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The effects of microcomputer use on the critical thinking skills of middle school students

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Harvey W. Perkins

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THE EFFECTS OF MICROCOMPUTER USE ON THE

CRITICAL THINKING SKILLS

OF MIDDLE SCHOOL STUDENTS

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CHAPTER 1

Introduction

Reactions to the emergence of the microcomputer as part of the educational scene are diverse. Pogrow (1982) suggests that computers will become infused into so many facets of U.S. society by 1985 that training in computer use will replace basic skills as the primary public concern in education (p. 610). Other educators feel that computer education is a passing fad that will have no more lasting effects on education than did programmed learning, reading machines, and the new mathematics (Kelman, 1982; Suhor, 1983). Unfortunately, empirical evidence revealing the effectiveness of the microcomputer in schools is limited (Becker, 1982; Ragosta, Holland and Jamison, 1982). Most research to date has been done with terminals attached to time-sharing computers in laboratories equipped with extensive computer hardware and operated by computer specialists. The focus of most studies has been on improving basic skills in mathematics and language arts through computer drill and practice (DeVault, 1981; Hallworth and Brebner, 1980; Vinsonhaler and Bass, 1972). Educators are now questioning whether the flexibility of the microcomputer, the development of new interactive software, and the control of the technology at the teacher-student level may have rendered previous research irrelevant (Becker, 1982).

New avenues for microcomputer use are being explored. Recent researchers (Damarin,1982; Gress, 1982; Montague, 1982) have suggested that the computer is a more appropriate tool for teaching higher level thinking skills than for drilling rote-learned rules of grammar and arithmetic.

Importance

The need to focus instruction more directly on the teaching of thinking skills has become especially evident since the "back-to-basics" movement of the 1970's (Whimbey, 1977; 1980). National Assessment of Educational Progress (NAEP, 1981) studies revealed that although teachers were doing a better job teaching some lower order skills, i.e. computation and grammar, losses in student achievement were observed in inferential comprehension, in problem solving, in mathematics, in writing, and in critical reading. More recently, the National Commission on Excellence in Education has observed that schools are emphasizing such rudiments as reading and computation at the expense of other essential skills such as comprehension, analysis,and problem solving. (The Excellence Report, 1983, p. 4).

Many educators have begun programs to develop inquiry skills in our young people (Glines, 1983; Houston, 1983; La Conte, 1983). A common element in each program is the emphasis on process, not content. While course titles and subject matter change from year to year, the emphasis on problem solving, critical thinking, decision making, and investigation remains constant (La Conte, 1983, p. 44). Using conventional teaching methods (e.g., discussion, demonstration, and paper and pencil activities), teachers encourage students to share how they solve problems by verbalizing their thought processes. Problem solving strategies are then critiqued either in pairs or in small groups. Empirical data have been collected which demonstrate an increase in students' problem solving skills as a result of participation in such programs (Costa, 1981; Link, 1983; Worsham and Austin, 1983).

The implications for the educational uses of the microcomputer are clear. If the microcomputer is to be the learning tool of the future, it must prove its effectiveness in developing those higher level thinking skills which our young people will need to confront the challenges ahead.

Statement of the Problem

The purpose of the study was to determine whether teaching critical thinking skills with the microcomputer produces a greater increase in the thinking skills of middle school students than teaching critical thinking skills with conventional methods.

General Research Hypotheses

The hypotheses tested in this study were as follows:

Hypothesis H_o1 states that students completing a microcomputer assisted learning module on verbal analogies will show significantly greater gains on a quantitative measure of analogic skills than students completing an equivalent module taught with conventional teaching methods.

Hypothesis H_o2 states that students completing a microcomputer assisted learning module on logical reasoning will show significantly greater gains on a quantitative measure of logical reasoning than students completing an equivalent module taught with conventional teaching methods.

Hypothesis H_o3 states that students completing a microcomputer assisted learning module on inductive/deductive reasoning will show significantly greater gains on a quantitative measure of inductive/deductive skills than students completing an equivalent module taught with conventional teaching methods.

Hypothesis H_o4 states that students completing a microcomputer assisted learning module on problem analysis will show significantly greater gains on a quantitative measure of problem analysis than students completing an equivalent module taught with conventional teaching methods.

Hypothesis H_o5 states that students completing microcomputer assisted learning modules on critical thinking skills will show significantly greater gains on a standardized scholastic aptitude test than students completing equivalent modules taught with conventional teaching methods.

Theoretical Rationale

Critical thinking skills have been defined by Bloom (1956) as belonging to the domain of analysis, synthesis, and evaluation. These skills require the learner to receive information, process it, and create a unique product or idea as a result of the experience. Lower order skills consist primarily of information acquisition and transmission. Bloom, Hastings, and Madaus (1971) suggest that education has traditionally emphasized lower order, not higher order skills. Guilford (1977) identifies a hierarchy of intellectual operations ranging from cognition and memory (lower order processes) through divergent production, convergent production, and evaluation (higher order processes). He goes beyond Bloom, however, by suggesting that these higher cognitive skills can be taught and reviewed through specific instructional strategies. His Structure-of-Intellect Problem Solving (SIPS) model (see chapter 2) attempts to integrate all five levels of information processing into a structured approach to creative thinking and problem solving.

Can all students be expected to demonstrate these critical thinking skills? For most of the past two decades, Piaget's stage theory of cognitive development (Furth, 1969; Inhelder and Piaget, 1958; Piaget, 1972) has suggested a positive response to this question. Piaget asserts that learners progress through the same sequential stages of cognitive development and that this development is a function of maturity and interaction of the learners with their environment. As children reach the age of eleven or twelve, they typically acquire the formal operational skills necessary to deal with the higher order cognitive processes required in critical thinking activities (Day, 1981).

Case (1978a, 1978b) suggests that many students who have the ability to think "formally" or critically on a particular task may not do so because they lack the "executive strategies" needed to solve the problem. "Executive strategies" are techniques which allow a learner to organize data for effective problem solving. For example, when comparing the effects of two or more items in an experiment, a child needs to use the control-of-variables strategy to hold all other things equal except that being tested. Failure to grasp this strategy could make an otherwise higher order thinker appear to be ineffective on a given task. In short, it is not enough for children to have the mental capacity to solve a problem; they must also be taught strategies to organize for problem solving (Case, 1978b; Day, 1981).

Feuerstein's Theory of Mediated Learning Experience formalizes and reinforces Case's argument for teaching problem solving strategies. Feuerstein (1980) asserts that deficient cognitive functioning stems from a lack of mediated learning experiences due to such factors as poverty of stimuli, cultural differences, or low educational level of parents (Hobbs, 1980). With proper assessment and the provision of appropriate learning experiences, he believes that learners can improve their problem solving skills at any age or stage of development. Feuerstein attributes the poor performance of many students on standardized intelligence measures to a failure on the part of educators to emphasize cognitive process instruction (Feuerstein, 1980; Hobbs, 1980).

Thus, Bloom and Guilford provide a theoretical base which defines the domain of critical thinking skills. Case and Feuerstein suggest that intervention strategies are effective in improving students' higher cognitive processes.

Definition of Terms

For the purposes of this study, the following definitions apply:

Microcomputer. A small stand-alone computer system designed to be accessed by one user at a time. Its memory capacity is small (usually 16K to 64K), and its central processing unit is a self-contained chip.

Time-Sharing Computer. A single computer system with a large memory and storage capacity to which a number of terminals are connected, allowing for simultaneous access to its resources by many users.

Computer-Assisted Instruction (CAI). A method of using a computer system to present individualized instructional material. The three primary modes of presentation are drill and practice, tutorials, and simulations.

Critical Thinking Skills. Four skills selected from the Analysis, Synthesis, and Evaluation levels of Bloom's *Taxonomy of Educational Objectives* (1956) define critical thinking as follows:

(1) Analogous reasoning - the ability to perceive interrelationships between groups of words.

(2) Inductive/deductive reasoning - The ability to identify the missing premise to complete a logical syllogism or to indicate logical fallacies in arguments.

(3) Problem analysis - the ability to analyze mathematical word problems to determine if the data provided is relevant or irrelevant to its solution.

(4) Logical reasoning - the ability to comprehend a rule or principle implicit in a pattern or sequence of numbers, letters, or figures.

Limitations

Studies by Case (1982a), Piaget (1972), and Stone and Day (1978) suggest that it is difficult to teach formal reasoning skills to children under twelve years of age. The seventh grade population chosen for this study was composed exclusively of children ages twelve to fourteen, and no attempts should be made to generalize findings to other age levels. Likewise, the geographic limitation of selecting the sample population from one school system suggests that the findings not be generalized to other school systems without careful study to determine if sufficient demographic similarities exist to make such a generalization.

Two additional limitations of this study concern the critical thinking skills domain as defined in this study and the microcomputer delivery system. Critical thinking as defined in this study includes analogous reasoning, inductive/deductive reasoning, logical reasoning, and problem analysis. No attempt should be made to generalize findings to other higher order thinking skills which may be grouped under the heading of critical thinking, e.g.evaluation of arguments or recognition of assumptions. Lastly, delivery of course content was administered using commercially available software with students working in a classroom with a two to one ratio of students to microcomputers. Findings are not generalizable to delivery systems which greatly alter the quality of the software or increase the student to microcomputer ratio.

Overview

In Chapter 2, theoretical concepts of cognitive process development and intervention are reviewed and relevant research on educational computing and critical thinking skills development is discussed. The methodology of the study is presented in detail in Chapter 3, including specific research hypotheses and research design. In Chapter 4, data collected during the study are presented and analyzed. Conclusions of the study and implications for future research are presented in the final chapter.

CHAPTER 2

Review of the Literature

Summary of Rationale and Relationship to the Problem

Several national studies of public education (NAEP, 1981; The Excellence Report, 1983) have cited a need for improved higher level thinking skills among our young people. Recent studies (Costa, 1981; Link, 1983; Whimbey, 1980; Worsham and Austin, 1983) have indicated that the direct teaching of thinking skills can improve problem solving performance. Ehrenberg (1981) points out, however, that many schools still emphasize fact learning rather than process learning. A catalyst is needed to reverse this instructional focus, and many educators feel that the microcomputer may serve as the catalytic agent (Becker, 1982; Deringer, 1983). Previous empirical data on the instructional effectiveness of computers in education have been gathered on lower order skills (drill and practice in math and language arts) on time-sharing computers in non-school settings (Vinsonhaler and Bass, 1972). It is the intent of this study to determine the effectiveness of the microcomputer in teaching critical thinking skills in the middle school setting.

Theoretical Concepts

Four concepts of cognitive process development and intervention provide the basis for this study. Bloom's taxonomy of educational objectives defines the domain of critical thinking skills; Guilford's conceptualization of information processing and problem solving suggests appropriate strategies for teaching higher level thinking processes; Case's neo-Piagetian perspective of cognitive development provides a rationale for teaching specific thinking strategies; and Feuerstein's concept of cognitive modifiability supports the assumption that intervening instructional strategies can mediate inadequate cognitive development.

Bloom's taxonomy of educational objectives. Bloom (1956) arranges cognitive processes into a hierarchy consisting of six major classes:

1.00 Knowledge - The process involved here is memory, the ability to file away information and recall it when necessary. Alteration of the material received is minimal.

2.00 Comprehension - This represents the lowest level of understanding. Processes of summarizing, paraphrasing, and translating are included here.

3.00 Application - This involves receiving information (principles, ideas, theories) and being able to apply that information in new situations.

4.00 Analysis - The ability to breakdown a communication into its component parts to make clear the relationships between ideas (unstated assumptions, inferences, propaganda).

5.00 Synthesis - The ability to take component parts and arrange or combine them to create a unique product or communication (poem, organizational plan, theory).

6.00 Evaluation - The ability to make qualitative or quantitative judgements about the extent to which material and methods satisfy criteria.

Bloom (1956) suggests that most educational experiences are targeted at the lower level of processing skills (knowledge and comprehension) and that the higher order skills (analysis, synthesis, and evaluation) which are essential for critical thinking and problem solving are rarely addressed (see also Bloom, Hastings, and Madaus, 1971).

Guilford's problem solving model. Like Bloom, Guilford (1977) has defined a hierarchical scheme to cognitive operations. He suggests that all mental processes are divided into five categories:

Cognition - the most basic kind of operation; it consists of the brain taking information from our senses and organizing it into items of information to be stored. Discovering, knowing, and understanding are all instances of cognition.

Memory - storage of items of information for later retrieval.

Divergent production - broad searches of our memory stores, seeking alternatives which fit a general requirement; for example, trying to think of a synonym as an alternative for a given word.

Convergent production - a focused search of our memory stores, seeking the one correct answer which will satisfy the requirements of the question or problem; for example, in deductive logic problems such as "Tom is taller than Dick and Dick is taller than Harry" we must conclude that "Tom is also taller than Harry".

Evaluation - checking on information that we know or that we have produced from our memory stores in order to determine its accuracy or suitability.

Guilford (1977) argues that most school activities and standardized tests "emphasize comprehension or understanding (cognition) rather than productive thinking (divergent and convergent), which is of greater importance in problem solving" (p. 160). He offers a model (see Figure 2.1) which identifies the cognitive processes necessary for problem solving. Simply stated, input is received to create an awareness that a

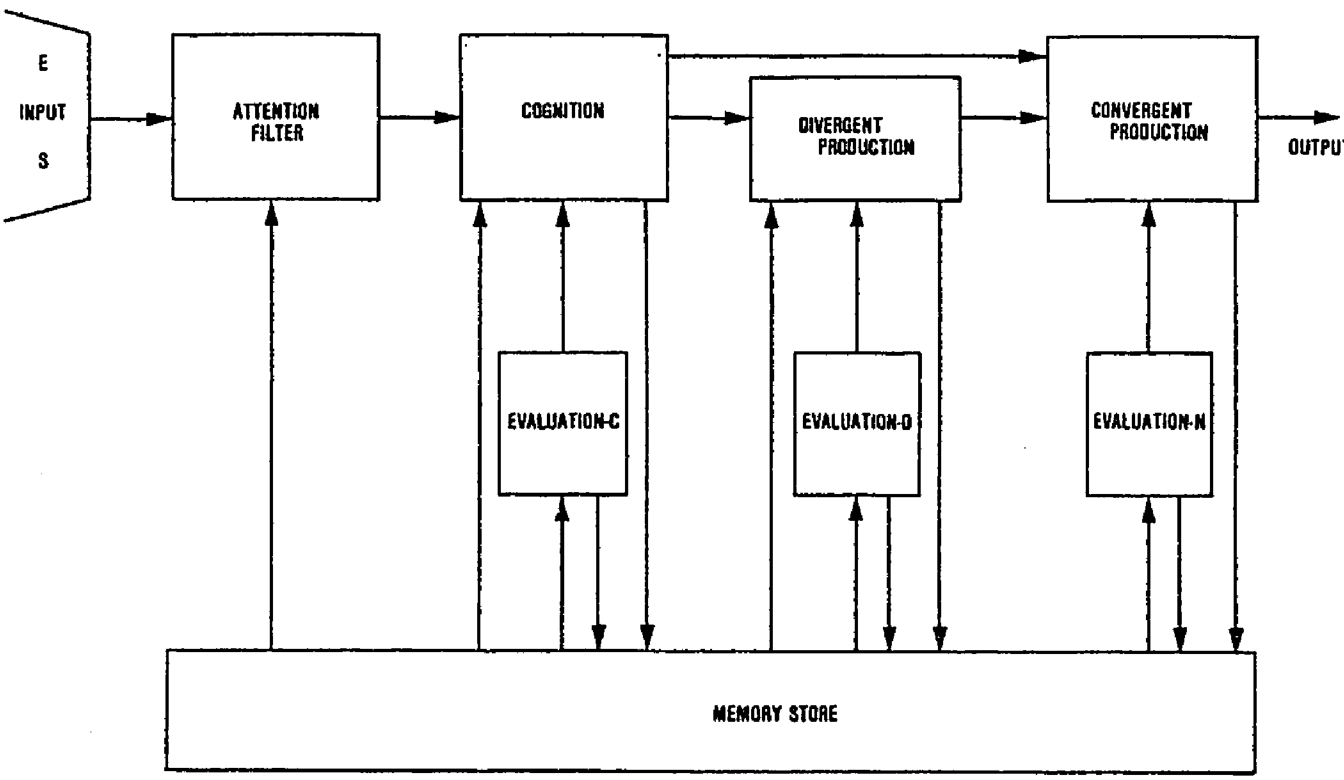

Figure 2.1 Guilford's Structure of Intellect Problem Solving Model.

problem exists (cognition). Ideas for solutions are generated (divergent and convergent production), and the conception of the problem and the solution are judged to be good or bad (evaluation). The processed information is put into storage for future use, immediate or delayed (memory). Guilford (1977) states that the implications of this model for education are to redirect instruction toward "productive thinking abilities". "We now have a better basis for seeing that it is not enough to fill young leaders with knowledge...; we must give the students instruction and exercise in using that knowledge" (p. 183).

Case's executive strategies. Case (1978a, 1978b), Pascual-Leone (1969), and Stone and Day (1978) have suggested a neo-Piagetian perspective on cognitive development which has specific implications for the teaching of thinking skills. According to Piaget (Inhelder and Piaget, 1958; Piaget, 1972) there are four major stages of development: the sensori-motor (ages 0-2), the pre-operational (ages 2-7), the concrete operational (ages 7-12), and the formal operational (12+). Children within each of these stages think about the world and attempt to solve problems in the same way. As children enter the formal operational stage at 11 or 12, they acquire the ability to deal with abstractions and think critically. If children gain this higher level of thinking skill merely through maturation and interaction with the environment, the need for formal education of thinking skills seems minimal. According to Stone and Day (1978), "For some years a central concern of research on formal operations has been the seemingly low incidence of this final stage of Piaget's supposedly universal sequence of cognitive development" (p. 1054). Epstein (1978) found only 34 percent of those tested over the age of twelve performing at this higher cognitive level.

Case (1978a, 1979b) suggests that the discrepancy between Piaget's theory and empirical research is the difference between competence and performance. While children twelve years of age and older may possess the cognitive abilities necessary for higher level thinking skills, they lack the command of the "executive strategies" necessary to perform the tasks. Executive strategies are problem solving tools that children can learn and use to organize lower level skills for problem solving. For example, in a typical Piagetian task such as determining the rule for why rods with different lengths, diameters, and compositions (wood, metal, glass) bend differently when equal weights are put on each end, the control-of-variables strategy is necessary. When testing for the effects of length, all other variables (diameter and composition) must be kept the same. A study by Stone and Day (1978) indicates the effects of one intervention with such a strategy. Twenty-eight children, covering ages 9, 11, and 13, were randomly assigned to a treatment group and a control group. Both groups attempted the bending rods experiment described above. Half way through the experiment, the treatment group was told about the control-of-variables rule. No teaching was done; they were simply told the rule. Results showed a statistically significant ($p < .05$) difference in formal reasoning skills displayed by the treatment group over the control group. Stone and Day (1978) conclude that many children who do not function at a higher cognitive level on novel tasks like the bending rods experiment have latent cognitive abilities that can be brought out by intervention with instruction on problem solving strategies.

Case (1978b) goes further in attempting to describe why children are unable to use the necessary executive strategies to solve a problem. Inhibiting factors are:

1. the child's experience with the materials involved in a problem;
2. the child's opportunity to learn the needed strategy;
3. the amount of practice the child has had on the basic skills needed to solve the problem; and
4. the child's habitual approach to problem solving.

Thus, Case would argue that interaction of learner and environment are not sufficient to guarantee optimum development of higher order thinking skills in students. Instruction in particular strategies and particular content areas is necessary in teaching critical thinking skills (Day, 1981).

Feuerstein's theory of mediated learning experiences. Feuerstein developed his theory after extensive work with Jewish refugee children in Israel (Chance, 1981; Hobbs, 1980). On most standardized measures of intelligence, many of the impoverished children appeared severely retarded. Feuerstein developed a Learning Potential Assessment Device (LPDA) to diagnose the deficient cognitive functions in the children. He then created a program called Instrumental Enrichment to correct these deficiencies. Feuerstein asserts that the "neglect of cognitive processes has conspired to produce a widespread belief that intelligence is something that one either has or does not have and that attempts to change the structure and course of intellectual development are futile, if not impossible" (Hobbs, 1980, p. 567). He concludes, however, that with proper assessment and the provision of appropriate learning experiences, human beings are open to modifiability at all ages and stages of development. According to Feuerstein, deficient cognitive functioning derives from a lack of mediated learning experiences (see Figure 2.2). These deficiencies

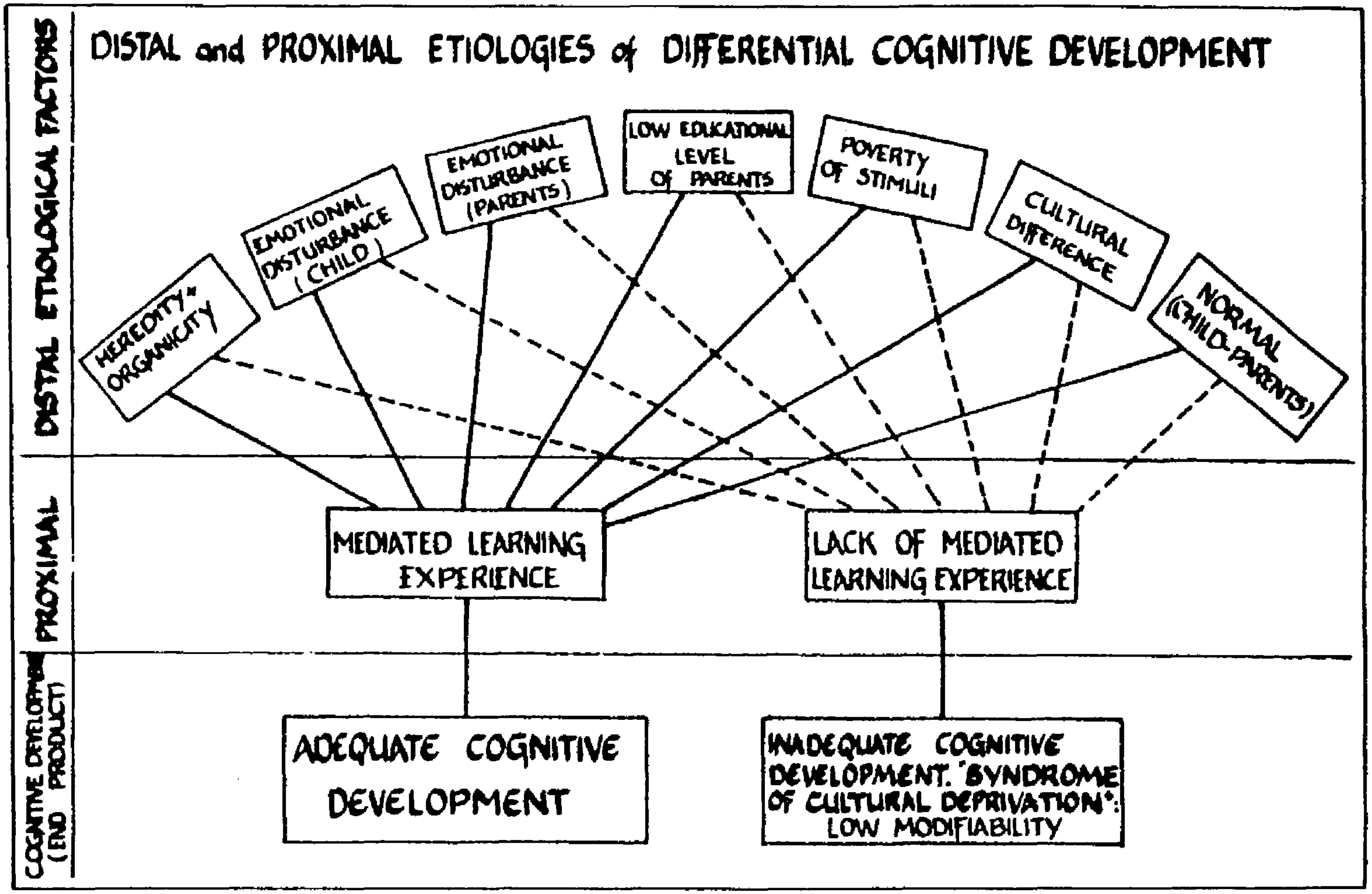

Figure 2.2

Reuven Feuerstein, Instrumental Enrichment: An Intervention Program for Cognitive Modifiability (Baltimore, Md.: University Park Press, 1980), p. 18.

reflect attitudinal and motivational problems and a lack of working habits and learning sets rather than structural incapacities (Hobbs, 1980). The task of formal education, therefore, is to provide mediating learning experiences in cognitive process instruction "to change the cognitive structure of the retarded performer and to transform him into an autonomous, independent thinker, capable of initiating and elaborating ideas" (Hobbs, 1980, p. 567).

Research on Educational Computing

The pre-commercial period. Two experimental programs in educational computing began in the early 1960's prior to the advent of commercial time-sharing. Both were funded through university research grants and provided the first empirical data on computer effectiveness. The first, Programmed Logic for Automated Teaching Operations (PLATO), was a project begun in 1960 by Donald Bitzer at the University of Illinois, Urbana. A two year longitudinal study of mathematics achievement in the project was conducted by the Educational Testing Service (Hallworth and Brebner, 1980). Eighteen classes of students in grades 4-6 were provided with four terminals per class. Students worked in fifty minute sessions of mathematics drill and practice daily. Using the Comprehensive Test of Basic Skills and a pretest-posttest control group design, researchers found the treatment group who received computer assisted instruction (CAI) outscored the control group who received traditional instruction at a significant level ($p < .01$) (Hallworth and Brebner, 1980).

The Stanford Project began in 1963 under the direction of Patrick Suppes. Between 1966-68 extensive research was conducted on elementary students receiving CAI in mathematics. Using the Stanford Achievement Test in arithmetic and a pretest-posttest control group design researchers again found significant results favoring students with 5-8 minutes of CAI daily over those receiving traditional instruction (Jamison, Suppes and Wells, 1974; Suppes and Morningstar, 1969).

Commercial time-sharing period. The initial effectiveness of CAI spawned a wide interest in the educational community during the 1970's when the emphasis was on a "back-to-basics" movement. Researchers from the PLATO project and the Stanford Project (now under the commercial name of Computer Curriculum Corporation) began to market their software on time-sharing systems. Research studies were abundant as educators attempted to validate the initial successes of CAI. Vinsonhaler and Bass (1972) reviewed ten major studies in the field. They found that each study was conducted on elementary students receiving 5-15 minutes daily of CAI drill and practice in language arts or mathematics over periods of time ranging from 3 to 10 months. Each study used the pretest-posttest control group design and a standardized achievement test as a measure (either the Stanford Achievement Test for Mathematics and Language Arts (SAT) or the Metropolitian Achievement Test (MAT)). In every study the CAI treatment group showed significant gains over the traditional instruction group. Vinsonhaler and Bass (1972) concluded: "The effectiveness of CAI over traditional instruction seems to be a reasonably well established fact in drill and practice for both mathematics and language arts, when performance is measured by SAT and MAT type tests" (p. 31).

Other studies during the 1970's supported the findings of Vinsonhaler and Bass but went beyond those studies to demonstrate that students take less time to learn the same material using CAI (Edwards, Norton, Taylor, Weiss, Van Dusseldorp, 1975; Rapaport and Savard, 1980), that CAI is more effective for low ability students than with average or above average students (Edwards et al., 1975; Jamison et al., 1974), and that students' attitudes towards school are better in CAI groups (Hallworth and Brebner, 1980; Rapaport and Savard,
1980).

The most comprehensive investigation of the longitudinal effects of computer use for education was conducted by the Educational Testing Service (ETS) in cooperation with the Los Angeles Unified School District (Ragosta, Holland, and Jamison, 1982). This five year study of CAI in compensatory education evaluated drill and practice instruction in mathematics, language arts, and reading. Four elementary schools were provided laboratories with terminals attached to a time-sharing computer. Students were randomly assigned to receive either mathematics, language arts, or reading CAI. The control group was formed from within the CAI sample, for example, the mathematics and language arts groups were the control for reading, and so forth. Thus, novelty effects were controlled. Using the Iowa Tests of Basic Skills, the Comprehensive Tests of Basic Skills, and local criterion referenced tests, the researchers set up a pretest-posttest non-equivalent control group design. Using regression analysis, researchers discovered that (1) students with up to 20 minutes of CAI daily in mathematics scored significantly higher than did students receiving the same amount of traditional instruction (2) CAI students gained in language arts and reading but not significantly over traditional instruction and (3) students in CAI language arts, mathematics, and reading maintained their increases over traditional instruction for the duration of the five year study (Ragosta et al., 1982).

Kulik, Bangert, and Williams (1983) used meta-analysis to integrate findings from 51 studies of computer-based instruction (a combination of computer-assisted instruction and computer-managed instruction). Results confirmed the findings of studies cited earlier that computer-based teaching increased achievement scores by approximately .32 standard deviations, or from the 50th to the 63rd percentile. Other results confirmed findings regarding improved student attitudes, improved retention rates, and reduced time required for learning for CAI students (Bracey, 1982; Kulik, 1983). Kulik et al. (1983) also observed that more recently completed studies showed greater gains than those conducted in the early 1970's, and he hypothesized that this may be due to the impact of improved technology and better use of that technology.

Microcomputer Period. Ironically, the abundance of empirical data on the effectiveness of CAI during the time-sharing period may have smothered the interest in microcomputer research instead of kindling it. For many, the questions regarding computer effectiveness have been answered. For those who realize the great differences in microcomputer technology and time-sharing systems, there are many questions still to be answered (Sheingold, Kane, Endreweit, and Billings, 1981). Ragosta et al. (1982) identified differences in microcomputer use which prohibit the direct transfer of findings from previous research on time-sharing systems:

(1) Microcomputers are usually used in a classroom under the supervision of a teacher with a few students working at a time; most time-sharing systems had laboratories where a whole class

could work for ten to twenty minutes under the direction of a trained computer operator.

(2) The software for the microcomputer is not compatible with the software of most time-sharing systems.

(3) The quality of microcomputer software is questionable. "Microcomputer drill and practice courseware may or may not be graphically more attractive, slower in operation, more self-paced and self-selected, and more narrowly focused within each CAI session. Whether the changes potentially increase or decrease the effectiveness of a mathematics CAI program is a question for future research to answer" (p. 34).

Unfortunately, the few field studies being done with microcomputers are flawed by insufficient equipment, poorly prepared courseware, and limited time on the computer by students (Cox, 1980; Signer, 1982). A study by Cox (1980) to determine the effects of using the microcomputer to teach problem solving skills to middle school students is a case in point. Eighty-seven students were selected from study halls to participate in the project; sixty-six completed all three sessions with the computer. The design called for students to complete only three 50-minute sessions on the computer. The content consisted of three problem situations created, designed, and programmed by the researcher. Students were pretested and posttested on a cognitive skills inventory also developed by the researcher. No validity or reliability data were reported. Results showed a significant increase in problem solving ability by the treatment group over the control group, however, the serious design flaws of the study allow little confidence to be placed in the results or conclusions.

Much of the university research with microcomputers has shifted beyond CAI to the study of artificial intelligence (Goldstein, 1976, 1980; Stansfield, Carr, Goldstein, 1976). Although no empirical evidence is available at this time, researchers are beginning to explore the effectiveness of the microcomputer as a coach to develop thinking skills and decision making abilities in students (Goldstein, 1980; Mandinach and Fisher, 1983). The first coaches were script-based CAI where student responses had to match a predefined domain of possible responses or the computer coach diagnosed them as incorrect. Limitations due to frequent or inappropriate interruptions indicated a need for a more "perceptive" coach. A learning overlay model is currently being used (Goldstein, 1976, 1980) in which the coach determines the presence or absence of skills by comparing student decisions with the decisions of experts working the same problem. A matching recognition pattern between student and expert responses is used to assess response histories and flag errors in logic. The computer coach then intervenes to suggest alternative moves or review collected data which may have been overlooked (Goldstein, 1976, 1980). This use of the microcomputer to model expert thinking skills for students parallels closely some of the conventional algorithmic methods of teaching thinking (Larkin, 1980; Whimbey and Lochhead, 1982) and promises to open new areas for study beyond the CAI drill and practice applications of the past decade.

Research on Critical Thinking Skills Development

Studies on cognitive process development (Case, 1978a, 1978b; Day, 1981; Stone and Day, 1978) suggest that many students need instruction in problem solving strategies to maximize their critical thinking abilities. Various instructional tools have proven effective in this regard.

Heuristics. Heuristics are strategies, independent of the subject matter, which help students understand and gather resources to solve problems (Polya, 1945). For example, in the following problem careless errors usually occur by making quick judgements without establishing the necessary relationships:

> "A politician claims that all Catholics and all homeowners in town will vote for him. How many votes does he claim, if Catholics number 400, homeowners 1200, and Catholic homeowners 300?" (Whimbey and

Lochhead, 1982, p. 133) Whimbey and Lochhead (1982) suggest an appropriate heuristic for this problem would be to draw a Venn diagram. Schoenfield (1978) suggests a list of heuristics such as "draw a diagram", "exploit symmetry", and "consider essentially equivalent problems". After teaching these strategies to his students, he observed a marked increase in their ability to solve math word problems. De Bono (1983) suggests the use of a heuristic which he calls PMI to encourage students to look in the plus direction (good points), the minus direction (bad points), and the interesting direction (novel points) when analyzing problems before attempting a solution. Although he offers no empirical data, he offers observational data to support increased problem solving by his students.

Protocol Analysis. Another tool for exploring problem-solving processes is protocol analysis. Bloom and Broder (1950) asked their college students to think aloud as they attempted to solve word problems. Upon analysis of these verbalized mental processes, the researchers discovered that unsuccessful problem solvers were "one shot thinkers" who were mentally careless, superficial, and quick to take an easy solution. Successful problem solvers were active, beginning with what they understood, drawing in other information in their possession, and following organized steps. Subsequent studies (Whimbey, 1977, 1980;

Whimbey and Lochhead, 1982) have demonstrated increased problem solving abilities of students working in pairs and thinking out loud. Larkin (1980) used protocol analysis to compare her students' solutions to physics problems with the solutions of experts (physics professors) as they thought out loud. She then gave half of the class more content instruction in the problem area and half of the class process instruction based on their deficiencies in the protocol analysis. In subsequent testing, each student in the "process" group outperformed the best student in the "content" group.

Algorithmic Approaches. Algorithmic approaches to problem solving suggest step-by-step prescriptions for handling certain types of tasks. Attempts (Dewey, 1910; Bruner, 1973) to define the steps of problem solving have been operationalized in programs such as Feuerstein's Instrumental Enrichment (Hobbs, 1980; Vye and Bransford, 1981). Two studies reported by Link (1983) on school systems using the Instrumental Enrichment program show significant differences on the California Achievement Test between the thinking skills group and the control group who received only content instruction. Thomas (1975) reports positive but not significant results in teaching thinking skills to middle school students through the use of programmed booklets on making judgements. Using a posttest only control group design with the Cornell Critical

Reasoning Test, he found sixteen of twenty subtests to be favorable to the treatment group over the control group who received no special instruction. A poor match between the Cornell Test and the instructional modules may have accounted for the lack of statistical significance.

Metacognition. Salomon (1974) suggests that teaching algorithmic approaches to thinking may not be the best method. His studies indicate that students with lower aptitude scores profit more from modeling of specific problem solving behaviors than did students who had high aptitude scores. Modeling of specific strategies interferred with the pre-developed strategies of brighter students and hindered their performance. Sternberg (1981a, 1981b) agrees that more flexibility is needed by the problem-solver. He concludes that intelligence is a set of developed thinking and learning skills which a student can be taught to use more effectively. To do this, the student needs a reservoir of strategies to call upon and the ability to discern the best choice for a given situation. This ability to think about one's cognitive processes is termed metacognition and is the focus of ongoing research in the thinking skills arena (Brown and De Loache, 1978).

Middle School Studies. Studies citing attempts to teach thinking skills to middle school students are limited in number and, for the most part, seriously flawed in design. Stewart (1978) reviewed fourteen studies on the teaching of logic to students in grades 7-12. While eleven of these studies showed significant ($p < .05$) gains favoring the treatment group over a control group receiving no thinking skills instruction, ten of the studies used evaluation measures designed by the researcher without citing appropriate reliability or validity data. The remaining four studies used well established instruments, the Watson-Glaser Critical Thinking Appraisal or the Cornell Critical Thinking Test, both of which were normed for a high school population.

Braxton (1973) used a pretest-posttest non-equivalent control group design to teach lessons in conditional logic to intact mathematics classes in grades 7-9 (N=157). Regular classroom teachers delivered lessons developed by the researcher for 30 minutes daily for a period of ten days. At the conclusion of the study, the treatment group at each grade level scored significantly higher ($p < .001$) than the control group which received no thinking skills instruction. The Cornell Conditional Reasoning Test, Form X was the measuring instrument. Although the treatment period covered only two weeks, the time was sufficient to teach one specific thinking skill, in this case, conditional reasoning.

Diffley (1971) used regular classroom teachers to deliver instruction in deductive reasoning to 100 classes

(N=1542) of students in grades 7-9. Fifty classes formed the treatment group and fifty the control group, all randomly assigned. The treatment group received instruction in deductive thinking 50 minutes daily for a two week period. A pretest-posttest control group design using the Paulus Conditional Reasoning Test as a learning measure showed a significant difference ($p < .005$) in the treatment group over the control group. The sample size was quite impressive in this study, but the Paulus Conditional Reasoning Test was quite weak in its field testing and reliability/validity data.

Howell (1967) used a prepared text, Effective Thinking, to teach reasoning skills to seventh grade students (N=157) at a Wisconsin junior high school. Using a non-equivalent control group design, half of the students received fifteen sessions, 42 minutes each, on the prepared program in logic. The remaining students received no special instruction. Using a self-developed test, the Test of Inference Patterns, Howell found a significant ($p < .05$) difference in the treatment group over the control group. The major flaw to this study was in the testing instrument which had not been field-tested prior to its use.

Summary of research and relationship to the problem

The field of cognitive psychology provides a theoretical framework for the teaching of critical thinking skills. Bloom (1956) and Guilford (1977) define critical thinking processes as belonging to the higher order cognitive abilities which require the learner to interact with incoming data to transform it into a new product or evaluate its worth. Both also assert that this level of thinking is rarely encouraged in public school settings and is not measured on most standardized testing instruments. Case (1978a; 1978b) suggests that in order for learners to maximize their critical thinking potential, they must receive direct instruction in strategies for organizing their cognitive skills for problem solving. Feuerstein (Chance, 1981; Feuerstein, 1980; Hobbs, 1980) operationalizes Case's theory in his Instrumental Enrichment program, an assessment and intervention program to mediate deficient cognitive abilities.

Although ample research has been done on the effectiveness of the time-sharing computer in teaching drill-and-practice materials (Vinsonhaler and Bass, 1972), research on the use of the microcomputer in education is inadequate (Becker, 1982; Sheingold et al., 1981). The recent emphasis on developing thinking and problem solving skills in our young people (La Conte, 1983) suggests a new direction for microcomputer use.

> If "computer-assisted instruction" is still to be the primary function of computers in the classroom, one must ask whether providing a new method for having students

> practice applications of rote-learned rules of grammar and arithmetic is more important than using school resources to develop more higher-level intellectual skills of students (Becker, 1982, p. 3).

Research in the teaching of thinking skills has shown that the direct teaching of thinking strategies increases problem solving performance (Larkin, 1980; Whimbey, 1980; Whimbey and Lochhead, 1982; Whimbey and Whimbey, 1976). Efforts to teach thinking skills to the middle school population by conventional methods have also proved effective (Braxton, 1973; Diffley, 1971; Howell, 1967; Stewart, 1978). The question then remains, "Will the microcomputer be a more effective tool for teaching critical thinking to middle school students than conventional methods?"

CHAPTER 3

Methodology

Population and Selection of the Sample

The research site for this study was a suburban school system in Virginia. Students were housed in nine elementary schools (grades 1-6), three intermediate or middle schools (grades 7-8), and three high schools (grades 9-12). Approximately 80% of the student population was white, 17% was black, and the remainder were Hispanics, Asians, and other minorities.

The target population consisted of seventh grade students who had registered for a class called, "Problem Solving with the Microcomputer". The sample consisted of ten intact class groups (N=204). Five of the classes (N=98) were assigned at random to two treatment groups, two classes to Group 1 (N=38) and three classes to Group 2 (N=60). The remaining five classes (N=106) served as the control group during phase one of the study and as treatment group 3 during phase two of the study. No prerequisites were required for course registration, therefore all seventh graders were eligible. Students were prohibited from taking the course only when scheduling conflicts with other required courses took precedence.

Treatment and Data Gathering Procedures

The treatment consisted of a nine week course in critical thinking and problem solving. From the domain of critical thinking skills, four skills were chosen for inclusion in the course: analogous reasoning, logical reasoning, inductive/deductive reasoning, and problem analysis. Two criteria were used in the selection of these skills: (1) the availability of valid and reliable instruments to measure development of the skill and (2) the availability of commercial microcomputer software to provide instruction and reinforcement of the skill. All software proposed for use in the course was reviewed, evaluated, and selected by the researcher and an independent educational computing consultant in order to provide as close a match as possible between the microcomputer material presented and the assessment instruments to be used. Table 3.1 describes the course learning modules, software materials, and assessment instruments.

In phase one of the study both treatment groups, Group 1 (N=38) and Group 2 (N=60), were taught two of the learning modules with the aid of the microcomputer and two of the modules using conventional methods. Group 1 received microcomputer instruction in analogous reasoning and inductive/deductive reasoning while Group 2 received conventional instruction in these skills. Conversely, Group 2 received microcomputer instruction in logical reasoning and problem analysis while group 1 received the conventional instruction. The control group (N=106)

TABLE 3.1 CONTENT AND ASSESSMENT MEASURES FOR CRITICAL THINKING COURSE

MODULE	CONTENT SAMPLE	SOFTWARE	MEASUREMENT
Analogous Reasoning The ability to perceive interrelationships between pairs of words.	"Wheat" is to "grow" as house is to build.	Analogies, (PDI) Word Analogies (SEI)	Ross Test, Section I
Logical Reasoning The ability to comprehend a rule or principle implicit in a pattern or sequence of numbers, letters, or figures.	Choose the part that would continue the sequence: M N P Q S T ?	Rocky's Boots, (Learning Co.) Inference and Prediction (Micro Learningware)	Test of Cognitive Skills, Section I, Sequences
Inductive/Deductive The ability to identify the missing premise to complete a logical syllogism or to indicate logical fallacies in arguments.	"All quarks are purple." "All purple things melt in the sun." If the above statements are true, then which conclusions logically follow?: "Quarks melt in the sun." "All purple things are quarks." "All things which melt in the sun are quarks."	Critical Reading (Borg-Warner) Snooper Troops (Spinaker) used to integrate all problem solving skills	Ross Test, Sections II and III
Problem Analysis The ability to analyze mathematical word problems to determine if the data provided is relevant or irrelevant to its solution.	"Oranges cost 10 cents at the Littletown Supermarket. How many oranges can a person buy for 50 cents? Choose: a. Cannot be solved; Not enough information given. b. Can be solved; exactly enough information given.	Problem Solving Strategies, (Reader's Digest)	Ross Test, Section VII (Overall Scholastic Aptitude: Otis-Lennon Mental Ability Test)

received no special instruction in thinking skills. The conventional instruction consisted of lecture, discussion, and paper-and-pencil worksheets covering the same instructional objectives being presented by the microcomputer software. All classes met daily for 50 minute periods for nine weeks.

Teachers participating in the study received two 3-hour training sessions regarding the process oriented approach to problem solving. A focal point of the training was Whimbey and Lochhead's Problem Solving and Comprehension (1982) which encourages students to think aloud as they solve their problems and to work in pairs using protocol analysis to improve problem solving strategies. These approaches have proven successful in developing problem-solving skills in earlier studies (Larkin, 1980; Whimbey, 1980). The teachers also had the opportunity to become familiar with the course software and to practice their problem solving strategies with children during two nine week pilot tests of this curriculum. During the pilot testing, course objectives were refined, inappropriate software was discarded, and new software was purchased to strengthen each learning module. Selected sub-tests (see Table 3.1) from the Ross Test of Higher Cognitive Processes (Ross and Ross, 1979) and from the Test of Cognitive Skills (McGraw-Hill, 1981) were administered to all students in the experimental and control classes as a pretest-posttest measure of critical thinking skills. The Otis-Lennon Mental Ability Test was also administered as a pretest-posttest measure of scholastic aptitude. (Studies by Feuerstein (1980), Guilford (1977), Sternberg (1981a, 1981b), and Whimbey and Whimbey (1976) suggest that the direct teaching of thinking skills will improve scholastic ability as measured by existing standardized intelligence instruments.) All pretest and posttest measures were administered by classroom teachers under the supervision of project directors. Each teacher recorded daily observations and anecdotal remarks concerning student progress. Periodic visits by project directors insured consistency among the treatment groups in terms of pacing and methods of presentation.

The microcomputer assisted instruction was conducted in laboratories located at each of three middle schools. Each laboratory contained 10 Apple IIe microcomputers with single disk drives and a combination of color and green phosphorous monitors. Each class consisted of twenty students, yielding a two to one student to microcomputer ratio. Software for the program was rotated between the laboratories on two week intervals, insuring that each student had the same amount of computer time (eight days per module) to complete the instruction. This rotation schedule required students at different sites to take the learning modules in a different sequence. However, empirical evidence exists which suggests that thinking skills are independent and are not affected by the order of presentation. Case (1978a, 1978b) and Day (1981) assert that teaching of specific learning strategies is needed for many students to activate their higher thinking processes. Case (1978a) also indicates that students must practice strategies specific to novel types of problems before they become useful for problem solving. Although intercorrelations for subtests on the Ross Test are not available, the Watson-Glaser Critical Thinking Appraisal (which tests the same categories of skills for the high school population) shows intercorrelations of subtests ranging from .21 to .50, supporting the contention that relatively distinct abilities are being measured.

In phase two of this study, the control group (N=106) from phase one served as treatment group 3 and participated in the nine week course in critical thinking. In an effort to replicate the findings regarding the effects of microcomputer use on student learning, Group 3 received microcomputer assisted instruction on all four learning modules. The teachers were the same as in phase one of the study and all testing and monitoring procedures remained constant.

Instrumentation

Subtests from two measures of critical thinking, the Ross Test of Higher Cognitive Processes (1979) and the Test of Cognitive Skills (1981), were used to assess changes in specific thinking skills. The Otis-Lennon Mental Ability Test was administered as a measure of scholastic aptitude to test the hypothesis that the teaching of critical thinking skills improves educational ability as defined by standardized intelligence tests.

The Ross Test of Higher Cognitive Processes (1979) is a paper and pencil test designed to measure ability in the levels of higher cognitive thinking referred to in Bloom's Taxonomy of Educational Objectives (1956) as analysis, synthesis and evaluation. The Administration Manual suggests its use as a pretest-posttest measure to determine "whether a student's higher-level thinking skills have changed over a period of time with or without specific instructional intervention" (Ross et al.,1979, p.4). Reliability procedures were performed on the Ross Test using test-retest and split-half procedures. A Pearson product moment coefficient was calculated from students' scores on the odd and even numbered test items, resulting in a split-half reliability coefficient of .92. Two administrations of the test to a sample of 100 students with a three day interval between administrations yielded a test-retest reliability coefficient of .94. Construct validity for the Ross Test was determined by correlation of total score with students' chronological ages and by group (gifted vs. non-gifted) differentiation.

In support of Piaget's (1958) and Case's (1978a) work relating increased thinking skill ability to chronological age, the correlation between the Ross Test total score and chronological age (N=339) was r= .674. A further measure of construct validity was the superior performance in every one of 54 instances of comparison of gifted over non-gifted students. Norms are available for gifted and non-gifted students in grades 4-6 (Ross et al., 1979).

The Test of Cognitive Skills (1981) is a series of paper and pencil ability tests in which "emphasis is placed on abilities of a relatively abstract nature that are important to success in an educational program" (p.1). The KR-20 reliability coefficients for all subtests average .81. No test-retest data were available. Construct validity was determined by correlation of the Test of Cognitive Skills (TCS) with standardized measures of educational achievement. A correlation coefficient of .86 was shown between the TCS and the California Achievement Test battery which measures basic skills achievement in reading, language arts, and mathematics. The TCS was standardized in the fall of 1980. The tests were administered to a national sample of 82,400 students in grades 2 through 12. The public school sample was stratified by geographic region, community type, and district size. Normative data for TCS are provided for appropriate grade groups and chronological age groups for this study.

The Otis-Lennon Mental Ability Test is a paper and pencil test designed to provide a comprehensive assessment of the scholastic aptitude of pupils in American schools. Reliability data were determined by split-half and Kuder-Richardson procedures to be .95; alternate forms reliability for the intermediate tests (Forms J and K) was .93. Validity data show a high correlation between the Otis-Lennon Test and other measures of general scholastic aptitude. The high correlations, for example, between the Otis-Lennon and the Iowa Tests of Basic Skills composite score leaves only 5% of the nonerror variance unexplainable at the fifth and eighth grade levels (Buros, Mental Measurements Year Book, 1972, p. 372).

Research Design

The nonequivalent control group design (Campbell and Stanley, 1963) was chosen for this study. A variation on this design was necessary to provide for inter-treatment control groups and to replicate the experiment to test for the the effects of extended microcomputer use on student learning. The inter-treatment control group procedure was recommended by Glass in the ETS/LAUSD study of computer use to control for the effects of novelty which plague most control group designs with computers (Ragosta et al., 1982). In this study both treatment groups received instruction with and without the computer, with the role of microcomputer assisted group and conventional group alternating between them. As mentioned earlier, the independence of the critical thinking skills (Case, 1978a; Day, 1981; Sternberg, 1981a; Watson-Glaser, 1964) precluded any contaminating effects due to varying instructional sequence or due to carry-over from one skill to the other. The design of the study was as follows:

Group 1 (N=38) O_1 M_1 C_2 M_3 C_4 O_2

Group 2 (N=60) O_1 C_1 M_2 C_3 M_4 O_2

Group 3 (N=106) O_1 O_2 M_1 M_2 M_3 M_4 O_2

where

O_1 = Pretest measures

M_1 = Microcomputer-assisted learning module in analogous reasoning C_1 = Conventional learning module in analogous reasoning

M_2 = Microcomputer-assisted learning module in logical reasoning

C_2 = Conventional learning module in logical reasoning

M_3 = Microcomputer-assisted learning module in inductive/deductive reasoning

C_3 = Conventional learning module in inductive/deductive reasoning

M_4 = Microcomputer-assisted learning module in problem analysis

C_4 = Conventional learning module in problem analysis

O_2 = Posttest measures

Efforts to control for teacher variability included the development of detailed course content guides for both microcomputer and conventional modules, staff development sessions to coordinate classroom activities with project teachers, and periodic site visitations by project directors to insure consistent pacing of content delivery. In addition to pre-packaged course modules for in-class use, out of class assignments were designated to insure equivalent instructional time was required by teachers of both treatment groups. Log books kept by teachers and project directors validated course sequencing and pacing as required in a project time line developed by the project directors and shared with teachers prior to the initiation of the study. Any additional contaminating effects due to differences in teacher effectiveness were compensated for by the study design with required each teacher to alternate between the microcomputer (M) and the conventional (C) modules in delivering course content to students as indicated below:

	Analogous Reasoning	Logical Reasoning	Inductive/Deduc Reasoning	Analysisblem Analysis
Teacher A	M	C	M	C
Teacher B	C	M	C	M
Teacher C	M	C	M	C
Teacher D	C	M	C	M

Statistical Hypotheses

Using the design notations above, the following directional hypotheses were tested:

H_o1: $M_1 = C_1 =$ Control There will be no significant difference in performance on a quantitative measure of analogical skills between students completing a microcomputer assisted learning module on verbal analogies, students completing an equivalent module taught with conventional methods, and a control group receiving no special instruction.

H_o2: $M_2 = C_2 =$ Control There will be no significant difference in performance on a quantitative measure of logical reasoning skills between students completing a microcomputer assisted learning module on logical reasoning, students completing an equivalent module taught with conventional methods, and a control group receiving no special instruction.

H_o3: $M_3 = C_3 =$ Control There will be no significant difference in performance on a quantitative measure of inductive/deductive reasoning skills between students completing a microcomputer assisted learning module on inductive/deductive reasoning, students completing an equivalent module taught with conventional methods, and a control group receiving no special instruction.

H_o4: $M_4 = C_4 =$ Control There will be no significant difference in performance on a quantitative measure of problem analysis between students completing a microcomputer assisted learning module on problem analysis, students completing an equivalent module taught with conventional methods, and a control group receiving no special instruction.

H_o5: $M_{1234} = C_{1234} =$ Control There will be no significant difference in performance on a standardized scholastic aptitude test between students completing microcomputerassisted learning modules on critical thinking skills, students completing equivalent modules taught with conventional teaching methods, and a control group receiving no special instruction.

Statistical Analysis

The analysis of covariance was used to test for significant differences between the microcomputer assisted treatment groups, the conventionally instructed treatment groups, and the control group. Cook and Campbell (1979) suggest the analysis of covariance as a technique to increase the precision of the nonequivalent control group design. The covariate in this analysis was the pretest scores on each of the learning measures administered. The independent variables were the treatments and the dependent variables were the posttest scores. This covariate procedure controlled for the effects of educational ability and prior knowledge in the skill areas (pretest scores) by removing the variance due to these measured variables from the dependent variable measures (posttest scores) before the test of significance was applied. Thus, the precision and accuracy of the results was enhanced. The 0.05 level of significance, suggested by Cook and Campbell (1979, p.40) as the standard for educational research, was selected for this study.

Ethical Safeguards and Considerations

All students involved in this study were registered for the course, "Problem Solving with the Microcomputer", a regular part of the program of studies of the school division. Students were informed that this course is a pilot studies program and as such, data would be collected for use in determining the efficacy of teaching problem solving skills in the middle schools. All students used in control groups completed the full microcomputer course in subsequent quarters. Grading for the course was based on classwork, homework, and class participation within each intact class, and thus, was not affected by the pretest-posttest scores which varied due to differing treatments.

Summary of Methodology

This study tested the effectiveness of the use of the microcomputer to teach critical thinking skills to middle school students. The target population consisted of seventh grade students expressing an interest in problem solving with the microcomputer. A non-equivalent control group design was used to compare two instructional methodologies for teaching thinking skills, microcomputer assisted teaching and conventional teaching. The Ross Test of Higher Cognitive Processes and the Test of Cognitive Skills were be used to measure changes in specific thinking skills. The Otis-Lennon Mental Ability Test measured the effects of teaching critical thinking on students' scholastic aptitude. An analysis of covariance was used to test the statistical significance of the relationship between the two instructional methodologies.

CHAPTER 4

Analysis of Results

The purpose of this study was to determine whether teaching critical thinking skills with the microcomputer produces a greater increase in the thinking skills of middle school students than teaching critical thinking skills with conventional methods. All testing was administered in the regular classroom setting by project teachers. Tests were collected and scored, and the resultant data were subjected to analyses using the Statistical Package for the Social Sciences (SPSS). The means and standard deviations for all subtests and groups were computed using the SPSS Package, CONDESCRIPTIVE. The analyses of covariance were computed on all groups and subtests using the SPSS Package, ANOVA.Additional data monitoring student attitudes and performance were recorded daily by project teachers.

Hypothesis H_o1

This hypothesis states that there will be no significant difference in performance on a quantitative measure of analogical skills between students completing a microcomputer assisted learning module on verbal analogies, students completing an equivalent module taught with conventional methods, and a control group.

The means and standard deviations of pretest and posttest scores on the verbal analogies subtest of the

Ross Test of Higher Cognitive Processes were computed for the microcomputer and conventional treatment groups and for the control group. The results indicated a mean gain of 1.486 from 9.057 to 10.543 in the microcomputer group, a mean gain of 1.397 from 9.069 to 10.466 in the conventional group, and a mean gain of .506 from 9.265 to 9.771 in the control group (see Table 4.1). An analysis of covariance was performed on the posttest results using the pretest scores as a covariate to determine whether significant differences ($p < .05$) in the achievement of analogous reasoning skills existed as a result of the treatments. A significant difference in achievement ($p < .01$) due to treatment was indicated (see Table 4.2) where both groups receiving instruction in verbal analogies scored significantly higher than the control. No significant difference in achievement was found between the students receiving microcomputer assisted instruction and those receiving conventional instruction (see Table 4.2). The verbal analogies subskill was unique among those being tested in that the conventional and microcomputer materials matched in both form and content the test items on the evaluation instrument. No information transfer was necessary from either of the methodologies to apply the concepts learned to the test.

On the basis of the increases in achievement scored by the treatment groups receiving instruction in analogous

TABLE 4.1

HYPOTHESIS 1 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE VERBAL ANALOGIES SUBSECTION OF THE ROSS TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	35	9.057	2.817	10.543	2.405
Conventional	58	9.069	2.846	10.465	2.501
Control	83	9.265	3.029	9.771	2.936

NOTE. Maximum Score = 14

[a] Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.2

HYPOTHESIS 1 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE VERBAL ANALOGIES SUBSECTION OF THE ROSS TEST
COVARIATE = PRETEST SCORES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Covariate					
Pretest	727.665	1	727.665	239.652	0.000**
Main Effects					
Treatments					
(Micro, Conventional, Control)	32.931	2	16.466	5.423	0.005 *
Treatments					
(Micro, Conventional)	0.157	1	0.157	0.053	0.819

* Significant at $p < .01$
** Significant at $p < .001$

reasoning over the control group, hypothesis H_o1 was rejected. There was no substantiation, however, for the hypothesis that instruction of verbal analogies with the microcomputer produces greater increases in analogous thinking than do conventional instructional methods.

Other Findings. In the second phase of the study the control group from phase one received microcomputer assisted instruction on all four learning modules. Posttest data were collected using the same testing instruments, personnel, and classroom facilities used during phase one. The SPSS subprogram, T-TEST, was used to determine the effect of the microcomputer instruction intervention on the achievement of this group in each of the critical thinking areas defined in this study. The results have been tabulated in Appendix A.

The control group in phase one achieved a pretest/posttest mean gain of .506 on the verbal analogies subsection of the Ross Test (Table 4.2). After the microcomputer instruction in verbal analogies during phase two of the study, this group achieved a 1.063 mean gain from 9.760 to 10.823. This represented a *t*-value of 4.49 which is significant at $p < .001$ (see Appendix A, Table A.1). This result reinforced the finding in phase one of the study that groups receiving instruction in analogous reasoning achieved higher scores on measures of analogic thinking than control groups receiving no special instruction.

Hypothesis H_o2

This hypothesis states that there will be no significant difference in performance on a quantitative measure of logical reasoning skills between students completing a microcomputer assisted learning module on logical reasoning, students completing an equivalent module taught with conventional methods, and a control group.

The means and standard deviations of pretest and posttest scores on the "Sequences" subtest of the Test of Cognitive Skills were computed for all groups in phase one of the study. The conventional treatment group achieved the greatest mean gain (2.848 points) from a pretest score of 12.758 to a posttest score of 15.606 (see Table 4.3). The microcomputer treatment gained 1.931 points from a mean of 12.345 to a posttest mean of 14.276. The control group gained 1.647 points from 13.471 to 15.118. An analysis of covariance on the posttest scores was computed to determine whether significant differences ($p < .05$) in logical reasoning achievement existed as a result of the treatments. No significant differences were indicated (see Table 4.4).

Although both the microcomputer and the conventional treatment groups showed a gain in their mean scores on the logical reasoning measure, the control group likewise showed a gain from pretest to posttest. The absence of a significant treatment effect on the logical reasoning

TABLE 4.3

HYPOTHESIS 2 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE SEQUENCES SUBSECTION OF THE TEST OF COGNITIVE SKILLS

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	58	12.345	4.704	14.276	4.012
Conventional	33	12.758	3.623	15.606	3.112
Control	85	13.471	3.966	15.118	3.695

Note. Maximum Score = 20

[a]Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.4

HYPOTHESIS 2 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE SEQUENCES SUBSECTION OF THE TEST OF COGNITIVE SKILLS
COVARIATE = PRETEST SCORES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Covariate					
Pretest	945.533	1	945.533	112.573	0.000*
Main Effects					
Treatments					
(Micro, Conventional, Control)	26.957	2	13.479	1.605	0.204

* Significant at $p < .001$

achievement of the microcomputer and the conventional groups led to the acceptance of the second hypothesis. No significant differences in logical reasoning skills were demonstrated as a result of the instructional intervention.

Other findings. The control group achieved a mean score gain of 1.647 points pretest to posttest without instructional intervention. During phase two of the study, the control group received the two week module on logical reasoning on the microcomputer, and posttest data again revealed a mean gain, from 14.784 to 15.722 (.938 points) (see Appendix A, Table A.2). Although this gain represents a t-value of 3.47 and is significant at the $p < .01$ level, the cause for the gain cannot be attributed to the treatment due to the gains achieved by this group without intervention during phase one.

Hypothesis H_o3

This hypothesis states that there will be no significant difference in performance on a quantitative measure of inductive/deductive reasoning skills between students completing a microcomputer assisted learning module on inductive/deductive reasoning, students completing an equivalent module taught with conventional methods, and a control group.

The means and standard deviations for the "Deductive Reasoning" and "Missing Premises" (inductive reasoning) subsections of the Ross Test of Higher Cognitive Processes were computed and the results have been tabulated in Tables 4.5 and 4.7. An analysis of the mean difference scores on deductive reasoning from pretest to posttest indicated a gain in the microcomputer and control groups and a loss (-.862 points) in the mean scores of the conventional group (see Table 4.5). The results of an analysis of covariance on the posttest scores indicated a significant difference ($p < .05$) in deductive reasoning achievement due to treatment (see Table 4.6) with the microcomputer and the control groups scoring significantly higher that the conventional group. Entries in teacher log books from the conventional classes indicated students did not have the mental maturity to deal with many concepts of logic. When students were cautioned about making unwarranted assumptions, they would go to extremes and assume nothing, e.g., the existence of life or the presence of air. This created great confusion as well as a loss of performance in this area. The microcomputer group was confined to specific responses and could not be carried away by such speculation. No significant differences were found between the microcomputer group and the control group (see Table 4.6).

Each of the three groups, microcomputer, conventional, and control, achieved mean gains from pretest to posttest on the "Missing Premises" (inductive reasoning) subsection

TABLE 4.5

HYPOTHESIS 3 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE DEDUCTIVE REASONING SUBSECTION OF THE ROSS TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	33	11.727	3.175	13.242	2.762
Conventional	58	12.414	2.450	11.552	3.073
Control	83	12.349	3.026	13.265	3.174

Note. Maximum Score = 18

[a]Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.6

HYPOTHESIS 3 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE DEDUCTIVE REASONING SUBSECTION OF THE ROSS TEST
COVARIATE = PRETEST SCORES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Covariate					
Pretest	521.539	1	521.539	83.357	0.000*
Main Effects					
Treatments (Micro, Conventional, Control)	136.049	2	68.025	10.872	0.000*
Treatments (Micro, Control)	3.348	1	3.348	0.606	0.438

* Significant at $p < .001$

TABLE 4.7

HYPOTHESIS 3 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE MISSING PREMISES SUBSECTION OF THE ROSS TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	33	4.152	2.152	4.879	1.833
Conventional	58	4.035	1.654	4.121	1.612
Control	85	4.341	1.855	4.435	1.918

Note. Maximum Score = 8

[a]Numbers indicate students who completed both pretest and posttest measures.

of the Ross Test. Gains ranged from .086 points for the conventional group to .727 points for the microcomputer group (see Table 4.7). An analysis of covariance on the posttest scores indicated that no significant differences in achievement in inductive reasoning skills existed due to treatments (see Table 4.8).

Since no significant differences were found between the control group and the microcomputer group in deductive reasoning achievement and no significant differences were found between any of the groups in inductive reasoning, hypothesis H_O3 was accepted.

Other findings. The greatest gain in inductive reasoning was achieved by the microcomputer group with a pretest to posttest mean gain of .727 points (see Table 4.7). The control group gain was .094 on the same measure. During phase two of the study, the control group participated in the microcomputer learning module on inductive and deductive reasoning. Posttest data indicated a mean gain of .729 from 4.323 to 5.052 (see Appendix A, Table A.1). This gain represents a *t*-value of 4.36 and is significant at the $p < .001$ level. While the analysis of covariance data in phase one did not indicate a significant difference in inductive reasoning skills due to treatment (see Table 4.8), the data collected on inductive reasoning in phase two indicated a consistently positive gain after the microcomputer treatment.

TABLE 4.8

HYPOTHESIS 3 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE MISSING PREMISES SUBSECTION OF THE ROSS TEST
COVARIATE = PRETEST SCORES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Covariate					
Pretest	225.829	1	225.829	114.135	0.000*
Main Effects					
Treatments					
(Micro, Conventional, Control)	10.565	2	5.282	2.670	0.072

* Significant at $p < .001$

Hypothesis H_o4

This hypothesis states that there will be no significant difference in performance on a quantitative measure of problem analysis between students completing a microcomputer assisted learning module on problem analysis, students completing an equivalent module taught with conventional methods, and a control group.

The means and standard deviation of the microcomputer, conventional, and control groups were computed using SPSS CONDESCRIPTIVE. An analysis of the data indicated that all three groups achieved mean gains from pretest to posttest, the microcomputer group increasing .207 points, the control group increasing .271 points, and the conventional group increasing .903 points (see Table 4.9). An analysis of covariance was computed on the posttest scores using the pretest scores as a covariate to determine whether significant differences ($p < .05$) existed in achievement in problem solving skills due to the treatments. No significant differences were indicated (see Table 4.10).

Hypothesis H_o4 was accepted. There was no significant difference in achievement between students in the microcomputer, conventional, and control groups in problem analysis skills.

Other findings. The control group mean gain of .271 points during phase one of the study (see Table 4.9) was

TABLE 4.9

HYPOTHESIS 4 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE RELEVANT AND IRRELEVANT INFORMATION SUBSECTION OF THE ROSS TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	58	6.241	2.604	6.448	2.597
Conventional	31	6.871	2.617	7.774	2.376
Control	85	6.871	2.298	7.141	2.829

Note. Maximum Score = 14

[a]Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.10

HYPOTHESIS 4 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE RELEVANT AND IRRELEVANT INFORMATION SUBSECTION OF THE ROSS TEST COVARIATE = PRETEST SCORES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Covariate					
Pretest	454.777	1	454.777	97.598	0.000*
Main Effects					
Treatments					
(Micro, Conventional, Control)	16.974	2	8.487	1.821	0.165

* Significant at $p < .001$

increased to a pretest to posttest mean gain of .760 after the microcomputer intervention in phase two. This gain represents a *t*-value of 2.76 which is significant at $p < .01$ (see Appendix A, Table A.1). Although not statistically attributable to treatment effect, positive gains did occur after the microcomputer treatment on problem analysis.

Hypothesis H_o5

Hypothesis H_o5 states that there will be no significant difference in performance on a standardized scholastic aptitude test between students completing microcomputer assisted learning modules on critical thinking skills, students completing equivalent modules taught with conventional teaching methods, and a control group.

The items on the Otis-Lennon Mental Ability Test were grouped by the researcher and an independent educational consultant into the four critical thinking areas defined for this study (see Appendix B, Table B.1). Items not included in these areas were figural analogies, vocabulary, and logical visual reasoning. The Otis-Lennon Test was scored by subsection and the means and standard deviations for the pretest and posttest scores were computed using SPSS CONDESCRIPTIVE. The results are tabulated in Tables 4.11-4.14. Analysis of the data indicated that mean gains were achieved by each group on

TABLE 4.11

HYPOTHESIS 5 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE VERBAL ANALOGIES SUBSECTION OF THE OTIS-LENNON MENTAL ABILITY TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n [a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	36	10.816	2.720	11.722	3.067
Conventional	59	9.600	3.248	11.407	2.786
Control	86	10.535	3.360	11.047	3.350

Note. Maximum Score = 19

[a] Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.12

HYPOTHESIS 5 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE LOGICAL REASONING SUBSECTION OF THE OTIS-LENNON MENTAL ABILITY TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	59	4.950	2.346	6.077	2.059
Conventional	36	5.526	2.424	6.926	2.274
Control	86	5.407	2.485	6.434	2.352

Note. Maximum Score = 10

[a]Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.13

HYPOTHESIS 5 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE INDUCTIVE/DEDUCTIVE REASONING SUBSECTION OF THE OTIS-LENNON MENTAL ABILITY TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
TREATMENT	n[a]	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
Microcomputer	36	8.789	2.570	8.528	2.952
Conventional	59	7.800	2.686	6.797	2.887
Control	86	8.733	2.490	7.791	3.505

NOTE. Maximum Score = 15

[a] Numbers indicate students who completed both pretest and posttest measures.

TABLE 4.14

HYPOTHESIS 5 - MEANS AND STANDARD DEVIATIONS OF THE PRETEST AND POSTTEST SCORES ON THE PROBLEM ANALYSIS SUBSECTION OF THE OTIS-LENNON MENTAL ABILITY TEST

		TESTING SESSION			
		PRETEST		POSTTEST	
Treatment	n[a]	Mean	Standard Deviation	Mean	Standard Deviation
Microcomputer	59	3.167	1.628	3.725	1.736
Conventional	36	3.526	2.128	4.006	1.927
Control	86	3.581	1.888	4.135	1.967

Note. Maximum Score = 7

[a]Numbers indicate students who completed both pretest and posttest measures.

each of the critical thinking skills with the exception of inductive and deductive reasoning where each of the three groups experienced a loss from pretest to posttest. An analysis of covariance was computed on the posttest scores using the SPSS ANOVA Package to determine whether significant differences ($p < .05$) due to treatments existed in achievement in the critical thinking subskills as measured by the scholastic aptitude instrument. No significant differences were indicated (see Table 4.15).

On the basis of the data collected from the Otis-Lennon instrument, hypothesis H_O5 was accepted. No difference in performance on a standardized aptitude test was indicated between students in the microcomputer, conventional, and control groups.

<u>Other findings</u>. After the microcomputer treatment during phase two of the study, the control group posttest data indicated significant gains ($p < .001$) were achieved in two subsections of the Otis-Lennon Test, verbal analogies and inductive/deductive reasoning (see Appendix A, Table A.3). Gains by the control group in these two areas during phase one were not significant ($p < .05$).

<u>Additional Findings</u>

A <u>t</u>-test was computed on the pretest and posttest scores of each subtest for each group (microcomputer, conventional, and control) to determine whether significant differences ($p < .05$) in critical thinking achievement

TABLE 4.15

HYPOTHESIS 5 - ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE SUBSECTIONS OF THE OTIS-LENNON MENTAL ABILITY TEST
COVARIATE = PRETEST SCORES

Subsection[a]	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Analogies	31.344	2	15.672	2.610	0.076
Logical Reasoning	5.143	2	2.572	1.020	0.363
Inductive/Deductive Reasoning	20.089	2	10.044	1.418	0.245
Problem Analysis	1.935	2	0.967	0.343	0.710

[a] The source of variance for each subsection is main effects for treatments (microcomputer, conventional, and control).

existed which were not attributable to random error. The results have been tabulated in Appendix C. Significant gains ($p < .05$) in achievement were indicated in analogies, deductive and inductive reasoning, and logical reasoning for the microcomputer group (see Appendix C, Table C.1), in analogies, problem analysis and logical reasoning for the conventional group (see Appendix C, Table C.2), and in analogies, deductive reasoning, and logical reasoning for the control group (see Appendix C, Table C.3). These findings, especially the gains experienced by the control group, suggest that other factors such as test/retest effects, heightened awareness to problem solving, or changes in student attitudes had a significant effect on the measurement of critical thinking skills. Data collected from teacher logs suggested that student attitudes toward the pretest and posttest sessions may have been the significant variable in the gains of the control group during phase one. The control group was pulled out of regular classes for the pretest session with no opportunity for dialogue or preparation for the activity. Students worked through the tests quickly, often finishing in half of the time allotted. The posttest session was held during the first three days of the course, "Problem Solving with the Microcomputer," and students had a vested interest in better performance. Student comments during this posttest session indicated that they had informally discussed among themselves the types of questions encountered on the pretest, and therefore, they entered the posttest session with a heightened interest and awareness for problem solving. Regardless of the reason for the control group gain in phase one, however, it is noteworthy that in phase two of the study the control group continued to make significant gains ($p < .01$) in seven of the ten subtests taken after the microcomputer treatment in critical thinking skills (see Appendix A, Tables A.1-A.3). An analysis of covariance was performed on the posttest scores of those students who completed both the control period and the fourth quarter treatment period (N=80) to determine whether the gains experienced by the microcomputer group during phase two were significant when measured against the gains experienced by the same students during the control period. While some contaminating effects may have resulted due to the fact that these two groups were not independent and were not tested simultaneously, the statistic provided a comparative base for the discussion of the *t*-test gains. The analysis of covariance on both the Ross Test and the Otis-Lennon Test indicated that significant differences ($p < .01$) in analogous reasoning achievement existed due to treatments where the microcomputer group scored significantly higher than it did while serving as the control group (see Appendix D, Tables D.1 and D.2). Significant differences ($p. < .001$) in favor of the microcomputer group were also found on the inductive reasoning subsections of both instruments (see Appendix D, Tables D.1 and D.2).Although not statistically defensible in this study, it is unlikely that such gains in phase two could be attributed solely to another test/retest effect or to further attitudinal changes. Exposure to problem solving techniques and strategies for critical thinking, whether delivered by conventional or microcomputer methods, seems to have had an effect on increased student performance.

Summary

The results of the study were as follows:

An analysis of covariance indicated that students in both the microcomputer and the conventional groups who received instruction in verbal analogies achieved significantly higher gains ($p < .01$) on the verbal analogies subsection of the Ross Test of Higher Cognitive Processes than the control group. No significant differences in achievement were found between students receiving microcomputer assisted instruction and those receiving conventional instruction. It was noted that both of these instructional modules were closely related in form and content to the subtest. The null hypothesis that there was no significant difference in achievement on a quantitative measure of analogic skills between students receiving microcomputer instruction, students receiving conventional instruction, and a control group was rejected.

Although all three groups (microcomputer, conventional, and control) achieved significant gains ($p < .001$) on the sequences subsection of the Test of Cognitive Skills, an analysis of covariance indicated that no significant differences ($p < .05$) in logical reasoning achievement existed as a result of the treatments. Therefore, the null hypothesis H_o2 was accepted.

Results on the Deductive Reasoning subsection of the Ross Test of Higher Cognitive Processes were mixed. The microcomputer group and the control group achieved significant gains ($p < .01$), but the conventional group declined from pretest to posttest. No significant differences due to treatment effect were indicated between the microcomputer and control group. On the Missing Premises (inductive reasoning) subsection of the Ross Test, no significant differences ($p < .05$) were indicated due to treatments. Therefore, the null hypothesis H_o3 was accepted. There was no significant difference in achievement in inductive/deductive reasoning between the microcomputer, conventional and control groups.

There were no significant differences ($p < .05$) between the treatment groups indicated by an analysis of covariance on the posttest scores for problem analysis. Hypothesis H_o4 was accepted.

The microcomputer, conventional, and control groups all achieved significant gains ($p < .05$) from pretest to posttest on the Otis-Lennon Mental Ability Test. An analysis of covariance on the posttest scores indicated that there was no significant difference ($p < .05$) between the three groups which could be attributed to treatment effects. Therefore, hypothesis H_o5 which states that there will be no significant difference in gains on a scholastic aptitude measure between the microcomputer, conventional and control groups was accepted.

During phase two of the study, the control group achieved significant gains ($p < .01$) on four of the five subsections of the Ross Test of Higher Cognitive Processes and gains at $p < .02$ on three of the four critical thinking subsections of the Otis-Lennon Mental Ability Test.

Analysis of covariance data on phase two posttest scores indicated that the control group demonstrated significantly greater gains ($p < .01$) in analogous reasoning and inductive reasoning after the microcomputer intervention than they did while serving as the control group with no critical thinking skills instruction.

CHAPTER 5

Summary and Conclusions

Summary

Purpose. Several national studies of public education (NAEP, 1981; The Excellence Report, 1983) have cited a need for improved higher level thinking skills among our young people. Conventional thinking skills programs (Costa, 1981; Link, 1983; Whimbey, 1980; Worsham and Austin, 1983) have indicated that the direct teaching of critical thinking skills can improve problem solving performance. Recent studies (Damarin, 1982; Gress, 1982; Montague, 1982) have suggested that the computer is an appropriate tool for teaching higher level thinking skills in a school setting. Previous empirical data on the instructional effectiveness of computers in education have been gathered on lower order skills (e.g., mathematics drill and practice) using time-sharing computers in laboratory settings. The purpose of this study was to determine whether teaching critical thinking skills with the microcomputer produces a greater increase in the thinking skills of middle school students than teaching critical thinking skills with conventional methods.

Review of the Literature. Four theoretical models of cognitive process development and intervention provided the basis for this study. Bloom's taxonomy of educational objectives (Bloom, 1956) defined the domain of critical thinking skills. Guilford's conceptualization of information processing and problem solving (Guilford, 1977) suggested appropriate strategies for teaching higher level thinking processes. Both, Guilford and Bloom asserted that critical thinking is rarely encourged in public school settings and is not measured on most standardized testing instruments. Case (1978a; 1979b) suggested that in order for learners to maximize their critical thinking potential, they must receive direct instruction in strategies for organizing their cognitive skills for problem solving. Feuerstein (Chance, 1981; Feuerstein, 1980; Hobbs, 1980) operationalized Case's theory by developing an assessment instrument and intervention program to mediate deficient cognitive abilities by teaching specific critical thinking strategies.

A review of the research in the teaching of thinking skills indicated that the direct teaching of thinking strategies increases problem solving performance (Larkin, 1980; Whimbey, 1980; Whimbey and Lochhead, 1982; Whimbey and Whimbey, 1976). Specific programs to teach critical thinking skills to middle school students using conventional teaching methods also proved effective (Braxton, 1973; Diffley, 1971; Howell, 1967; Stewart, 1978). Research on the effectiveness of the microcomputer in school settings was limited (Becker, 1982; Sleingold et al., 1981). Since ample laboratory research was available to support the effectiveness of the time-sharing computer in teaching drill-and-practice type skills (Hallworth and Brebner, 1980; Ragosta, Holland, and Jamison, 1982; Vinsonhaler and Bass, 1972), the trend for microcomputer research in the 1980's shifted from the study of CAI to the study of artificial intelligence (Goldstein, 1976, 1980). In light of the rapid growth of the microcomputer as a classroom teaching tool, a need to evaluate its effectiveness using regular classroom teachers and commercially available software was evident.

Methodology. The sample consisted of ten intact classes (N=204) of seventh grade students who had registered for a class called, "Problem Solving with the Microcomputer." Five of the classes were assigned at random to two treatment groups and five classes served as the control group during phase one of the study. Trained teachers instructed the treatment groups in a nine week course in critical thinking and problem solving consisting of four learning modules: Analogous reasoning, logical reasoning, inductive/deductive reasoning, and problem analysis. Both treatment groups were alternately taught two of the learning modules with the aid of the microcomputer and two of the modules taught with conventional methods. The control group received no special instruction in critical thinking skills. The conventional instruction consisted of lecture, discussion, and paper-and-pencil worksheets covering the same instructional objective presented by the microcomputer software. All classes met daily for 50 minute periods.

Selected subtests from the Ross Test of Higher Cognitive Processes and from the Test of Cognitive Skills were administered to all students in the experimental and control classes as pretest-posttest measures of critical thinking skills. The Otis Lennon Mental Ability Test was administered as a pretest-posttest measure of scholastic aptitude.

In phase two of the study, the control group from phase one participated in the nine week course in critical thinking, receiving all four modules with the aid of the microcomputer. All teachers, software, and testing and monitoring procedures remained constant.

Major Findings. A statistical analysis of the data collected regarding each hypothesis revealed the following findings:

1. An analysis of covariance indicated that students in both treatment groups, microcomputer and conventional, who received instruction in verbal analogies achieved significantly higher gains ($p < .01$) on the verbal analogies subsection of the Ross Test of Higher Cognitive Processes than the control groups. No significant differences in achievement were found between students receiving microcomputer assisted instruction and those receiving conventional instruction. Both the conventional instructional materials and the software in the analogies learning modules were closely aligned in form and content with the verbal analogies subtest.

2. There were no significant differences ($p < .05$) between the three groups (microcomputer, conventional, and control) indicated by an analysis of covariance on the posttest scores for the inductive reasoning, logical reasoning, or problem analysis subsections of the Ross Test. On the deductive reasoning subsection of the Ross Test, the microcomputer and control groups achieved significant gains ($p < .01$), but the conventional group declined from pretest to posttest. Teacher log books documented an observed lack of maturity in dealing with some of the concepts of deductive logic which contributed to this decline. An analysis of covariance indicated a significant difference ($p < .05$) in deductive reasoning achievement due to treatment. No significant differences due to treatment were indicated between the microcomputer and control groups on the deductive reasoning measure. As a result of these findings, the null hypotheses (that there was no difference in achievement between the microcomputer, conventional, and control groups) were accepted for

the skill areas of logical reasonging, inductive/deductive reasoning, and problem analysis.

3. No significant differences ($p < .05$) in achievement wereindicated by an analysis of covariance on the posttest scores of the Otis-Lennon Mental Ability Test between the three groups. Therefore, the hypothesis was accepted that there was no difference in scholastic aptitude achievement between the microcomputer, conventional, and control groups.

4. During phase two of the study, the control group received all four learning modules in critical thinking with the aid of the microcomputer. A _t_-test analysis of pretest-posttest scores indicated the group achieved significant gains ($p < .01$) on four of the five subsections of the Ross Test of Higher Cognitive Processes and gains at $p < .02$ on three of the four critical thinking subsections of the Otis-Lennon Mental Ability Test. Analysis of covariance data on phase two posttest scores indicated that the control group demonstrated significantly greater gains ($p < .01$) in analogous reasoning and inductive reasoning after the microcomputer intervention than they did while serving as the control group with no critical thinking skills instruction.

Conclusions

The major findings of the study led to the following conclusions:

1. Use of the microcomputer to teach critical thinking skills to seventh grade students produced results which were equal to but not greater than those produced by conventional instruction.

2. Seventh grade students receiving critical thinking skills instruction produced significantly greater gains than students not receiving critical thinking instruction when the instructional module was closely matched to the assessment measure, i.e., verbal analogies.

3. When transfer of the thinking skill was required between the instruction and the assessment measure (problem analysis, logical reasoning, inductive/deductive reasoning), significant gains were not demonstrated.

4. The teaching of critical thinking skills produced no significant gains in the scholastic aptitude of seventh grade students as measured by a standardized scholastic aptitude instrument.

Discussion

The significant gains in achievement on verbal analogies support the intervention theories of Case (1978a, 1978b), Stone and Day (1978), and Feuerstein (1980). When children in the target population were given problem solving strategies specific to the task to be solved, significant growth was indicated. In other thinking skills areas measured by this study, the assessment items required the student to use additional strategies not specifically taught during the instructional module. For example, in the problem analysis module (both conventional and microcomputer), students were required to analyze word problems, identify necessary data, set up an equation to solve the problem, and finally, determine the correct answer. The assessment of this skill by the Ross Test did not involve finding the answer but required the student to analyze the problem and discriminate between three conditions: a. the problem cannot be solved due to lack of enough information; b. the problem can be solved and exactly enough information is given; or c. the problem can be solved but extra information is given. Since the assessment items would require an extension of the thinking skills beyond those skills which were instructed, it is consistent with Case's theory that significant gains were not realized because the students were not given the particular strategies needed to solve the problem.

This difficulty of matching critical thinking skills instruction to appropriate measurement instruments supports the observations of Bloom (1956) and Guilford (1977) that standardized instrumentation to measure critical thinking abilities is limited. Interviews with project teachers and an analysis of teacher log books after the study indicated that an observable change in the process of student problem solving occurred as a result of the instruction. Students read problems more deliberately, established models for problem solving, and discussed problem solving alternatives openly. The standardized testing instruments did not assess this area of critical thinking growth. Critical thinking skills defined in Bloom's taxonomy of analysis, synthesis, and evaluation (as well as Guilford's skills of divergent and convergent thinking) require an assessment instrument more sensitive to creativity, originality, and process than present standardized instruments provide.

The unanticipated gains by the control group in phase one of the study (see Appendix C) raise some interesting questions. As suggested in Chapter 4, project teachers and directors noted a significant attitudinal change from pretest to posttest by the control group caused by the timing of the testing. Students also indicated they had informally discussed test items after the pretest session. In addition to these variables, Case (1978a, 1978b) suggests that additional exposure to and practice with specific problem solving materials enhance student problem solving. This theory is supported by the continued growth in thinking skills achievement demonstrated by the control group during phase two of the study where gains in 7 of the 10 subtests were significant at the $p < .01$ level (See Appendix C). To what extent student attitudes, heightened awareness levels, exposure to problem solving strategies, or test-retest effects contributed to changes in students' critical thinking performance was not answered within the scope of this study.

Proposals by Sternberg (1981a, 1981b) and Feuerstein (1980) that intelligence is a set of learned skills which can be taught through direct instruction were not supported by this study. Although direct instruction did not have a significant effect, gains at a statistically significant level ($p < .01$) from pretest to posttest by all three groups (microcomputer, conventional, and control) (see Appendices A and C) indicated that growth in scholastic aptitude does occur as a result of intervention whether that intervention be exposure to problem solving materials, test-retest effects, heightened awareness to problem solving or other variables not identified in this study.

Recommendations for Future Research

As a result of the analysis of the results of this study, recommendations are suggested for future research which will overcome the limitations of this study and provide additional information regarding the effectiveness of the microcomputer as a teaching tool for higher cognitive processes:

1. Research and development of assessment instruments to measure growth in critical thinking skills is essential. These measures must be more dynamic than the present paper-and-pencil instruments in order to assess process as well as product outputs.

2. Research and development of microcomputer software which can model problem-solving strategies and guide students' thinking processes would provide both a tutor and an evaluator for cognitive development. Current studies in intelligent computer assisted instruction (ICAI) have concentrated on games (chess, checkers, etc.), but little has been done to create content area software with these capabilities.

3. A study of the effects of teaching critical thinking with the microcomputer to different age levels and ability levels of students would be helpful to determine where the use of this technology produces the greatest results.

4. A longitudinal study of the effects of using the microcomputer to teach thinking skills would be beneficial in determining whether increased time with the microcomputer produces continued gains or whether the novelty of the technology would diminish and effect long term results.

5. A study comparing different levels of exposure to problem solving strategies and materials would be helpful to determine how much time and which activities are most instrumental in stimulating students' latent cognitive abilities. This study would also add information regarding test-retest effects in the area of higher cognitive process development.

6. A study evaluating the effectiveness of a combination of conventional and microcomputer instruction on the development of critical thinking skills would be beneficial to determine whether the use of the microcomputer as a supplementary teaching tool would be a more effective instructional strategy.

APPENDIX A

Results of _t_-Test on the Pretest and Posttest Measures of Critical Thinking Skills

Microcomputer Group - Phase Two

TABLE A.1

RESULTS OF *t*-TEST ON THE PRETEST AND POSTTEST SCORES OF SUBSECTIONS OF THE ROSS TEST MICROCOMPUTER TREATMENT GROUP - PHASE TWO

Subsection[a]	Mean	Standard Deviation	Degrees of Freedom	*t* Value	Significance
Analogies					
Pretest	9.760	2.853	95	4.49	0.000**
Posttest	10.823	2.828			
Deductive Reasoning					
Pretest	12.854	3.318	95	1.75	0.083
Posttest	13.323	3.171			
Missing Premises					
Pretest	4.323	1.992	95	4.36	0.000**
Posttest	5.052	2.018			
Analysis of Relevant and Irrelevant Information					
Pretest	6.990	2.845	95	2.76	0.007*
Posttest	7.750	2.836			

NOTE. Pairwise deletion on the t-test caused a change in n and a change in the pretest means from those recorded in Tables 4.1-4.10 due to missing cases.

[a] *n* = 96

*Significant at $p < .01$

**Significant at $p < .001$

TABLE A.2

RESULTS OF *t*-TEST ON THE PRETEST AND POSTTEST SCORES OF THE SEQUENCES SUBSECTION OF THE TEST OF COGNITIVE SKILLS MICROCOMPUTER TREATMENT GROUP - PHASE TWO

Subsection[a]	Mean	Standard Deviation	Degrees of Freedom	*t* Value	Significance
Sequences					
Pretest	14.784	4.136	96	3.47	0.001*
Posttest	15.722	3.931			

NOTE. Pairwise deletion on the t-test caused a change in *n* and a change in the pretest means from those recorded in Table 4.3 due to missing cases.

[a] $n = 97$

* Significant at $p < .01$

TABLE A.3

RESULTS OF *t*-TEST ON THE PRETEST AND POSTTEST SCORES OF THE SUBSECTIONS OF THE OTIS-LENNON MENTAL ABILITY TEST
MICROCOMPUTER TREATMENT GROUP - PHASE TWO

Subsection[a]	Mean	Standard Deviation	Degrees of Freedom	*t* Value	Significance
Analogies					
Pretest	10.937	3.245	94	3.79	0.000**
Posttest	12.168	3.954			
Logical Reasoning					
Pretest	6.274	2.420	94	2.39	0.019*
Posttest	6.737	2.544			
Inductive/Deductive Reasoning					
Pretest	7.737	3.532	94	8.31	0.000**
Posttest	10.158	3.099			
Problem Analysis					
Pretest	4.082	1.955	94	0.39	0.695
Posttest	4.158	1.892			

NOTE. Pairwise deletion on the t-test caused a change in *n* and a change in the pretest means from those recorded in Tables 4.11-4.14 due to missing cases.

[a] *n* = 95

* Significant at $p < .05$
** Significant at $p < .001$

APPENDIX B

Otis-Lennon Test Items Grouped by Critical Thinking Subsection

TABLE B.1

TEST ITEMS ON THE OTIS-LENNON MENTAL ABILITY TEST
GROUPED BY CRITICAL THINKING SUBSECTION

Subsection	Test Items (Form J)	Test Items (Form K)
Analogies	1, 5, 6, 12, 15, 23, 30, 33, 38, 42, 44, 47, 52, 58, 67, 69, 71, 76, 80	1, 7, 11, 23, 27, 32, 33, 36, 40, 41, 43, 45, 48, 50, 54, 59, 75, 77, 80
Logical Reasoning*	7, 11, 13, 24, 29, 37, 50, 57, 63, 66, 72	2, 6, 14, 22, 51, 57, 60, 67, 74, 79
Inductive/Deductive Reasoning	17, 28, 34, 39, 40, 41, 46, 51, 54, 59, 60, 62, 65, 77, 79	4, 10, 19, 28, 31, 39, 42, 44, 49, 52, 64, 68, 69, 70, 73
Problem Analysis*	3, 25, 31, 45, 70	12, 15, 35, 37, 47, 55, 63

* Due to differences in item totals in these categories, raw scores were converted to standard numbers prior to statistical analysis.

APPENDIX C

Results of *t*-Test on the Pretest and Posttest Measures of Critical Thinking Skills

Treatment Groups - Phase One

TABLE C.1

RESULTS OF *t*-TEST ON THE PRETEST AND POSTTEST MEASURES OF
CRITICAL THINKING SKILLS
MICROCOMPUTER GROUP - PHASE ONE

Instrument/Subtest	*n*	Mean	Standard Deviation	Degrees of Freedom	*t* Value	Significance
Ross/ Analogies						
Pretest		9.057	2.817			
	35			34	4.12	0.000***
Posttest		10.543	2.405			
Ross/Deductive Reasoning						
Pretest		11,727	3.175			
	33			32	2.81	0.008**
Posttest		13.242	2.762			
Ross/Missing Premises						
Pretest		4.152	2.152			
	33			32	2.29	0.029*
Posttest		4.879	1.833			
Ross/Relevant Information						
Pretest		6.241	2.604			
	58			57	0.78	0.440
Posttest		6.448	2.597			
TCS/Sequences						
Pretest		12.345	4.704			
	58			57	3.44	0.001***
Posttest		14.276	4.012			

* Significant at $p < .05$
** Significant at $p < .01$
***Significant at $p < .001$

TABLE C.2

RESULTS OF t-TEST ON THE PRETEST AND POSTTEST MEASURES OF CRITICAL THINKING SKILLS CONVENTIONAL GROUP

Instrument/Subtest	n	Mean	Standard Deviation	Degrees of Freedom	t Value	Significance
Ross/ Analogies						
Pretest	58	9.069	2.846	57	4.12	0.000**
Posttest		10.466	2.501			
Ross/Deductive Reasoning						
Pretest	58	12.414	2.450	57	- 2.20	0.032*
Posttest		11.552	3.073			
Ross/Missing Premises						
Pretest	58	4.035	1.654	57	0.46	0.648
Posttest		4.121	1.612			
Ross/Relevant Information						
Pretest	31	6.871	2.617	30	2.62	0.014
Posttest		7.774	2.376			
TCS/Sequences						
Pretest	33	12.758	3.623	32	5.11	0.000**
Posttest		15.606	3.112			

* Significant at $p < .05$

** Significant at $p < .001$

TABLE C.3

RESULTS OF t-TEST ON THE PRETEST AND POSTTEST MEASURES OF CRITICAL THINKING SKILLS
CONTROL GROUP

Instrument/Subtest	n	Mean	Standard Deviation	Degrees of Freedom	t Value	Significance
Ross/ Analogies						
Pretest	83	9.265	3.029	82	2.49	0.015*
Posttest		9.771	2.936			
Ross/Deductive Reasoning						
Pretest	83	12.399	3.026	82	3.54	0.001**
Posttest		13.265	3.174			
Ross/Missing Premises						
Pretest	85	4.341	1.855	84	0.56	0.580
Posttest		4.435	1.918			
Ross/Relevant Information						
Pretest	85	6.871	2.298	84	0.95	0.344
Posttest		7.141	2.829			
TCS/Sequences						
Pretest	85	13.471	3.966	84	5.40	0.000**
Posttest		15.118	3.695			

* Significant at $p < .05$

** Significant at $p < .001$

APPENDIX D

Results of Analysis of Covariance on the

Posttest Measures of

Critical Thinking Skills

Control Group with Microcomputer Group - Phase Two

TABLE D.1

ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE SUBSECTIONS OF THE ROSS TEST AND THE TEST OF COGNITIVE SKILLS: CONTROL GROUP WITH MICROCOMPUTER GROUP/PHASE TWO

Subsection[a]	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Ross/Analogies	22.482	1	22.482	6.765	0.010*
Ross/Deductive Reasoning	11.450	1	11.450	1.187	0.278
Ross/Missing Premises	24.497	1	24.497	11.954	0.001**
Ross/Relevant Information	34.311	1	34.311	2.770	0.098
TCS/Sequences	3.545	1	3.545	0.576	0.449

[a] The source of variance for each subsection is main effects for treatments (control and microcomputer/phase two).

* Significant at $p < .01$

** Significant at $p < .001$

TABLE D.2

ANALYSIS OF COVARIANCE ON THE POSTTEST SCORES OF THE SUBSECTIONS OF THE OTIS-LENNON MENTAL ABILITY TEST: CONTROL GROUP WITH MICROCOMPUTER GROUP/PHASE TWO

Subsection[a]	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Analogies	48.221	1	48.221	6.514	0.012*
Logical Reasoning	1.979	1	1.979	0.713	0.400
Inductive/Deductive Reasoning	448.663	1	448.663	68.146	0.000**
Problem Analysis	0.719	1	0.719	0.245	0.621

[a]The source of variance for each subsection is main effects for treatments (control and microcomputer/phase two).

* Significant at $p < .01$

** Significant at $p < .001$

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ABSTRACT

THE EFFECTS OF MICROCOMPUTER USE ON THE CRITICAL THINKING SKILLS OF MIDDLE SCHOOL STUDENTS

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Chairman: Dr. G. William Bullock, Jr.

The purpose of this study was to determine whether teaching critical thinking skills with the microcomputer produces a greater increase in the thinking skills of middle school students than teaching critical thinking skills with conventional methods.

The sample consisted of ten intact classes (N=204) of seventh grade students who had registered for a class called, "Problem Solving with the Microcomputer." Five of the classes were assigned at random to two treatment groups and five classes served as the control group. Trained teachers instructed the treatment groups in a nine week course in critical thinking and problem solving consisting of four learning modules: analogous reasoning, logical reasoning, inductive/deductive reasoning, and problem analysis. Both treatment groups were alternately taught two of the learning modules with the aid of the microcomputer and two of the modules taught with conventional methods. The control group received no special instruction in critical thinking skills. The conventional instruction consisted of lecture, discussion, and paper-and-pencil worksheets covering the same instructional objectives presented by the microcomputer software. All classes met daily for 50 minute periods. Selected subtests from the Ross Test of Higher Cognitive Processes and from the Test of Cognitive Skills were administered to all students as pretest-posttest measures of critical thinking skills. The Otis-Lennon Mental Ability Test was administered as a pretest-posttest measure of scholastic aptitude.

The major findings of the study were:

1. Students in both treatment groups, microcomputer and control, who received instruction in verbal analogies achieved significantly higher gains ($p < .01$) than the control group who received no instruction. A close match between the instruction and the assessment instrument seemed to be a contributing factor to this result.

2. No significant differences ($p < .05$) were found between the control, microcomputer, and conventional groups on logical reasoning, inductive/deductive reasoning, or problem analysis skills.

3. No significant differences ($p < .05$) in scholastic aptitude were found between the three groups as a result of instruction in critical thinking skills.