screen (Watson, Lange, & Brinkley, in press; Watson, Lange, & Brinkley, 1991).

FI children performed equally from all four side perspectives as predicted on analytic tasks. Performance was no different between right, top, left, and bottom side perspectives. FD children also performed equally from all four side perspectives on analytic tasks. It is possible that the FD children demonstrated such success at programming the turtle due to the problem-solving skills they learned during the 8-week training session.

Hypotheses 3d., 3e., and 3f. Results showed no significant differences for FI/FD and side perspective on number of total grids for relational tasks. There was a near significant trend for side perspective (p = .1064). Visual inspection of cell means showed that there were more total grids from the top side perspective (mean = 81.84) and fewer grids from the bottom side perspective (mean = 66.63). Both FI and FD children crossed more grids when generating solution paths from the top than when generating solution paths from the bottom for relational directions.

At first glance, this finding may seem counterintuitive since it was the opposite finding of that predicted by the hypothesis. It does seem logical that the more solution paths a child is able to generate, the more grids s/he will cross, thereby having a higher total number of grids. However, a great number of grids in a single solution path would indicate that the child is not efficient in generating the solution path. Although the relational tasks do not specifically ask that the child be efficient in finding as many solution paths as s/he can, it is presupposed that the more solution paths a child finds within the 2-minute time limit, the more efficient s/he has been. It seems plausible that when children were asked to solve a task from the top perspective that they had more difficulty in mapping out a strategy for a solution path, thereby 'wandering' around the screen using grids in an inefficient manner. Fay & Mayer (1987) reported that performance was lowest when the turtle was heading at a 180-degree orientation from HOME position (i.e., the turtle's left was now the child's right and the turtle's right was the child's left), while performance was highest when the turtle was in HOME position. In the present study children were more efficient (i.e., used fewer grids) from the bottom perspective because it was easier for them to take a bottom-up or forward perspective with the turtle.

There was also a near significant trend for an interaction between FI/FD and side perspective on number of solution paths for relational tasks (p = .1027). Marginal means were 3.06 for FI children versus 2.64 for FD children. FI children were better overall at generating more solution paths from all four side perspectives than FD children. This finding is supported by others who found that FI individuals are better in general at programming problem solutions than FD individuals (Canino & Cicchelli, 1988; Howard, Sheets, Ingels, Wheatley-Heckman, & Watson, 1988). There was a significant difference between side perspectives (p = .0568). Results showed a significant difference between the bottom and right sides. Overall, FI and FD children completed more solution paths from the bottom side (mean = 3.22) and fewest solution paths from the right side (mean = 2.59). This finding is intuitively correct and is supported by other studies that report more success when the turtle's perspective matches that of the child's (Fay & Mayer, 1987; Brinkley & Watson, 1990). When the turtle is at the bottom of the screen it is easier for the child to move forward. When the turtle is at the right side of the screen pointing to the child's left, directions are now different for the turtle (i.e., left is now at the bottom of the screen and right is at the top). Also, the directional flow of the problem from right-to-left is opposite to the familiar reading strategy left-to-right. Therefore, children would have less experience to rely on to solve a task using a right-to-left strategy.

FI children performed equally from all four side perspectives on number of grids and solution paths on relational tasks. As discussed earlier, this finding is well-documented in the literature and was predicted. FD children also performed equally from all four side perspectives on number of grids and solution paths for relational tasks. Although this finding was not predicted, it can be explained by prior training on Logo concepts within the microworld.

The regression analyses yielded no significant differences between FI/FD children on number of surplus grids for analytic tasks, and number of total grids and solution paths over time for relational tasks. FI children did not differ significantly from FD children in their overall performance. However, an interesting pattern did emerge upon further visual inspection of the regression plots. It appeared that for approximately the first half of the tasks, for both analytic and relational, the children were demonstrating success as measured by relatively few numbers of surplus grids for analytic tasks and higher numbers of grids and solution paths for relational tasks. Then for approximately the last half of the tasks, performance begin to decline as indicated by higher numbers of surplus grids (13 of 16 children, approximately 81%) and lower numbers of grids (8 of 16 children, approximately 50%) and solution paths (6 of 16 children, approximately 38%). An opposite pattern occurred from that predicted. It was reasoned that perhaps the children became bored with the onscreen tasks that were similar in nature, hence the decline in performance. A second explanation is that the children could have become more confused over the course of the study when they were asked in a random order to find either the shortest route or as many routes as possible on a given task.

This study tested an issue of major debate in the literature, that is, whether or not young children are able to learn the syntax and semantics of Logo commands in order to program within the spatial domain of the microworld (Mayer & Fay, 1987). Using an alternative method of programming commands (i.e., labeling keys with orange and green arrows and big/little steps) provided an age-appropriate format of using single keystroke commands for this group of preliterate children. Also of importance is the application of this teaching strategy to a group of minority preschool children coming from disadvantaged backgrounds. Sixteen Black children learned to program successfully in Logo. Very few studies have provided any data on minority (i.e., predominantly Black) children using Logo (Vaidya, 1985). Therefore, this study contributes to the literature with cultural findings on a different sample of children.

The teaching method used in this study was very effective and the children's programming success largely can be attributed to it. Studies that previously found success in learning computer programming skills (Clements & Gullo, 1984; Clements, 1986; Miller & Emihovich, 1986; Klahr & Carver, 1988) used structure in their teaching methods. In studies failing to find enhanced problem-solving skills, researchers found that the 'discovery-method' cannot be used necessarily to relay important concepts of problem-solving within the Logo microworld (Pea & Kurland, 1984; Linn, 1985). Linn (1985) stated that explicit instruction may promote problem-solving ability. Miller & Emihovich (1986) used explicit instructional prompting with preschool children in a mediational format in which the teacher built on the child's response and encouraged the child to think about the logical next step in the problem solution. Other researchers have concurred that children learn specifically what they are taught (Kinzer, Littlefield, Declos, & Bransford, 1985; Krendl & Lieberman, 1988; Swan, 1991). Swan (1991) stressed that explicit instruction in problem-solving with mediated Logo programming practice could result in the development and transfer of the following problem-solving strategies: breaking problems into subgoals, solving the problem in one-step increments, using systematic trial and error, and using analogy to map a strategy between two similar problems. Swan also found that using discovery-learning in Logo with fourth-sixth graders, as well as explicit instruction with concrete objects (i.e., paper cut-outs) failed to teach the four problem-solving strategies above.

In the present study children were provided with praise and encouragement as needed. If a child became 'stuck' during the problem solution the experimenter would say, "Which way does the turtle need to go?" and would encourage the child to point in that direction with his/her finger. During the initial training sessions prior to this study, the experimenters would provide intensive feedback as well as minor assistance (i.e., such as giving the child a choice of three keys to select) to help the child develop a problem solution. It is likely that this assistance provided the child with some level of confidence for later problem solution. The experimenters observed much progress over the course of the study for children who were initially very hesitant about programming keystrokes for the turtle.

CHAPTER VI

CONCLUSIONS

This study empirically investigated the strategies that minority preschool children use in solving Logo problems in an age-appropriate format. Sixteen Black, four-year-olds were trained in Logo and were included in a quasi-experimental study designed to assess differences between cognitive style (FI/FD) within treatments (quadrants, corners, and side perspectives) for number of surplus grids on analytic instructions and number of total grids and solution paths for relational instructions. The children completed the 24 tasks with both analytic and relational instructions, for a total of 48 tasks.

Quadrant Performance

Results showed that FI children were more efficient (i.e., used fewer surplus grids) in the upper left quadrant than FD children on number of surplus grids. The problem solution required a right-to-left directional flow from the center of the screen upward to the upper left quadrant. This strategy is more difficult than the left-to-right directional flow as in reading, particularly for FD children who do not separate relevant aspects of the problem from the entire context as easily as FI children. Within the group of FI children, performance between the four quadrants was no different as was predicted. Within the group of FD children, performance between the four quadrants also was no different.

It is likely that the FD children benefitted from the initial Logo training which enhanced their problem solutions.

Corner Performance

Overall, there were no significant differences between FI/FD children in surplus grids, total grids, or solution paths. However, there was a significant corner effect for number of solution paths on relational instructions. Both FI and FD children completed more solution paths in the upper left corner and completed fewest solution paths in the upper right corner. Solution paths from the upper left corner were easier to formulate because the directional flow of the problem followed the familiar reading strategy of beginning at the top left and moving right in a downward fashion. Problem solutions in the upper right corner were most difficult because the directional problem flow was 'backwards' (i.e., from right-to-left) from most spatial experience the children were likely to have had. Again, performance between corners was equal for FI children as well as for FD children. The most likely explanation is that FD children benefitted from the previous introductory Logo training.

Side Perspective Performance

Results revealed significant differences for cognitive style, with FI children performing better from all side perspectives on number of surplus grids than FD children. When the turtle's orientation changes and the child must take a perspective different from his own, FD children demonstrate more difficulty because they are more susceptible to misperceptions of cues in the context as a whole. FI children are able to screen out relevant information about the discrete item or problem.

There were no significant differences between FI/FD on side perspective for number of total grids on relational instructions. There was a near significant effect for side perspective on number of total grids, with both FI and FD performing more efficiently (i.e., using fewer total grids) from the bottom perspective than from the top perspective. As discussed earlier, it is logical that if a child was demonstrating difficulty in taking a top-down perspective with the turtle (i.e., where right and left are now opposite of the child's right and left) that the child would be less efficient in finding a solution path, thereby using more grids to reach the goal. Problem solutions were easier for both FI and FD from the bottom side perspective, which is the same as the child's egocentric perspective. Similarly, there was a significant side perspective effect for number of solution paths on relational instructions. Both FI and FD completed more solution paths from the bottom side perspective and completed fewest solution paths from the right side perspective. Children used their egocentric perspective to help them from the bottom side perspective but were unable to use such a strategy to help them from the right side perspective. Overall, FI children were slightly better at generating more solution paths from all four side perspectives.

This study provided evidence that young minority children are able to learn to program the turtle successfully using an age-appropriate format in Logo within a relatively short period of time (i.e., less than 10 hours training). Both FI and FD children were able to take the turtle's perspective to program a solution, although they demonstrated more difficulty from the top-down perspective. Overall, results did not support the degree of cognitive style difference in performance as was predicted.

Implications for Future Research

The major limitation of this study was the small sample size. Replication with a larger sample of at least 30 children would be recommended. Also with a larger sample, classification of cognitive style could be accomplished using the top and bottom thirds of the PEFT scores to delineate more comfortably between field independence/dependence. With the preschool population one cannot be sure of the stability of the cognitive style dimension; however, it is well-documented that the PEFT is measuring at least one aspect (i.e., separating figure from ground) of information processing. Perhaps using the PEFT in conjunction with other measures, such as the RFT, as recommended by Busch et al. (1990) would enable researchers to determine exactly which variables need to be manipulated in subject treatment. Another strong recommendation would be the development of new measures to assess global characteristics of the child, such as personality variables (i.e., introvert/extrovert, sociability) and behavior variables (i.e., risk-taking, activity/arousal level) in addition to attention, memory, and biases in perception and problem-solving. Replicating such a study with cross-cultural samples (e.g., Hispanic, Native American, Asian) would also help tease apart the influence of socialization versus genetic predisposition.

In future studies it is suggested that providing analytic treatment separately from relational treatment in a counter-balanced design would help prevent the potential problems of boredom and/or confusion by the subjects. Further analysis of problem-solving strategies may be achieved by asking the child to explain reasons for selecting that particular problem solution or by asking the child to think of and name other tasks/experiences that relate to the Logo problem. An assessment of reading readiness skills would provide some evidence for type of problem-solving strategies being used (i.e., left-to-right). If the child's language ability (i.e., receptive and/or expressive) is a limitation to the inquiry method, the researcher could observe and perform a MANOVA across treatment phases (i.e, quadrants, corners, and side perspectives) to determine which type of directional problem-flow in general (i.e., left-to-right, right-to-left, top-to-bottom, bottom-to-top) the children had the most success.

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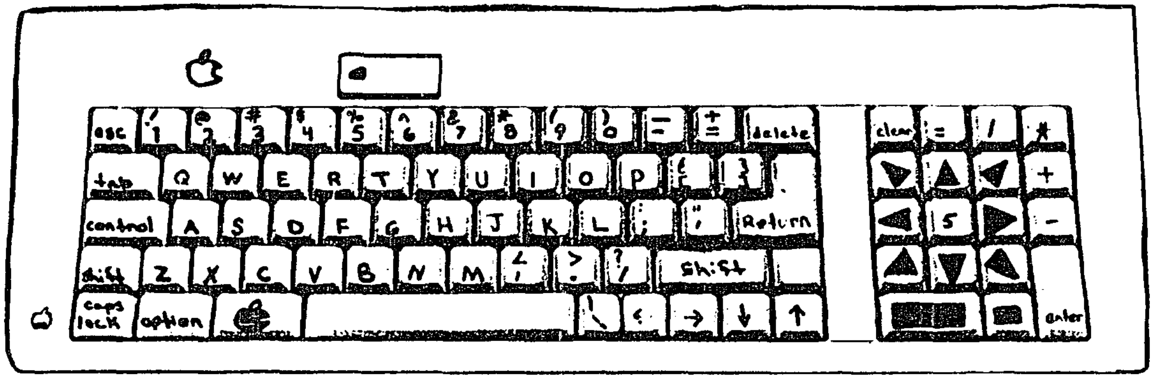
APPENDIX A

KEYBOARD

KEYBOARD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APPENDIX B

ANALYTIC INSTRUCTIONS

ANALYTIC INSTRUCTIONS

Phase 1

Card 1 - Tina Turtle dropped the apple she was taking to her teacher. Help her find it as fast as you can before someone else does. (target: apple)

Card 2 - Someone hid the apple that Tina Turtle brought for snack today. Please hurry and help her find it because she is hungry. (target: apple)

Card 3 - Tina Turtle is late for her first day at work. Help her find the quickest way to her office so she will be on time. (target: door)

Card 4 - Tina Turtle's office has moved to a new building. She does not know where it is. Help her find her new office as fast as you can. (target: door)

Card 5 - Yesterday Tina Turtle was playing on the merry-go-round when she lost her bracelet. Help her get back to the merry-go-round as quickly as you can so she can look for it. (target: merry-go-round)

Card 6 - Tina Turtle's friends have invited her to go to the park to play on the merry-go-round. Help her find the shortest way to get there so she won't be late. (target: merry-go-round)

Card 7 - Tina Turtle bought a brand new shiny sportscar! But she has lost her key.Please help her find it as fast as you can so she can go for a ride. (target: key)

Card 8 - Tina Turtle forgot to park her car in the garage. Can you hurry and help her park it inside before it starts to rain? (target: key)

Phase 2

Card 1 - Tina Turtle was taking a boat ride when she spotted a puppy out in the water. Help Tina get to the life preserver as fast as she can so she can throw it to the puppy and save him. (target: life preserver)

Card 2 - Tina Turtle is the captain of a big ship. She wants to steer the ship away from some rocks she sees out in the water. Help her get to the ship as fast as you can so that the ship will not have a wreck. (target: life preserver)

Card 3 - Tina Turtle is trying out for the Olympics. She has been practicing her dives from the diving board. Help her get to the swimming pool as fast as she can so she can practice one more time before her contest. (target: diving board)

Card 4 - One day Tina Turtle is on her way to the pool when she sees a squirrel who has fallen in and cannot swim. Help Tina get to the diving board as fast as she can so she can rescue the squirrel. (target: diving board)

Card 5 - Tina Turtle is out for a walk one day when she sees a firetruck on its way to a big fire. The firemen need some help and they want Tina to get on the firetruck so she can help them put out the fire. Can you help get her on the truck quickly? (target: fire extinguisher)

Card 6 - Tina Turtle is going to ride the firetruck with the firemen. She wants to spray the fire extinguisher to see if it works. Can you help her find the shortest way to get to the fire extinguisher? (target: fire extinguisher)

Card 7 - Tina Turtle is taking a trip on an airplane. But she almost forgot her suitcase! Hurry and help Tina put her suitcase on the plane before it takes off. (target: suitcase)

Card 8 - Tina Turtle forgot to pack her toothbrush and cannot get on the plane. Help her hurry and put her toothbrush in her suitcase so she can go on her trip. (target: suitcase)

Phase 3

Card 1 - Tina Turtle is hungry and spots an apple that has fallen off the tree. Can you help her find the shortest path to get to the apple so she can eat it? (target: apple)

Card 2 - An apple has fallen off the tree. Tina thinks that Mr. Horse would like to eat the apple. Help Tina get the apple to take it to Mr. Horse as fast as she can. (target: apple)

Card 3 - Tina Turtle is at the zoo. She buys some peanuts to feed Mr. Elephant. He is very hungry. Help Tina feed Mr. Elephant as fast as she can. (target: peanuts)

Card 4 - Mr. Elephant is almost out of peanuts. Tina Turtle can get him some more if she has a basket to put them in. Help Tina find Mr. Elephant's basket as fast as you can so she can bring him some more peanuts. (target: peanuts)

Card 5 - Tina Turtle is going to Grandma's house for a visit. Grandma was expecting her a long time ago, but she is running late. Help Tina hurry to Grandma's house, but she must not forget to use the mat to wipe her feet before she goes inside. (target: door mat)

Card 6 - Tina Turtle is going to help Grandma clean her house today. Grandma asks Tina to please clean the doormat. Help Tina find the mat quickly so she can help Grandma some more. (target: door mat)

Card 7 - Tina Turtle is out of food at her house. She needs to go to the grocery store. Help Tina find the shortest path to the store so she can do her shopping. (target: grocery cart)

Card 8 - The grocery store is having a sale on turtle food. Help Tina Turtle get to the store as fast as she can before they sell all of the turtle food. (grocery cart)

APPENDIX C

RELATIONAL INSTRUCTIONS

RELATIONAL INSTRUCTIONS

Phase 1

Card 1 - Tina Turtle dropped the apples she was taking to her teacher. Help her find as many apples as you can. (target: apple)

Card 2 - Someone hid the apples that Tina brought for snack to give to her friends. Help her find enough apples so that her friends can have their snack. (target: apple)

Card 3 - Tina Turtle is on her way to work. Help her to find as many different ways as you can to go to the office. (target: door)

Card 4 - Tina Turtle's office has moved to a new building. Help her find as many different paths as you can to get Tina to her office. (target: door)

Card 5 - Yesterday Tina Turtle was playing on the merry-go-round when she dropped some money. Help Tina get back to the merry-go-round to find her money. Each time she goes back she finds another nickel, dime, or quarter. (target: merry-go-round)

Card 6 - Tina Turtle's friends have invited her to go to the park to play on the merry-go-round. She is lost and cannot find her way. Please help Tina by showing her many different ways to get there so she will not get lost again. (target: merry-go-round)

Card 7 - Tina Turtle bought a brand new shiny sportscar! She wants to give all of her friends a ride in it, but only one friend can ride with her each time. Help Tina give each one of her friends a ride in her new car. (target: key)

Card 8 - Tina Turtle's new car has flat tires and she needs your help to change them. She can only bring one new tire with her each time she goes to the car. Help her change as many tires as you can. (target: key)

Phase 2

Card 1 - Tina Turtle wants to go fishing on the boat. She can only catch one fish at a time. Help Tina catch as many fish as she can for dinner. (target: life preserver)

Card 2 - Tina Turtle is the captain of a big ship. She looks ahead and sees some huge waves coming at her ship. Help her get to the steering wheel to turn her ship away from the big waves. She can only avoid one wave each time. (target: life preserver)

Card 3 - Tina Turtle is trying out for the Olympics. The judges are watching her dive off of the diving board. Each time she dives she gets another point. Help Tina get a lot of points so she can win the prize. (target: diving board)

Card 4 - One day Tina Turtle is on her way to the swimming pool when she sees a bunch of Easter eggs floating in the pool. She wants to get them out but she can only carry one egg at a time while she swims in the water. Help Tina get as many eggs as she can. (target: diving board)

Card 5 - Tina Turtle is on a walk one day when she sees a firetruck on its way to a big fire. The firemen need Tina's help. Help Tina carry as many buckets as she can to help put out the fire. Remember, she can only carry one bucket at a time. (target: fire extinguisher)

Card 6 - Tina Turtle is helping the firemen to wash their firetruck. They are hot and thirsty. Tina wants to take them some lemonade to drink, but she can only carry one glass at a time. Help Tina carry as many glasses of lemonade as she can to the men on the firetruck. (target: fire extinguisher)

Card 7 - Tina Turtle is going away on a big vacation, so she must take many clothes with her. She has packed a bunch of suitcases and needs some help to get them on the plane. Can you help Tina get all of her suitcases on the plane? Remember, she can only carry one suitcase at a time. (target: suitcase)

Card 8 -Tina Turtle is taking all of her neices and nephews on an airplane trip with her. But she must take each child one at a time and put them on the plane and fasten their seat belt. Can you help Tina get all of her neices and nephews on the plane? (target: suitcase)

Phase 3

Card 1 - One day Tina Turtle is playing out in a field when she sees a huge apple tree with big red apples on it! Some of the apples have fallen on the ground. Help Tina pick up as many apples as she can to put in her basket. (target: apple)

Card 2 - Grandma has asked Tina Turtle to go out in the backyard to pick up some apples that have fallen on the ground. Grandma said she would make an apple pie for Tina if she could find enough apples. How many apples can you help Tina find? (target: apple)

Card 3 - Tina Turtle went to the zoo to see the animals. The zookeeper has asked Tina to help feed the elephant. Help Tina take enough food to the elephant so that he won't be hungry. How many bites can you help Tina feed him? (target: peanuts)

Card 4 - Mr. Elephant has made a mess with peanut shells in his cage. Tina Turtle said she would help him clean up the mess. How many peanut shells can you help Tina pick up and put in the bucket? (target: peanuts)

Card 5 - Tina Turtle is looking for Easter eggs at Grandma's house. Each time she finds one in the yard she takes it inside the house. How many eggs can you help Tina take inside the house? (target: door mat)

Card 6 - Grandma has been having trouble with ants coming into her house. She asked Tina to spray some ant spray on the doormat to get rid of the ants. How many times can you help Tina spray the doormat? (target: doormat)

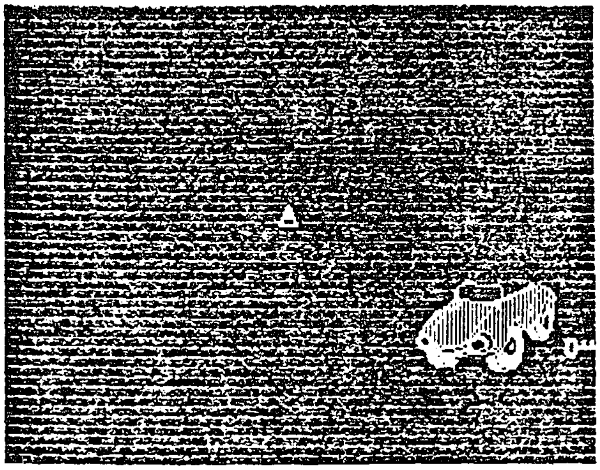
Card 7 - Tina Turtle is doing her grocery shopping today. She will need a lot of grocery carts because she is buying a lot of food. How many grocery carts can you help Tina find? (target: grocery cart)

Card 8 - Tina Turtle got a new job! She is working at the grocery store down the street. Her job is to find the grocery carts that people leave in the parking lot and take them back inside the store. How many grocery carts can you help Tina find? (target: grocery cart)

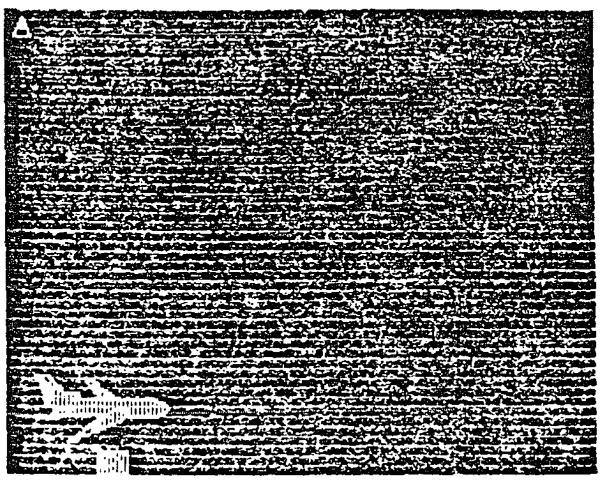
APPENDIX D

PROBLEM CARD EXAMPLES

Quadrant



Corner



Side Perspective