The University of Manitoba

The Relationship between the Learning of BASIC Programming and Improved Students' Conditional Reasoning.

by

Leo Terry Fogg

A Thesis

Submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the
Degree of Masters of Education

Department of Curriculum: Mathematics and Natural Sciences
Winnipeg Manitoba
August 1983

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ABSTRACT

This study investigated the effect of BASIC programming on the conditional reasoning of adolescent students. Two hypotheses were tested: 1) Exposure to BASIC programming enhances students' conditional reasoning as measured by the Cornell Conditional-reasoning Test and 2) If an improvement in conditional reasoning occurs, it will be further enhanced by teacher explanation of programming techniques. The conceptual framework of the study was derived from Piagets' theory of cognitive development, the principles of propositional logic, and objectives of computer literacy programs.

Subjects for the study were Grade 8 students from a rural school serving a middle-class community. Subjects were two found grade eight classes (N=26, and N=29) with random assignment to experimental or control groups in each class. The control groups received instruction in computer literacy topics other than BASIC programming over a one month experimental period. One experimental group worked on BASIC programming unassisted by the instructor; the second experimental group worked on BASIC programming supplemented by teacher explanation of BASIC logic and programming techniques. The Cornell Conditional-reasoning Test was administered as post-test.

Analysis of variance using the Student-Newman-Keuls for main effects was performed. The difference in scores achieved by experimental and control groups was significant at the p<.01 level. There was no significant difference measured between the two experimental groups. Students taught BASIC programming showed an increase in mastery of conditional logic but teacher explanation did not enhance their mastery. A post-hoc item-by-item analysis indicated that experimental group subjects increased mastery of most valid principles of conditional logic, particularly detachment and contraposition principles, but not for invalid principles. Further research on the effect of BASIC programming on specific principles of conditional logic was recommended.

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INTRODUCTION

Purpose of the Study

Research indicates that a student operating below the formal operational stage of cognitive development will not attain many of the concepts taught in science and mathematics (Lowell, 1979). Jean Piaget's theory of cognitive development proposes an invariant sequence of stages, every stage characterized by certain patterns of reasoning. Piaget viewed cognitive development as resulting from maturation and experience with development limited by maturation. Educators have had little success accelerating students through these stages (Lawson and Wollman, 1976). Instructional activities based on the child's cognitive level but producing cognitive dissonance and opportunities for equilibration did seem to encourage the transition from the concrete to the formal operational stage (Raven, 1974).

Piaget (1958) described formal operational thought in terms of schemata and described combinatorial, proportional, probabilistic, and propositional reasoning as formal operational schemata. Recent research suggested that propositional reasoning occurred in association with formal operational thought but developed at a different rate (Lawson, Karplus, and Adi; 1978). Nevertheless, attempts to teach propositional reasoning and to increase mastery of propositional logic principles met with equivocal results (Ennis, 1965; Taplin, 1974).

The introduction of computer literacy programs to students is a recent but widespread phenomena (Luehrmann, 1982; Johnson et al, 1980). The number of computers in education has increased greatly due to the reduction in price and size and concommitant increase in power and availability. Models for computer literacy curricula or instructional methods have not yet been universally adopted but most educators teach some BASIC programming within that context.

BASIC language is relatively easy for students to learn but most students will not become professional programmers who may use it daily. However, it does possess a logical structure that may be easy to understand. Many of the subjects or methods taught in our school have little application in later life. If BASIC does produce a measurable increase in a child's logical reasoning abilities, that could serve as justification for the teaching of BASIC to our students. The purpose of this study is to determine if experience with BASIC programming enhances some aspects of a child's reasoning abilities.

This study tested two hypotheses:

1) Whether experience with BASIC programming could enhance a child's conditional reasoning ability.

2) If an increased ability in conditional ability does occur, whether it can be further enhanced by teacher explanation of BASIC logic and techniques.

CHAPTER II

REVIEW OF THE LITERATURE PERTAINING TO FORMAL OPERATIONAL THOUGHT AND PROPOSITIONAL LOGIC

Piaget's Theory of Cognitive Development - Its Acceptance and Currency amongst Educators

The theoretical framework used for this study was Jean Piaget's theory of cognitive development. Piaget was an epistemologist concerned with the structure and acquisition of knowledge rather than with the methodology of instruction. His theories have profoundly influenced the direction of educational research.

Linn (1982) identified some of the specific influences of Piaget's work on educational research and consequent practice. Attention had been paid to content - free strategies for teaching, developmentally based mechanisms of learning, and structural models of each stage of reasoning. On the other hand Piaget's influence minimized the importance of practical factors in teaching and shifted research away from 1) the role of factual knowledge in reasoning, 2) the diagnosis of specific task-based errors in reasoning, 3) the influence of individual aptitudes on reasoning, and 4) the effect of educational interventions designed to change reasoning. To phrase these factors more simply, Piaget provided an accepted model that focusses on the process of thinking rather than the content of that thinking. The previous points were highlighted not as subjects of investigation but to demonstrate the importance of Piaget's theories of cognitive growth.

PIAGET - Summary of Theory

Piaget's theory of cognitive development described intelligence as an adaptation to a demanding environment. The individual coped with the environment by means of two major processes, assimilation and accommodation. Assimilation is the process by which an individual incorporates new information into an existing mental framework. Accommodation represents the process by which an individual modifies the existing mental framework to fit new perceptions of the environment (Medinnus and Johnson, 1976). Stated simply, there is a dynamic balance between information perceived and conceptual framework. Piaget described these two processes as always in operation but within four developmental stages through which an individual progressed in a definite sequence. These stages were identified as sensorimotor, preoperational, concrete operational, and formal operational. Each stage is characteritized by distinctive modes of logical thinking and general chronological levels.

Linn (1982) identified these principles as central to Piaget's theory:

1) as individuals develop, they proceed in an invariant sequence through four distinct stages of reasoning.

2) these steps are governed by an information processing developmental mechanism termed assimilation and accommodation. Assimilation and accommodation form an

equilibrium at each stage.

3) each stage of reasoning is characterized by a unique structure or method of reasoning.

The Sensorimotor Stage

The first stage of development is called "sensorimotor" and initially is not any more sophisticated than the child's built-in reflexes. However, even these simple reflexes are integrated into patterns of behaviour called schemas. These schemas allowed the child to interact more effectively with its environment. Through various experiences the child is able to establish cause-and-effect relationships between himself and his environment. A concept of self develops for the child and this leads to simple representational thought. Objects are seen to exist beyond the child's immediate experience. The sensorimotor stage occurs between the period of birth and two years of age, and, as such, was not a main concern in this study.

Preoperational Stage

As the child develops greater facility for representational or symbolic thought, he is said to enter the preoperational stage. The child increasingly thinks through problems rather than solving them by actually carrying out the actions associated with the problem. However, these thought processes are still dominated by the child's immediate perceptions. Generalizations are made and relationships observed in the environment but they are made from particular phenomenon to particular phenomenon. This mode of thinking is termed transductive as compared to adult thinking which can be deductive (inference from general rule to specific situation) or inductive (inference from specific situations to a general rule). The child's thought processes are centred on one aspect of a situation and he is incapable of simultaneously considering two or more aspects of a situation. A child typically remains in the preoperational stage from two years of age to seven years of age. He is be said to be entering the concrete-operational stage when he begins to free his logic from his own viewpoint (Fast, 1977).

Concrete Operational Stage

As a child enters the concrete operational stage, he becomes increasingly logical in his thought. The child can consider a number of variables simultaneously and operations become reversible. Objects are no longer just considered as part of a dichotomous relationship (presence or absence of an attribute) but can be classified as part of a serial continuum. The child becomes more logical and coherent in thought and he is freed from an egocentric point of view. Broad categories of events and objects can be considered, and from different viewpoints (Medinnus & Johnson 1976).

Even though the concrete operational stage represents a qualitative advancement over the previous stages, there are still limitations in his logical abilities. The child is able to consider a number of variables simultaneously, but he typically does not consider all of the possible combinations in an operation. He considers those attributes that he can observe directly and remains tied to the physical or concrete world. The operations that a concrete operational child can make include the ability to serially order, conserve attributes of length-area-weight-volume, perform two-way classification, and make a one-to-one correspondence (Fast,1979). The child is limited in ability to reason symbolically and can not identify or control all variables when considering an operation. The ages for the concrete operational stage are typically between 7-8 years and 11-12 years although there is great variation within this range.

Formal Operational Stage

The stage of formal operational thought represents the highest level in Piaget's theory of cognitive development. Characteristics of this stage are broadly categorized as adaptability and flexibility. Propositions can be considered symbolically and all relevant variables can be identified and controlled. The child is able to draw logical conclusions from a set of observations. He has the ability now to form a hypothesis, consider its implications, and either substantiate or discard the hypothesis. This mode of thought is referred to as hypothetico -deductive reasoning. A unique feature of the formal operational stage is that the hypotheses do not need to have any base in reality. An imaginary hypothesis can be formulated and the child can reason with it. This is referred to as "operations on operations" and can be contrasted with the concrete operational stage which deals directly with operations.(Ault, 1977). The transition from concrete operational stage to formal operations was believed by Piaget to occur between the ages of 11 and 15.

Advantages of Formal Stage

The advantages for a student to perform at the formal operational level are numerous and it is the general goal of educators to aid students in the acquisition of formal operational skills. Howe and Mierzwa (1977) stated that students would have difficulty with secondary science curricula unless they developed increased ability for logical thinking. They were able to increase the logical skills of eight-grade students from a low socioeconomic background through training with Piagetian tasks. The increase in logical skills was retained after a six-week period but the authors did not suggest that they moved the students to a higher level of cognitive operations. Cantu and Herron (1978) found that students identified as formal operational could learn concepts better than concrete operational students at both the concrete and formal levels. A corollary of their research showed that concrete operational students could not learn concepts as well as formal operational students regardless of the simplicity of the concept or the teaching strategy employed.

General advantages of formal operational skills have been identified by Lowell (1979), and Sternberg and Downing (1982). Lowell studied the concept of abstraction in human reasoning in an experimental study using Piagetian tasks with junior and senior high science students. Theoretical structures are extensively employed for representing physical experience in science so that the ability to reason in abstract terms is essential. Lowell (1979) attempted to correlate operational levels with reliance or nonreliance upon concrete clues in problem solving. The results suggested that formal operational students did not rely upon concrete clues. Sternberg and Downing found that formal operational students could work with second-order analogies whereas concrete operational students could not. To solve a second-order analogy a student must infer the relationship between terms in one argument and then apply the inferred relationship to a new, idealized concept. These findings can be applied to suggest an improved ability with analogies for formal operational students.

Other researchers have attempted to correlate cognitive style with level of cognitive operations. Lawson and Snitgen (1982) associated formal operational skills with reasoning strategies such as control of variables and probabilistic, correlational, proportional, and combinatorial reasoning. The authors investigated the effects of a college biology course employing direct but open-ended inquiry on the formal reasoning ability for pre-service elementary teachers. Although Lawson and Snitgen produced a transition from concrete to formal operational level for all students previously classified as concrete operational, it was non-specific transfer of training. Subjects did not apply their newly acquired skills to other situations involving formal operational ability. Students identified as possessing a field-dependent cognitive style showed the greatest improvement. This suggested that these students performed below their logical capability because of oversensitivity to irrelevant but distracting clues in the experimental testing situation. The conclusion offered by Lawson and Snitgen was that becoming formal operational involves the disembedding of problem-solving strategies or reasoning patterns from their general milieu. Hence, a field independent cognitive style favours the development of formal operational ability. It was found, in a study by Hassell (1982), that field-dependent students traditionally did poorly in introductory programming courses. A highly structured approach to programming helped these students. This suggested that computer programming required formal operational abilities. Hassell also noted that scientists and this culture were biased toward more field independent cognitive styles.

Criticism of Piaget's Stages

Even though Piaget's theory of cognitive development provided a useful model for researchers to investigate, its principles were not universally accepted. Researchers have disputed some aspects of the theory on grounds ranging from methodology, and interpretation, through to philosophy.

Linn (1982) presented a number of criticisms within this wide range and adopted the initial stance that Piaget has had a tremendous influence on educational research. Perhaps her greatest criticism was that Piaget's theory had shifted the focus of cognitive research from factual research and teacher intervention to a content-free and developmental model. Within this context Linn commented on both the methodology and results of Piaget's investigations. The sample size was stratified and biased and the interviewing and scoring techniques were idiosyncratic and difficult to replicate. Subsequent investigations using Piaget's methods have not revealed a crisp emergence of each Piagetian stage. Further, the several strategies of formal reasoning were acquired unevenly, contrary to what Piaget's theory would suggest. Linn cited three main criticisms against what Piaget stated in his theory, these being: 1) a lack of crispness for each stage, 2) definitions of the cognitive structure for each stage were not clear, 3) the formal operational stage may not be the ultimate achievement in reasoning- there may be a fifth stage characterized by dialectics. Linn also offered comments for the mechanisms not included in Piaget's theory: knowledge can influence performance as well as individual aptitudes, field dependent/independent characteristics, and male/female differences.

Ennis (1965, 1975, 1976) conducted many studies based on Piaget's theories and offered some criticisms similar to those of Linn. Like Linn, Ennis objected to Piaget's claim of a quantum jump between operational stages for logical and practical reasons. His logical objection was the lack of a clear boundary line between operational stages and his practical objection was that a larger sample size with longitudinal studies should have been conducted before many of Piaget's claims were made. Piaget suggested that young children cannot perform propositional logic whereas adolescents can handle it. Although Ennis (1965) did not indicate a quantum jump in his own investigation he did agree that many young children do reason with at least some principles of propositional logic. Ennis (1975) found that college students have difficulty with some aspects of propositional logic. Piaget did not make clear what he meant by the ability to "handle" propositional logic. Ennis found that children had more difficulty judging invalid logic, as did adolescents. One of his conclusions stated that many adolescents failed to reason in accord with the basic principles of invalidity but there was general progress as children get older. The main criticisms by Ennis were that Piaget's logic used a restrictive interpretation, it invited overgeneralization, and he obtained odd results. Ennis (1976) did not reject Piaget outright but he did feel that Piaget was unacceptably idiosyncratic. Ennis provided an alternative to Piaget's conceptualization of logic which is examined later in this study.

This writer, like Ennis, supported the main tenets of Piaget's theory but questioned some of his techniques and assertions. Piaget used a rigorous representation of students' logical arguments even though Piaget (1972) stated that they do not employ symbolic logic. This writer believed that students can experience a gradual transition between stages and express characteristics of two stages of cognitive operations. The transition is not as crisp as Piaget had maintained.

Measurement of Operational Level

Much of the recent research in cognitive psychology attempts to verify and measure the postulates of Piagets' theory rather than implementing the theory. Many researchers still used Piaget's techniques to replicate and extend his findings (De Luca and Scouten, 1981).

Dettrick (1975) used the interview technique with his subjects wherein he tape-recorded their responses to Piagetian tasks, with the interviewer verbalizing some of the subject's unspoken operations. He found a continuous development of cognitive operations within the concrete operational stage but this process occurred two or three years later than Piaget had suggested. A similar interview technique was employed by Kuhn (1977) but different results were obtained. Kuhn found that young children were capable of correct conditional reasoning if it occurred within the context of simple, concrete, conversational situations. The data from Kuhn's study showed that young children had acquired the logical operations for solving traditional syllogisms (sentence propositions) by middle childhood. Kuhn suggested that poor performance on traditional syllogistic tests was due to a variety of task processing variables that may inhibit the student's performance.

Results from Tobin and Capie (1981) were not supportive of the clinical interview procedure. Its widespread administration was hindered by the length of time needed to perform the tests and the level of expertise required by the investigator. Objective tests on the other hand could be criticized because it was not possible to investigate a subject's thinking beyond the level of the question (Karplus and Karplus,1970). However, testing techniques developed by Lawson (1978) and refined by Lawson, Adi and Karplus (1979) represented an exception to the limiting objective tests because they required written justification for student answers. Tobin and Capie (1981) developed the TOLT (Test of Logical Thinking) based upon the earlier research of Lawson et al. Their test was able to measure reliably five modes of formal reasoning: controlling variables, proportional reasoning, combinatorial reasoning, probabilistic reasoning, and correlational reasoning. The TOLT showed a strong correlation with clinical interview procedures in determining a measure of formal reasoning.

Roberge (1976) had used an earlier objective test to chart the development of formal operational structures through the middle years and he obtained results not later answered by Tobin and Capie. As with previous studies by Dettrick (1975), Roberge found a gradual increase in formal reasoning abilities but he was able to discriminate between combinatorial thinking and conditional reasoning. Although there was a general increase in these abilities from grades five through eight there was little correlation between the rate of acquisition of these abilities. Roberge suggested that this had implications for Piaget's theory which stated that both abilities were part of formal operational thinking.

Other methods for assessing cognitive level have been employed in addition to the clinical interview and the written test. DeLuca (1977 and 1979) developed an electronic equivalent test for Piaget's chemical test. He felt that his equipment overcame the logistical problem of earlier physical tests and had the advantage of including immediate scoring. DeLuca reported the same results as for Piaget's chemical test but he did not show gender effects that had sometimes appeared. Students preferred this test. Hale (1979) was not supportive of DeLuca's study because he felt that the design of the test as well as the scoring criteria suggested that DeLuca did not understand the formal operational schemata as described by Piaget.

Pallrand (1979) suggested that the use of any equipment may inhibit the use of certain cognitive structures. This problem was exacerbated when more elaborate and complex equipment was used. However, a final testing procedure reported by DeLuca and Scouten (1980) used a microcomputer for presenting and scoring Piagetian tasks. Advantages reported by the authors included control of task familiarity and content bias, increased comprehensiveness and accuracy of data collection, and transportability.

Encouraging Transition

Piaget's theory is of interest to educators because it provides a model for explaining a child's cognitive growth through operational stages. A corollary of this theory is that educators should provide the tools or environment that allow a child to develop through these stages. Cantu and Herron (1978) proposed that priority be given to the development of formal reasoning ability in middle and high school students through the use of appropriate curriculum materials. However, just as there was not agreement among educators for the validity of Piaget's theory, there was not agreement on the best method to encourage the transition from concrete to formal operational stage.

Pallrand (1979) concluded that the transition was age-related. He attempted to measure the operational level of students with a variety of Piagetian tasks that were representative of the proportional and combinatorial schemes (components of the formal operational schemata).

Pallrand determined that the transition was gradual rather than abrupt as had previously been supposed. However, cognitive growth was not necessarily transferable from one skill to another. The ability to succeed on one task within a scheme does not necessarily imply that an individual will succeed on other tasks which seem to call for the same logical operations. One recommendation by Pallrand was that a teacher was in a unique position to encourage the transition from concrete to formal operational stage. Pallrand did not describe any procedure for encouraging the transition.

Some hints were made by Renner and Grant (1978) who had shown that a higher proportion of physics students were operating at a formal level than was true of the general student population. A correlation was established in the study but no indication was made for a cause-and-effect relationship. It was not clear whether physics instruction encourages formal thought or whether the formal level was prerequisite for success in a physics course.

Lawson and Wollman (1976) commented more directly on the problem of facilitating transition in students. They acknowledged that little was presently known about specific factors and how they interact and affect the transition. Piagetian theory only provided a framework. The authors attempted to design instruction that encouraged transition as shown in specific transfer (success with other examples of the same task). In the study by Lawson and Wollman the students were taught specifically on the concept of controlling variables. Although the authors did produce significant results, they attributed the outcome to a lack of performance by the control group (a type of Hawthorne Effect). They cited Raven (1974) for three instructional strategies to facilitate transfer: 1) task orientation must correspond to the child's level of reasoning. 2) the instructional strategy must incorporate the active engagement of the student in using his logical operations in the construction of rules and concepts. 3) concrete referents must be used.

Lawson and Snitgen (1982) incorporated some of these findings in a later study that taught formal reasoning strategies to pre-service elementary teachers. The authors used a direct but still inquiry-oriented approach in presenting concepts. Formal reasoning strategies were first introduced in familiar contexts with familiar terminology and applied in a wide range of contexts beyond discipline-specific boundaries.

Differences Between Formal Operational Thought and Propositional Logic

Kuhn (1977) linked conditional reasoning to the emergence of formal operations. She presented the differences between a concrete operational child and a formal operational child in her interpretation of Inhelder and Piaget's work, The Growth of Logical Thinking. A concrete operational child generates the four products of the logical multiplication of two attributes, p and q. The four products or base associations are $(p \cdot q)$, $(p \cdot \bar{q})$, $(\bar{p} \cdot q)$ and $(\bar{p} \cdot \bar{q})$, and these enable the child to master a variety of hierarchical classification tasks. What differentiates the formal operational child is that he forms a combinatorial system of the sixteen possible combinations that use one, two, three, or four of the four base associations. This combinatorial system is associated with a number of important behaviourial schemes such as variable isolation and systematic combination. Conditional reasoning is used by a student when he is evaluating propositions that follow from the applied use of the combinatorial system.

It followed that conditional reasoning was a part of formal operational thinking but it was not the only part. Roberge and Paulus (1971) obtained results through research on conditional reasoning abilities which supported Piaget's theory since they showed a spurt in these abilities during adolescence. These findings were in dispute, however, since other studies (Ennis, 1969 ; Ennis, 1965) were not able to demonstrate a similar, clear-cut increase in abilities. A concrete operational student was able to reason with some of the principles of conditional logic but the statements had to be presented in the context of simple, concrete, interesting situations (Ennis, 1969). Roberge and Paulus (1971) studied both conditional reasoning and combinatorial reasoning and identified them as formal operational tasks.

Formal thought was described by Lawson, Karplus, and Adi (1978) as the employment of a set of operational structures based on propositional logic. They cited Inhelder and Piaget (1958) as having given a broader characterization of formal thought. Inhelder and Piaget described formal thought as entailing propositional logic and a series of operational schemata which included combinatorial operations, proportions, double systems of reference, a scheme of mechanical equilibrium, multiplicative probabilites and correlations. However, Inhelder and Piaget stated that these schemata and propositional logic appeared in synchrony as formal operational abilities developed during adolescence.

Lawson et al (1978) attempted to determine whether these formal operational abilities developed in synchrony, and whether development was gradual or abrupt. They studied 507 students ranging in age from 11 - 20 years and representing elementary, junior high and senior high students from the San Francisco Bay area. It was a descriptive study with no experimental treatment. Lawson et al found an obvious increase in percentages of mastery with age for any tasks that required the use of formal schemata but there was no clear and substantial improvement with age for propositional reasoning. Their findings suggested that formal operational schemata and propositional logic were separate psychological factors. The formal schemata of proportions, correlations, and probability were shown to develop together and Lawson and Renner (1974) suggested that problems involving the isolation and control of varibles were linked to this group of schemata.

The term "formal operational" suggested a relationship with formal logic and Lawson et al questioned whether formal logic was decisive for this schemata. For that reason they preferred the term "hypothetico-deductive thought". They assumed propositional logic played no role in hypothetico-deductive thought. Students could have had some difficulty answering questions testing a rule (propositional logic) but they did quite well testing to see if familiar objects conformed to a rule.

Roberge and Flexer (1979) used a different definition for formal thought but their studies hinted at results similar to Lawson et al. Formal thought is based on a system of second order operations which are operations that are based on the coordination of relations among relations. Second order operations include combinations, proportionality, and propositional logic. Their studies produced equivocal results for the interrelationships of these schemata. Roberge and Flexer suggested different explanations. Their results could have been due to the markedly different tasks for the different abilities and they pointed out that most studies were performed on college undergraduates. They did not suggest removing propositional logic from formal operational schemata.

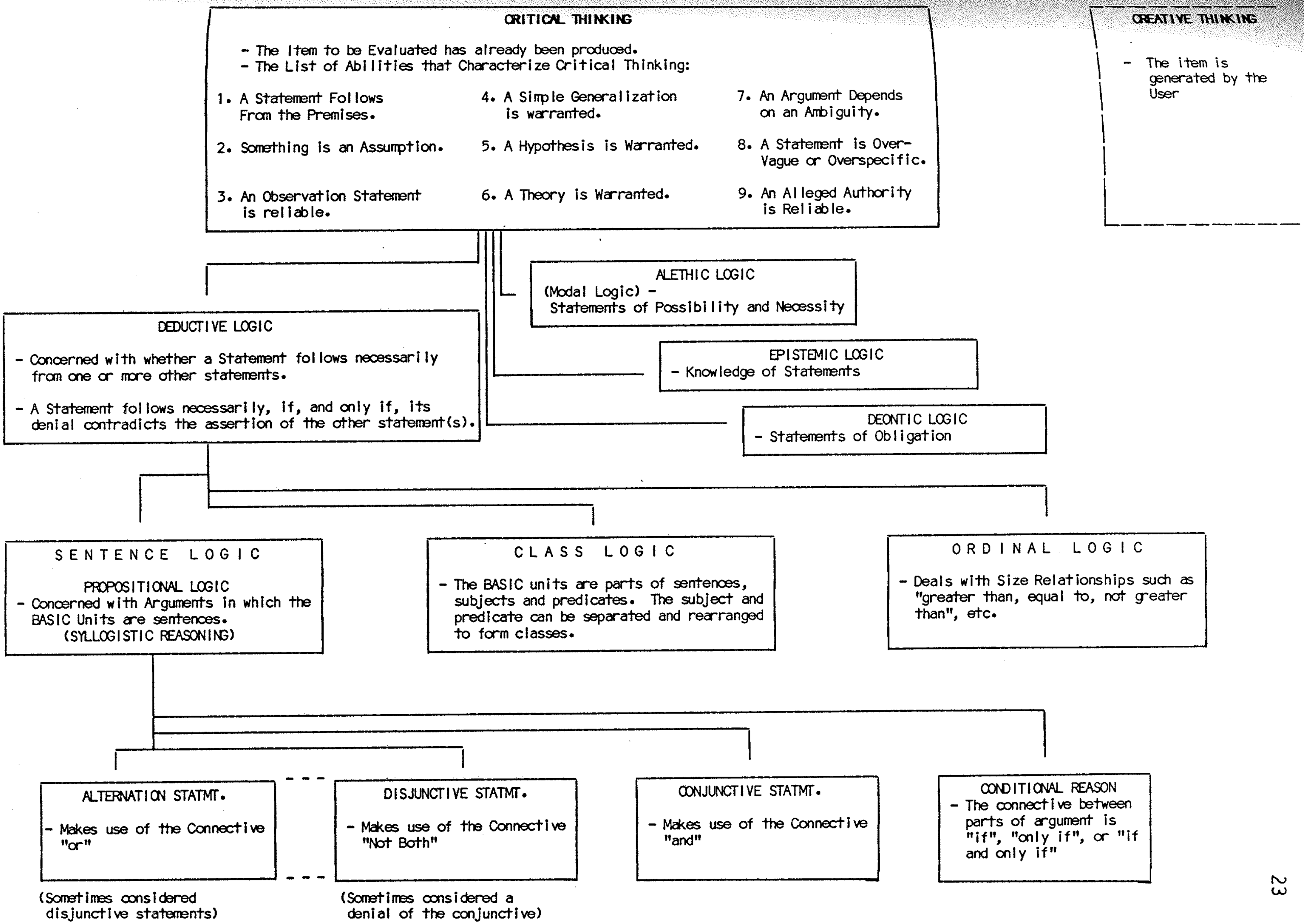
Ennis (1975) cited Piaget and Inhelder (1958) to give a definition of formal operational thought that centred on propositional reasoning. Formal operational thinkers were able to comprehend the 16 binary operations, distinguish each from the others, and use them to make inferences. They were capable of reasoning with verbally stated hypotheses and deducing the consequences that they necessarily imply. Although the other researchers were not in agreement on which schemata were associated with formal thought (and even if propositional logic was included), propositional logic was regarded in this study as being one part of formal operational thought. Ennis (1965,1969, and 1975) gave a comprehensive description of the principles of propositional logic and these are examined next.

Propositional Logic

Ennis (1975) described propositional logic as a necessary tool for critical thinking. The basic units of propositional logic are are propositions that can stand alone or can be joined or modified by logical operators that remain essentially unchanged throughout the course of an argument. Propositional logic is related to other forms of logic such as conditional reasoning and deductive logic. The relationships between these different kinds of logic and critical thinking is described in the following paragraphs.

Critical thinking is distinguished from creative thinking in that critical thinking evaluates items or ideas that have already been generated while creative thinking is

FIGURE 1: HIERARCHY FOR TYPES OF LOGIC



CRITICAL THINKING

- The Item to be Evaluated has already been produced.
- The List of Abilities that Characterize Critical Thinking:

1. A Statement Follows From the Premises.
2. Something is an Assumption.
3. An Observation Statement is reliable.
4. A Simple Generalization is warranted.
5. A Hypothesis is Warranted.
6. A Theory is Warranted.
7. An Argument Depends on an Ambiguity.
8. A Statement is Over-Vague or Overspecific.
9. An Alleged Authority is Reliable.

CREATIVE THINKING

- The item is generated by the User

ALETHIC LOGIC

(Modal Logic) -
Statements of Possibility and Necessity

EPISTEMIC LOGIC

- Knowledge of Statements

DEONTIC LOGIC

- Statements of Obligation

DEDUCTIVE LOGIC

- Concerned with whether a Statement follows necessarily from one or more other statements.
- A Statement follows necessarily, if, and only if, its denial contradicts the assertion of the other statement(s).

SENTENCE LOGIC

PROPOSITIONAL LOGIC
- Concerned with Arguments in which the BASIC Units are sentences.
(SYLLOGISTIC REASONING)

CLASS LOGIC

- The BASIC units are parts of sentences, subjects and predicates. The subject and predicate can be separated and rearranged to form classes.

ORDINAL LOGIC

- Deals with Size Relationships such as "greater than, equal to, not greater than", etc.

ALTERNATION STATMT.

- Makes use of the Connective "or"

(Sometimes considered disjunctive statements)

DISJUNCTIVE STATMT.

- Makes use of the Connective "Not Both"

(Sometimes considered a denial of the conjunctive)

CONJUNCTIVE STATMT.

- Makes use of the Connective "and"

CONDITIONAL REASON

- The connective between parts of argument is "if", "only if", or "if and only if" the creation of new ideas. A critical thinker is able to analyze statements and make judgments on their validity. Ennis (1965) stated that there were nine criteria for evaluating any logical argument. A critical thinker should be able to discern whether these nine criteria are met. A critical thinker is characterized by proficiency in judging whether:

1) A statement follows from the premises
2) Something is an assumption
3) An observation statement is reliable
4) A simple generalization is warranted
5) A hypothesis is warranted
6) A theory is warranted
7) An argument depends on an ambiguity
8) A statement is overvague or overspecific
9) An alleged authority is reliable.

Deductive logic is concerned with whether a statement follows necessarily from one or more other statements. A statement follows necessarily, if and only if, its denial contradicts the assertion of the other statement(s). From the above list of aspects of critical thinking, deductive logic can be seen to follow directly from the first aspect named. Ennis ascribed greater importance to deductive logic as part of critical thinking. It is a constituent of the application of the criteria and/or principles of the other eight attributes. Ennis (1969) presented five basic facts about deductive arguments. If an argument is valid, then it follows that:

1) The assertion of the premises commits one to the assertion of the conclusion.
2) The denial of the premises does not by itself require the affirmation of the conclusion.
3) The affirmation of the conclusion does not by itself require the affirmation of the premises.
4) The denial of the conclusion requires the denial of the conjunction of the premises (though not necessarily each premise).
5) If the argument's complete premises are the conclusion of another valid argument (called here a "second argument"), then the argument consisting of the first arguments and the second arguments' premises is itself a valid argument.

These basic facts are phrased in broad terms for deductive logic but they are also principles of sentence logic. They will be named and examined more closely in a later context.

Deductive logic in turn encompasses other types of logic. These are usually recognized as ordinal logic, class logic, and sentence logic. Ordinal logic deals with size relationships between items. Sentence examples of ordinal logic usually contain comparatives such as "greater than," "less than" or "equal to". The basic units of class logic are parts of sentences where the subjects and the predicates are phrased as classes of objects. Arguments in class logic often contain phrases such as "all of", "some of", "at least part of " and "none of" which denote membership in a group. Sentence logic has arguments in which the basic units are sentences that are connected or modified by logical connectives such as "if", "only if", "then", "and", "or", "not", and "both".

Types of sentence logic can be classified according to the type of logical connective used. The structure of this logic will be examined before the types of sentence logic logic are examined. An argument is developed by statements being given (or premises, or propositions), and the user evaluating whether a given conclusion must necessarily follow from those statements. The first statement given is usually called the major premise (or "p"), the second statement is usually called the minor premise (or"q"). Equivalent terms for sentence logic are propositional logic or syllogistic reasoning (pertaining to sentences).

Different connective words can be placed between the premises to suggest the different relationships which form the basis for the different types of propositional logic. Arguments which have the premises linked by the connective "or" (p or q) are called alternation statements. A variation on this form is shown by disjunctive statements which read "p or q but not both". A third type of propositional logic has the premises linked by the connective "and" (p and q). Some logicians consider all arguments containing "or" to be disjunctive statements and the argument "but not both" to be a denial of the conjunctive.

The type of arguments that are considered most closely in this study are conditional arguments that make use of "if - then" as logical connectives. Conditional arguments are of the form "if p, then q" where each part gives a condition for the other part. Consider the example "If it is raining, then the ground is wet" where the premise "it is raining" is the "p" element and the conclusion "the ground is wet" is the "q" element. In this statement, that it is raining is a sufficient condition for the truth of the ground being wet; and that the ground is wet is a necessary condition for the truth of the claim that it is raining. The forms of conditional logic are "if p, then q", "p only if q", "p if and only if q". Reasoning associated with conditional arguments is called conditional reasoning.

Referring back to the original definition of deductive logic (a statement follows necessarily from other statements), a deductive argument can be seen to be a conditional statement. For any deductive argument the premise can be substituted for "p", the conclusion can be substituted for "q", and the implication of q by p is logically necessary. The five principles of deductive reasoning described earlier are parallel to the five basic principles of conditional logic. For each principle it should be assumed that a conditional (If p, then q) is given:

1) Basic Understanding (of the forward conditional). The affirmation of the if-part (p) implies the affirmation of the then-part (q).
2) Inversion. The denial of the if-part (p) does not by itself mean denial of the then-part (q).
3) Conversion. The affirmation of the then-part (q) does not by itself imply an affirmation of the if-part (p).
4) Contraposition. The denial of the then-part (q) implies the denial of the if-part (p).
5) Transitivity. Given another conditional (if r, then p) which has for its consequent the antecedent (p) of the first conditional, the affirmation of the if-part (r) of the second conditional implies the consequent of the first conditional (q).

(Ennis, 1969)

These five basic principles have been expanded, through examination of other possible combinations of p and q, as well as particular and specific situations, into twelve principles of conditional logic. That is, the first principle cited above is known as detachment or biconditionality and it can be represented in combinations of forward positive detachment, reverse positive detachment, forward negative detachment, and reverse negative detachment. The principle of inversion has both particular and full forms, as do contraposition and conversion. For a more detailed presentation of the twelve propositional arguments, refer to Table 2.

Examples of the twelve principles of conditional logic can be presented in different contexts. Ennis (1965) taught principles of conditional logic to elementary and secondary students and tested them with logical questions in three forms. The forms Ennis used were concrete familiar objects (with which the students should be familiar), symbolic (terms like "x" or "y" make up the argument), and suggestive (in which the content is familiar but the truth status of the statement is not known by the student). In addition, a propositional argument can be presented in an unfamiliar context where the student has not experienced the objects in the argument.

Ennis used Piaget's theory of cognitive development as a foundation in his investigations of childrens' use of logic. Although there was general agreement between Ennis and Piaget concerning the principles of logic, there were still differences that need to be examined. The correspondence between Piaget's logic and Ennis' logic was great in Ennis' Critical Thinking Readiness Project (Ennis, 1965) and the points of difference were small. Piaget studied the development of a child's knowlege of logic while Ennis studied the child's capacity to learn logic. What was called sentence logic by Ennis was referred to as propositional logic by Piaget but their interpretations were similar. Piaget resisted the trend to merge propositional logic and class logic in order to avoid complex language in logical statements. Piaget made the distinction between propositional logic and class logic by noting that, although class logic decomposed and recomposed the content of propositions, it did not deal with the combination of those propositions as independent units. Propositional logic deals with the combinations of propositions as independent units. Propositional logic is concerned with relations between propositions which remain unchanged throughout an argument. Ennis accepted this distinction.

Ennis disagreed with Piaget's criteria for judging whether a student was using propositional or class logic. Piaget believed propositional logic was being used if a student worked within a system using all possible combinations of variables. The defining characteristic for use of class logic was the failure to work within a system of all possible combinations. These criteria were too restrictive for Ennis to accept and Piaget was not clear in explaining them. Furthermore, Ennis judged Piaget as having used unacceptably idiosyncratic interpretations of whether a student was using conditional or class logic (Ennis, 1965). Ennis examined four possible criteria that Piaget may have considered as evidence that a child was using a combinatiorial system. The four criteria were: 1) the use of the language of propositional logic; 2) suppositional reasoning; 3) distinguishing one operation from another; and 4) isolating the variables (Ennis,1975). However, Ennis pointed out contradictory assertions by Piaget concerning each of these criteria and concluded that there were different interpretations available.

Although Ennis disagreed with both Piaget's use of logic and Piaget's claims about what logic children could do, he did not reject Piaget's large scheme of conditional logic. The points of contention were for specific interpretations that were not within the scope of this investigation. Ennis judged Piaget's propositional logic to be roughly comparable to his own system. Piaget presented a model of cognitive development that showed the use of some propositional logic principles to be characteristic of formal operational thought. Ennis' work was more germane to this investigation and his statement of logical principles was used here.

Acquisition of Propositional Logic

The pattern that emerged was that propositional logic was considered to be one of the attributes of formal operational thought but it was not acquired in synchrony with the other schemata. Lawson et al (1978) stated that proportional, probabilistic, and correlational reasoning (the components of formal operational thought) were not acquired as a result of any direct and/or short-term teaching programs. These reasoning abilities were acquired as a consequence of the gradual process of equilibration. They did recommend that curricula designed to promote the acquisition of these reasoning abilities should provide opportunities for equilibration.

The above conclusions of Lawson et al arose from their main finding that propositional logic mastery did not improve with increasing chronological age. Treagust (1979) believed that Lawson et al erred in their study and he gave two alternate explanations. First, he felt the propositional logic tasks they used were not homologous with the underlying propositional logic required to complete the tasks testing for formal operations. Treagust quoted Piaget (1958) as saying that subjects could use propositional logic but Piaget did not say that subjects could solve arguments of propositional logic. That is, the subject did not possess symbols or propositional logic. He did not reflect on the structures of logic he was using, he used them. A second explanation Treagust offered for the results of Lawson et al was that the propositional logic tasks may have been homologous but that the tasks testing for formal schemata were not evaluating the same propositional logic. There was a lack of congruence between tasks evaluating formal schemata and those evaluating the ability to solve problems of propositional logic. Treagust argued that the only valid way to assess reasoning was by questioning the response of the student.

Roberge and Flexer (1979) also found that there was asynchronous acquisition of logical operations. They cited Piaget (1972) as asserting subjects may only display formal thought when the content of the problem was related to their interests, aptitudes, and specializations. Piaget's claim, however, had been contraindicated by studies of Bart (1971), Roberge and Antonak (1979), and Dreyfus and Jungwirth (1979) while reports of Linn (1982) and Levine and Linn (1977) have been supportive of Piaget's claim. These reports will be examined when the phenomenon of transferability is discussed. Roberge and Flexer reported that subjects had difficulty with propositional logic involving conditional rules. They also found significantly higher scores for males on proportionality and propositional logic. This was consonant with Piagets' findings of sex differences for formal operational tasks.

Recent research had investigated how students acquired mastery of specific logical principles. Adi, Karplus, and Lawson (1980) defined mastery of a logical principle as the successful recognition of the validity of an argument which imbedded that logical principle. They used a test with written justification that was adapted from the four - card problem developed by Wason and Johnson-Laird (1972). Adi et al considered the logical principles of detachment, particular contraposition, particular inversion, and particular conversion. The first two principles were valid arguments while the latter two were invalid. They assessed two performance outcomes in their investigation:1) the behavioural performance which referred to whether the deduced logical conclusions were correct or incorrect; and 2) the reasoning performance which referred to the students' justification. Some reported improvements in mastery were for the principle of detachment which showed 50 percent mastery by fourth graders which increased to 90 percent for twelfth grade students. Mastery of logical contraposition showed 35 percent for fourth graders, increasing to 60 percent mastery for twelfth grade students. There was a lower initial mastery and increase in percentage mastery for both invalid principles. They concluded that it was much easier for students to recognize the validity of logical detachment and particular contraposition than to recognize the invalidity of particular conversion and particular inversion. Adi et al used a test that called for written justification but they did not report results much different form similar tests in clinical settings.

Ennis (1965) reported a different result for improvement in mastery. The principles of contraposition (basic and practical) and perhaps the principle of affirming-the-antecedent showed improvement but the greatest improvement was for fallacy principles (conversion and inversion). Ennis (1976) summarized the results of his Critical Thinking Readiness Project (1965) and these are presented in Table 1. The mastery of some principles showed a decrease for the ninth-grade subjects but Ennis attributed this to a poorly motivated class of subjects. The tendency could be seen to be a general improvement of mastery with increasing age for most logical principles but

TABLE 1

PERCENTAGES OF STUDENTS SATISFYING THE CRITERION FOR MASTERY OF CERTAIN CONDITIONAL-LOGIC PRINCIPLES[a]

	GRADE			
	5	7	9	11
N	102	99	80	74
Mean CA (years-months)	10-9	12-9	15-4	16-11
Mean IQ[b]	108	117	110	109
Principles:				
1. Detachment	51	56	66	62
2. Particular Transitivity	26	52	53	55
3. Full transitivity	25	45	40	38
4. Particular contraposition	30	41	35	35
5. Full contraposition	34	40	35	33
6. Biconditionality	23	40	46	40
7. Particular conversion	2	3	4	3
8. Full conversion	2	5	11	19
9. Particular inversion	3	6	5	12
10. Full inversion			Not Tested	

[a] From Ennis and Paulus (1965), pp. V-16 and V-18).

[b] Lorge-Thorndike or California Test of Mental Maturity.

the invalid principles only showed a strong improvement around the eleventh grade.

Roberge (1972) summarized recent research on the mastery of conditional logic principles and these are presented in Table 2. Ennis (1976) acknowledged Roberge's study but would not summarize the results because there was widespread lack of congruence over the names of logical moves, over what was important, over what was to count as success in logic, over test items, and even over what was valid. The conclusion reached by Roberge was that instruction in the common schemes of inference as well as instruction in the fallacies could be included in mathematics curricula.

Taplin et al (1974) performed similar tests with conditional arguments with third-grade to eleventh-grade students. Although their results confirmed the previously established finding that performance improves with age (particularly between 11 and 15 years of age), they offered another possible explanation. They felt that logical reasoning increased with age or it could have been due to an improved understanding of linguistic meaning - specifically, the connectives "If...Then". In the context of their experiment, Taplin et al could not make a clear decision between the two alternatives. However, they cited Piaget as stating that connectives specifying causal or implicative relations were used infrequently by younger children but their use increased with age. Taplin et al

TABLE 2

PERCENTAGE INCREASE IN MASTERY FOR LOGICAL PRINCIPLS (REPORTED BY ROBERGE, 1976)

[Compilation of Research Performed in Studies by Roberge (1970), Miller (1969), Miller (1968)]
[Ennis and Paulus (1965, Martens (1967), Gardiner (1965), Howell (1965)]

	PRINCIPLE*	SYMBOLIC LOGIC	EXAMPLE	GRADES												
				4		5	6		7	8		9	10		11	12
1)	Detachment	If p, then q . p. Therefore q. VALID	If the hat on the table is blue, then it belongs to Joan. The hat on the table is blue, Therefore, the hat on the table belongs to Joan.	MODUS PONENS (I)** 50% in intermediate grades, increased substantially at junior high level and greater than 90% at upper levels												
									56	74			95			
									75	78		66			62	97
				53		51	54		91	95		74	100			
					59			79			89			99		
2)	Particular Inversion	If p, then q. not p. Therefore not q. INVALID	If Tom lives in the white house, then his last name is Smith. Tom does not live in the white house, Therefore, Tom's last name is not Smith.	DENYING THE ANTECEDENT (III) NOT VALID												
									6	0		5	3			9
				2		3	Q		0	1		0	5		12	7
									0	0						
					2			2			4			20		
3)	Particular Conversion	If p, then q q. Therefore p. INVALID	If Mary lives in the white house, then her last name is Brown. Mary's last name is Brown, Therefore, Mary lives in the white house.	AFFIRMING THE CONSEQUENT (II) NOT VALID												
									3	0						6
									0	1		4	4			
				2		2	0		0	0		0	19		3	9
					0			0			4			20		
				This fallacy mastered by less than 10% with few exceptions occurring at upper grades.												
4)	Particular Contraposition	If p, then q. not q. Therefore not p. VALID	If the car in the parking lot is Mr. Smith's, then it is blue. The car in the parking lot is not blue, Therefore, the car in the lot is not Mr. Smith's.	MODUS TOLLENS IV												
									41	23		35	64		35	56
				35		30	23		13	70		43	65			78
									87	74						
					16			23			48			47		
				Reaches a pinnacle in grade 9-10 and showed a tendency to decline slightly at upper grade levels.												
5)	Full Transitivity	If p, then q. If q, then r. Therefore, if p, then r. VALID	If Sam misses the bus, he will walk to school. If Sam walks to school, he will cross the bridge. Therefore, if Sam misses the bus, he will cross the bridge.	HYPOTHETICAL SYLLOGISM V												
									45	58		40	84			54
				28		25	28		58	57		83	82		58	79
									81	81						
				Between 25 and 30% in intermediate grades, showed a marked increase at the junior high level and reached apex at upper grade levels.												
6)	Full Contraposition	If p, then q . Therefore, if not q, then not p. VALID	If Mrs. Smith entered the flower show, Then she entered her roses. Therefore, if Mrs. Smith didn't enter her roses, Then she didn't enter the flower show.	PRINCIPLE VII (Roberge)												
									4	11		2	57			67
				28					39	48						
								30			54			66		

* Principle as identified by Ennis (1965)
** Principle as identified by Roberge (1976)

TABLE 2 continued

PERCENTAGE INCREASE IN MASTERY FOR LOGICAL PRINCIPLES (REPORTED BY ROBERGE, 1976)

	PRINCIPLE*	SYMBOLIC LOGIC	EXAMPLE	GRADES 4	5	6	7	8	9	10	11	12
7)	Full Conversion	If p, then q . Therefore, if q, Then p. INVALID	If the chair is green, Then the table is black. Therefore, if the table is black, Then the chair is green.	NOT CORRELATED WITH ROBERGE'S PRINCIPLES								
8)	Reverse Negative Detachment	p only if q. not q. Therefore not p. VALID	John is in the kitchen Only if there is food in the kitchen. There is no food in the kitchen, Therefore, John is not in the kitchen.	NOT CORRELATED WITH ROBERGE'S PRINCIPLES								
9)	Forward Positive Detachment	p only if q. p. Therefore q. VALID	Harry is on the football team Only if he has his mother's permission. Harry is on the football team. Therefore, Harry has his mother's permission.	PRINCIPLE VII (Roberge)								
							4	11				
							39	48	2	57		67
				28			0	0	0	19	3	9
					30	54				66		
				Percentages of mastery here were consistently greater than for pr. VI in the one study which examined ability to reason with both principles								
10)	Forward Negative Detachment	p, if, and only if, q. Not p. Therefore, not q. VALID	Bill will see Audrey this year, if, and only if, he goes to Montreal this year. Bill will not see Audrey this year, Therefore, Bill is not going to Montreal this year.	PRINCIPLE IX (Roberge)								
				18		50				64		
11)	Principle XI	p only if q. q. Therefore p. INVALID	Dick is using the classroom dictionary Only if the library is closed. The library is closed, Therefore, Dick is using the classroom dictionary.	NOT CORRELATED WITH ROBERGE'S PRINCIPLES								
12)	Principle XII	p only if q. Not p. Therefore not q. INVALID	Jane went to the park yesterday Only if she saw her friend Pat yesterday. Jane did not go the park yesterday, Therefore, Jane did not see her friend yesterday.	NOT CORRELATED WITH ROBERGE'S PRINCIPLES								

* Principle as identified by Ennis (1965)
* Principle as identified by Roberge (1976)

ADAPTED FROM ROBERGE (1976)

interpreted Piaget as suggesting some change in the meaning of the connective was taking place.

Non-transferability of Propositional Logic

The research cited so far has suggested that the acquisition of conditional reasoning resulted from a developmental process. Lawson, Karplus,and Adi (1978) stated that reasoning abilities were not acquired as the result of any direct reaching programs. Research that was examined here suggested that familiarity or interest in related subject material did not facilitate acquisition either.

Roberge and Antonak (1979) claimed that recent research on adults' propositional reasoning abilities have not supported Piagets' claim regarding the influence of professional specialization on logical reasoning ability. Piaget (1972) had claimed that all normal individuals reached the formal operational level between the ages of 11 and 20. However, they reached this stage in different areas according to their aptitudes or professional specializations. Roberge and Antonak cited Bart (1971) who found that the interests of adolescents and young adults in a given subject-matter area had little relation to the level of their propositional reasoning in that area. He concluded that interest and specialization have little effect on the development of hypothetico-deductive reasoning. Roberge and Antonak found that a group of graduates in special education performed only as well as other education graduate students in a test of propositional reasoning that was weighted with special education content. Roberge and Antonak concluded that Piaget's earlier claim should be re-examined.

Dreyfus and Jungwirth (1979) conducted a more detailed study of the transferability of propositional reasoning between different curricular contexts. The authors designed a questionnaire based on logical fallacies presented in different contexts. The main purpose of the investigation was to determine if students reacted similarly when confronted with equivalent situations in different contexts. Dreyfus and Jungwirth concluded that students did not react similarly. Although a logically "right" answer drew its validity from a universal principle applicable in many and varied situations, the logical principle got lost in the "noise" of the context. The confusion from the different contexts produced elements of dissimilarity which overcame the similarity between problems. There was no transferable principle left for generalization. For that reason, Dreyfus and Jungwirth advocated relevant content rather than abstract content for presenting logical principles.

These findings were contraindicated by Linn (1982) who stated that knowledge of content did influence performance with propositional reasoning. She cited a study by Pulos and Linn (1981) which investigated the effect of expertise on reasoning. The tests of reasoning focused on a narrow range of skills for controlling variables. Subjects performed better on tests controlling variables if they involved familiar content. It was also found that subjects showed poorer performance in areas where they had previously been unsuccessful. The subjects apparently refused to reason. In this study the failure to control variables reflected a lack of factual knowledge as to which variables were important. Linn argued against Piaget's emphasis on content-free reasoning with her contention that factual knowledge did improve performance on reasoning problems, and that some influences were predictable.

Advantages of Propositional Logic

Although the use of propositional logic was considered by Piaget (1958) to be a distinguishing characteristic of formal operational thought, it was still difficult to identify specific uses for propositional logic in curricula. Some applications for propositional logic could be found in science curricula.

Enyeart, Baker, and Vanharlingen (1980) studied whether both inductive and deductive components of logical reasoning contributed equally to achievement in an introductory college physics course. They found that general logical ability was important for success but that deductive logic was more important for achievement than inductive logic. Students in physics were usually involved in testing hypotheses rather than formulating them. That is, students would more often evaluate the validity of a given proposition instead of generating the proposition.

Bady (1979) cited the study by Wason and Johnson-Laird (1972) where students were given a hypothesis of the form p->q and then given data to test it. They found that few students sought out possible falsifying clues. The students used verification strategy instead of falsification strategy. This finding seems to reinforce Ennis' result (1965) that students were better at mastering valid inferences rather than invalid ones. Wason and Johnson-Laird found improved performance was shown when meaningful materials were used rather than abstract. Bady used a test derived from Wason and Johnson-Laird and did not obtain results much better than the original study. He noted that few students seemed to grasp the logic of hypothesis testing. Less than half of high school students could be expected to realize that hypotheses could only be tested by attempting falsification. Bady suggested two implications followed from this: 1) students did not interpret implications of scientific statements correctly and 2) students did not understand the nature of science. Anyone who did not realize that scientific hypotheses cannot be proven at all, only disproven, cannot be said to understand truly the nature of science. Bady suggested that the often reported poor understanding of science may arise from students being exposed to science without having developed the requisite logical skills. The implication of Bady's research, for the purposes of this argument was that a better grasp of propositional logic will result in a better understanding of the nature of scientific hypotheses.

Applications of Propositional Logic

Other applications for propositional logic were generally framed in the larger context of critical thinking. Dreyfus and Jungwirth (1979) argued that many educators perceive education for critical thinking as a way of improving the skills of the citizen in dealing with everyday situations and problems. This formulation implied that techniques of critical thinking could be transferred from the classroom to real-life situations. It has already been demonstrated that there were equivocal results for tranferability of propositional reasoning. Many learners were unable to deal with abstract scientific problems. Dreyfus and Jungwirth suggested that the science curriculum should be more closely linked to concrete examples of real-life situations and interests. Since their study demonstrated that students reacted differently when presented with equivalent situations in different contexts, Dreyfus and Jungwirth were skeptical of propositional reasoning having a broader applicability to different curricular areas. As long as this tendency persists, transfer of critical thinking ability from one contextual area to another cannot be regarded as probable. They suggested that teachers should not take such an ability for granted.

Weinstein and Laufman (1980) gave a more favourable presentation for the advantages of logical reasoning ability. They referred to Kneller (1966) for a definition of logic: "Logic is the tool of rational thinking, the study of principles and methods of vaild inference. What interests the logician is the connection between the conclusions they assert and the grounds (or evidence) on which they assert them."

The proponents of logic for children argued that in order to think clearly and rationally, students must be taught to use logic as the tool of good thinking. Lipman, Sharp, and Oscanyan (1980) maintained that the study of logical thinking held several benefits:

1) It teaches students positive reasoning but also protects them from fallacies of thinking (argumentum ad absurdio, generic fallacy, false analysis, and coincidences).

2) Students learn rules of reasoning (the premises which are necessary for asserting conclusions).

3) Students learn inductive reasoning, the logic of scientific enquiry.

4) Through formal analysis, students learn to discuss concepts by examining their language.

It should be noted that the points advanced by Weinstein and Laufmann referred to deductive reasoning rather than just propositional logic, they made broad claims without much reference to substantiating research, and they ignored contradictory research cited earlier in this study.

Teaching Methods For Propositional Logic

The specific advantages of ability in propositional reasoning are not certain and it is not being taught as a discipline in schools. Most of the teaching methods that had already been cited were used as a vehicle for conducting research in propositional reasoning or, more specifically, conditional reasoning. To that end, most of those teaching methods simply involved the administration of reasoning tests. However, many of the researchers, in their discussion of results, recommended that elements of propositional reasoning be included in mathematics or science curricula.

Roberge (1972) cited recommendations from conferences and commissions concerning deductive reasoning for proposed mathematics curricula. These recommendations included instruction in deductive reasoning in algebra and geometry and explicit instruction in the recognition of inference schemes in the elementary school. No specific teaching methods were described, however. Other research by Roberge (Roberge, 1976 and Roberge and Flexer, 1979) used only testing procedures in their methodology.

Lawson, Karplus, and Adi (1978) also gave recommendations for teaching methods to facilitate the acquisition of reasoning abilities but these methods were not actually employed by the researchers in the study.

They suggested that curricula designed to promote the acquisition of these reasoning abilities should provide opportunities for equilibration. In the same study, however, they found that propositional logic may not have been important for formal operational thought. Teaching programs that taught propositional logic as a means to improve thinking may have been misguided.

Lawson and Wollman (1976) provided a more specific suggestion for teaching reasoning. They found that equilibration was facilitated by providing students with problems from a wide variety of contexts. Interdisciplinary programs that taught the various aspects of formal reasoning from widely differing content areas allowed equilibration through various reasoning patterns.

Palmer (1980) discussed mathematics as a use of reasoning. He suggested that not every child could without assistance transfer the reasoning skills learned in the mathematics class. Elements of mathematics which were compulsory for most curricula did not give much practice in assessing or even in constucting arguments. Palmer taught logic on a voluntary basis to interested students. He advised that logical arguments be set out in words rather than in symbols.

Ennis (1965) supervised the Critical Thinking Readiness Project which had as its goal, the investigation of student's readiness to master logic. The orientation of the study, therefore, was to teach principles of conditional or class logic rather than to measure students' abilities. Tests for conditonal logic and class logic were developed for the study and two staff members "taught specifically to the test", 15 minutes per day. Ennis was not any more specific than the above as to the pedagogical techniques that were used. The implication for this study was that the researchers used situational tactics, whatever would work on a particular day. Results from this study showed that there was not much learning of conditional logic in grades five, seven, and nine. However, there was a large improvement by grade eleven, particularly for principles involving invalid arguments.

He attempted to refine these results in a later study. Ennis (1969) taught conditional logic for 15 weeks but obtained no significant difference in mastery between the experimental and control groups. Ennis stated that he used an audio-tutorial method and although he described the logistical problems of instruction and included sample lesson scripts, he did not comment on the efficacy of this method of instruction. He found a wide variation amongst his subjects for the age of demonstrating mastery. Ennis also commented that not all teaching methods were effective (not explained further) but some students learned conditional logic anyway. Selected science concepts were chosen as the context for teaching conditional logic. Ennis attributed the anomolous results to many causes, notably a lack of motivation in the one class of grade nine students.

CHAPTER III

REVIEW OF THE LITERATURE PERTAINING TO BASIC PROGRAMMING AND COMPUTER LITERACY

Computer Literacy

The increase in power, distribution, and availability of computers, coupled with the decrease in price has presented educators with the opportunity as well as the necessity for introducing computers to students. Three broad educational uses for computers have been identified (Ragsdale, 1982). These include computer assisted instruction, programming, and computer literacy. The first use (CAI) is not within the scope of this project and a search of the literature does not reveal any fundamental changes in the offerings of computer programming courses to students. More students are taking computer science courses at the secondary level (Luehrmann, 1982) but it is still being presented at the upper secondary grades. However, computer programming skills are increasingly being taught in another context, as part of computer literacy curricula.

Moursund (1979) had written extensively on the subject of computer literacy and presented a broad definition. "Computer literacy refers to a knowledge of the non-technical and low-technical aspects of the capabilities and limitations of computers, and the social, vocational, and educational implications of computers." That definition refers more to the social effects of computers rather than focusing on specific computing skills. Johnson et al (1980) produced a similar definition when citing the 1977 position paper of the National Council of Supervisors of Mathematics. They described computer literacy as one of ten basic skill areas:

> "It is important for all citizens to understand what computers can and cannot do. Students should be aware of the many uses of computers in society, such as their use in teaching/ learning, financial transactions and information storage and retrieval. The "mystique" surrounding computers is disturbing and can put persons with no understanding of computers at a disadvantage. The increasing use of computers by government, industry, and business demands an awareness of computer uses and limitations."

The MECC Computer Literacy Study cited by Johnson et al (1980) identified six main content areas that should be included in any computer literacy course: hardware; programming and algorithms; software and data processing applications; impact; and attitudes, values and motivation. The MECC study was quite specific insofar as it outlines detailed objectives in both the cognitive and affective domains. The implicit definition of computer literacy embodied in the MECC study still recognizes the social aspects of computer literacy but it gave greater emphasis on programming than did Moursund. Nevertheless, the MECC study has been criticized by Luehrmann (1981) for not giving greater emphasis to programming skills. Luehrmann stated that fully four-fifths of the MECC objectives do not advance computer literacy. He maintained that computer literacy means the ability to do computing. Alternate objectives suggested by Luehrmann are intended to develop greater programming skills.

Contradicting Luehrmann and defending the MECC study was the response by Anderson et al (1981). They advanced the general argument that most of what the ordinary citizen should know about computers will not be learned from learning how to program. Anderson et al cited the report by Klassen et al (1980) which indicated a low level of test performance in programming questions for students who had previously received computer programming instruction. Further, the numbers of hours allocated for hands-on compuuter activities did not contribute as much to computer learning as did factors such as the type of course and time spent on computer topics. Anderson et al also questioned the type of programming being taught, suggesting that a typical course approach often requires the students to write a few programs in the BASIC language. They felt that this could stifle creativity and motivation and could lead to poor algorithmic thinking.

Other curricula plans for computer literacy are being brought forward and they generally contain objectives similar to the MECC proposal. Andrews (1981) proposed eight major topics for computer literacy objectives: applications, hardware, impact, limitations, programming/algorithms, software and data processing, usage, and values and feelings. Andrews' objectives were based upon MECC model and the list of objectives seemed to have been expanded slightly to include limitations and usage of computers. Programming was still included.

The Board of Cooperative Educational Services in Suffolk County, New York described projects for computer literacy in K-12 education (Murphy, 1980). They did not specify cognitive objectives as in the proposals of Anderson et al (1980) and Andrews (1982) but used performance criteria for computer-based tasks. The model for the school districts addresses the three areas of student awareness, programming proficiency, and staff education. Programming proficiency is presented for three levels: elementary programming, intermediate programming, and advanced programming. The stated goal for this curriculum throughout the K-12 grades is for students to be able to create successful programs appropriate to the ability level.

Bitter (1981) proposed a curriculum that would encompass computer literacy topics such as hardware, software, computer generations, and flowcharting. However, the grade 4-6 level that he considered included a pronounced emphasis on programming. He strongly suppported the use of BASIC as the programming language and suggested using a guided discovery strategy that first introduces the non-mathematical aspects of BASIC programming. The sequence of topics that Bitter recommended is: print and REM statements, LET, INPUT, GOTO, formula, string data, relation, if-then, read-data, for-next statements, and random number generation.

Teacher Uses of Programming

Just as there is only a broad consensus of what curriculum topics constituting computer literacy, there is a varied approach to teaching programming in the classroom. Shavelson et al (1983) attempted to survey the instructional uses of microcomputers in public schools. They were unable to implement a survey because they were unable to find similar pairs of successful computer-using situations. The authors turned to the educational technology literature and found little that was systematic or indicated how microcomputers could be used "successfully" by teachers. Shavelson et al suggested that successful teachers are set apart by their attempt to individualize computer activities for students and to differentiate amongst different computer activities for different goals.

Rice and O'connor (1981) identified two methods of introducing computer literacy: infusion and unit integration. The process of infusion involves bringing computer literacy objectives into existing curricula, using whatever materials and equipment are available. Unit integration involves intoducing a computer literacy unit alongside existing curricula. For both methods, Rice and O'Connor identified the strong desire of students to learn programming.

Burns (1980) described activities that prepare students for developing the sequential precise instructions needed for a programming language. She claimed that students learn best by active involvement and relate best to their own experiences. The pre-programming activities she described included preparing a peanut-butter and jelly sandwich through a list of written instructions. Tocci and Laskowski (1979) recommend introducing the concept of conditional branching through games. This approach will give young students an idea of how computers function.

Halapin (1982) recommended a lot of hands-on experience in a computer literacy course that had three levels of activity: awareness, orientation, and programming. He was experimenting with grade six pilot programs using BASIC and PILOT language. Halapin suggested programming is teaching high-level thinking and this could produce cognitive advancement and development of logical thinking. However, these were speculative projections and Halapin did not substantiate these statements. The classroom procedure Halapin used for introducing programming concepts was lecture and demonstration, then an assignment for that skill.

Zukas (1980) presented a minicourse on computers that did not involve any computer equipment. He worked with fourth and fifth grade students and activities included decoding computer cards, flow-charting and writing computer programs. Zukas found that students' success in this course was limited by their ability to understand abstract mathematical concepts. Shea (1973) investigated the effects on achievement and attitude for calculator flow-charting technique. This technique was found to be superior for improving computation in fourth grade students but did not effect gains in arithmetic concepts or attitudes. Moshnell (1982) presented a cautionary view for using flow-charting techniques with students. Students cannot just be taught flow-charts and then expected to understand a program's semantics. This gives them two new languages instead of one. Although flow-charting skills are not transferable to programming skills, they do help students with highly visual approaches to reality.

Bork (1983) advocated a more direct approach for teaching programming to students. He argued that programming style is more important than the programmer or the programming language. Bork warned against developing poor habits in programming. To that end, students should be taught structured programming and started with a programming language other than BASIC. Students should work in teams and learn by studying programming examples. Corens and Corens (1982) also recommended a team approach for students learning to program. They made no comment on improved performance but spoke of the need for interactive skills which can be more important then technical skills.

Educators have identified more methods for delivering instruction on computer programming. Van Horn (1982) suggested that teachers have students work from programming manuals. Advantages that he cited were: students learn to follow directions, the instructions are machine specific, they gain experience in reading, and they can work at their own pace. Van Horn seemed to mistake the very different functions of programming and computer assisted instruction when he argued that programming is less expensive than CAI. Stier (1983) described a computer literacy course which included the common elements of societal effects of computers, parts of the computer, and programming. However, subjective evaluation of the computer literacy course reported increased interactive skills and an increase in reading ability. Ahl (1981) suggested that students can learn about the functioning of computers and develop interactive skills by building computers from kits.

A picture emerges of computer programming skills being taught through a wide variety of approaches. This variety can perhaps be summarized by examining the following methods for teaching programming. Bitter (1981) recommended a "guided discovery" approach to programming. Within that context he presents a detailed list of programming objectives for grades 4-6. Eisele (1980) suggested including problem-solving techniques with programming. Recommendations he made for instruction include describing steps, developing a logical sequence, and learning two languages. Luehrmann (1981) advocated structured programming for teaching BASIC language and he cautioned teachers against rushing students through the rules of

BASIC. In another study Luehrmann (1982) predicted that there will be three levels of computer programming courses taught. He used the labels of Bonehead Computing, Computing Orthodonture courses, and Honours Computer Science with the purposes of upgrading, remediation, and advanced training, respectively.

Basic Language

A programming language is the set of instructions needed to be placed into the computer for it to perform its assigned functions. For a number of reasons, the programming language most likely to be used by secondary school is BASIC. BASIC, an acronym for Beginner's All-purpose Symbolic Instruction Code was developed by John Kemenny and Thomas Kurtz at Dartmouth College in 1964. Rather than being designed for professional applications, BASIC is intended for beginner computer users, irrespective of their background. It is a procedure-oriented language with the characteristics of being easy to learn, easy to use, and easy to remember. It consists of a few syntax rules, and a small number of statement types, and can be used for a wide variety of applications. BASIC is available on almost all computer systems ranging from hand-held computors through to large main-frame systems (Spencer, 1983). All popular commercial microcomputers support BASIC.

Although researchers are still arguing the merits of introducing BASIC to students, citing reasons of lack of structure and poor procedure (Evans, 1981; Ever, 1981), BASIC still enjoys favour among educators. It is a language simple enough to be taught to bright elementary students while possessing enough power to allow secondary school students to produce interesting programs (Coburn et al, 1982). BASIC is the language most likely to be taught in intrduction computer science courses as well as later computer literary courses. However, it has been suggested by Johnson et al (1981) that the development of the BASIC language has paved the way for a narrow view of computer literacy and educational programming.

Correspondence of Basic Language with Propositional Logic

A program in BASIC consists of statements which may contain expressions. A statement is a complete instruction which tells the computer to perform specific operations. Expressions include numeric expressions, string expressions, relational expressions, and logical expressions. Relational expressions touch on ordinal logic but logical expressions in a BASIC statement are very similar to statements in propositional logic.

Logical expressions contain logical operators that make logical comparisons. Normally, they are used in IF/THEN statements to make a logical test between two or more relations. If the expression represents a true condition, control proceeds to the action-clause contained in that statement. If the expression represents a false condition, control passes to the next statement or follows an ELSE instruction.

The IF/THEN statement in BASIC is very similar in structure and function to a propositional argument in conditional logic. Both statements contain a first premise (p) related to a second premise (q). Other expressions in BASIC make logical comparisons but they usually make use of ordinal logic rather than propositional or sentence logic. A FOR/NEXT statement usually evaluates a numeric relationship as does an ON...ELSE statement.

Although an IF/THEN statement is presented in one form such as IF (first premise) THEN (second premise), the context of the statement determines different relationships between the premises. This researcher contends that BASIC programming contains statements that correspond to all twelve principles of conditional logic. The correlation between BASIC and conditional logic is presented in Table 3. The articulation of BASIC statements was developed with face validity only. They were constructed to contain a conditional logic argument. It remains an open question as to the likelihood that a student would be exposed to BASIC programming that illustrates an obscure logical argument.

Basic Programming

It has been shown that educators use a number of different approaches for teaching programming. BASIC is a programming language that has been used for intermediate and junior high grades. Logo is a highly interactive programming language that is most often used with primary and intermediate grades. Logo will be examined in a later

CORRESPONDENCE OF BASIC WITH PROPOSITIONAL LOGIC

	PRINCIPLE*	SYMBOLIC LOGIC	EXAMPLE	BASIC EXAMPLE
1)	*Detachment*	*If p, then q .* *p.* Therefore q. VALID	If the hat on the table is blue, then it belongs to Joan. The hat on the table is blue, Therefore, the hat on the table belongs to Joan.	10 PRINT "Would you like more questions?" 20 INPUT A$ 30 IF A$ = "YES" GO TO 100 : 100 PRINT "Here are more questions" p = yes q = more questions **AN IF/THEN STATEMENT WHERE CONDITION IS SATISFIED**
2)	Particular Inversion	If p, then q. not p. Therefore not q. INVALID	If Tom lives in the white house, then his last name is Smith. Tom does not live in the white house, Therefore, Tom's last name is not Smith.	10 PRINT "Would you like more questions?" 20 INPUT A$: 40 PRINT "Goodbye for Today" p = "no" answer q = end of program **AN IF/THEN STATEMENT WHERE CONDITION IS NOT SATISFIED**
3)	Particular Conversion	If p, then q q. Therefore p. INVALID	If Mary lives in the white house, then her last name is Brown. Mary's last name is Brown, Therefore, Mary lives in the white house.	10 PRINT "Which are bigger - pigs or horses?" 20 INPUT A$ 30 IF A$ = "Horses" GO TO 100 : 100 PRINT "You got that one right!" p = "horses" answer q = right answer **TO GET CONSEQUENT STATEMENT, STUDENT MUST ANTICIPATE ANTECEDENT**
4)	Particular Contraposition	If p, then q. not q. Therefore not p. VALID	If the car in the parking lot is blue, Mr. Smith's, then it is blue. The car in the parking lot is not blue, Therefore, the car in the lot is not Mr. Smith's.	10 PRINT "Which are bigger - pigs or horses?" 20 INPUT A$: 30 PRINT "Sorry, you got that one wrong!" : p = wrong answer q = responses for incorrect answer **STUDENT MUST ANTICIPATE NEGATION OF ANTECEDENT TO GET NEGATION OF CONSEQUENT**
5)	Full Transitivity	If p, then q. If q, then r. Therefore, if p, then r. VALID	If Sam misses the bus, he will walk to school. If Sam walks to school, he will cross the bridge. Therefore, if Sam misses the bus, He will cross the bridge.	10 LET A = 0 20 PRINT "How many questions would you like?" 30 INPUT N 40 PRINT "Try this one". : 70 LET A = A+1 75 NEXT I 80 IF A = N GO TO 100 : 100 PRINT "That's all for today". p = questions selected q = questions given r = end of program **THE NUMBER OF QUESTIONS SELECTED IMPLIES THE NUMBER OF QUESTIONS GIVEN. THE NUMBER OF QUESTIONS GIVEN IMPLIES THE END OF THE PROGRAM.**

TABLE 3 continued

CORRESPONDENCE OF BASIC WITH PROPOSITIONAL LOGIC

	PRINCIPLE*	SYMBOLIC LOGIC	EXAMPLE	BASIC EXAMPLE
6)	Full Contraposition	If p, then q . Therefore, if not q, then not p. VALID	If Mrs. Smith entered the flower show, Then she entered her rose. Therefore, if Mrs. Smith didn't enter her rose, Then she didn't enter the flower show.	Example for particular contraposition (above) would also apply for full contraposition. p = wrong answer q = response for incorrect answer
7)	Full Conversion	If p, then q . Therefore, if q, Then p. INVALID	If the chair is green, Then the table is black. Therefore, if the table is black, Then the chair is green.	10 FOR I = 1 to 4 20 PRINT "Would you like more questions?" 30 INPUT A$ 40 IF A$ = "NO" Go to 100 50 PRINT "Try these questions." : 90 NEXT I 100 PRINT "Goodbye for today." p = "No" Answer q = "Goodbye" response **THERE IS MORE THAN ONE CONDITION POSSIBLE TO PRODUCE THE CONSEQUENT.**
8)	Reverse Negative Detachment	p only if q. not q. Therefore not p. VALID	John is in the kitchen Only if there is food in the kitchen. There is no food in the kitchen, Therefore, John is not in the kitchen.	10 FOR I = 1 to 3 20 PRINT "Try that question again" : 50 I = I + 1 60 NEXT I 70 PRINT "I'm Sorry, you're Wrong" p = question given q = acceptable counter value **STUDENT MUST ANTICIPATE CONSEQUENCE FOR PROGRAM WHEN COUNTER EXCEEDS TOTAL ALLOWED**
9)	Forward Positive Detachment	p only if q. p. Therefore q. VALID	Harry is on the football team Only if he has his mother's permission. Harry is on the football team. Therefore, Harry has his mother's permission.	10 FOR I = 1 to 4 20 PRINT "Try this question" : 50 NEXT I 60 END p = question given q = acceptable counter value **A FOR/NEXT LOOP WILL OPERATE ONLY IF CONDITION IS SATISFIED.**
10)	Forward Negative Detachment	p, if, and only if, q. Not p. Therefore, not q. VALID	Bill will see Audrey this year, if, and only if, He goes to Montreal this year. Bill will not see Audrey this year, Therefore, Bill is not going to Montreal this year.	EXAMPLE FOR REVERSE NEGATIVE DETACHMENT (ABOVE) COULD ALSO EMBODY THIS PRINCIPLE. p = question given q = acceptable counter value **STUDENT MUST ANTICIPATE CONDITIONS UNDER WHICH THE FOR/NEXT LOOP WILL NOT OPERATE.**

TABLE 3 continued

CORRESPONDENCE OF BASIC WITH PROPOSITIONAL LOGIC

11)	Principle XI (Not Named)	p only if q. q. Therefore p. INVALID	Dick is using the classroom dictionary Only if the library is closed. The library is closed, Therefore, Dick is using the classroom dictionary.	40 PRINT "Do you want to continue?" 50 INPUT A$ 60 IF A$ = "No" Go To 100 : 100 PRINT "Goodbye" 110 END p = "No" Answer q = Goodbye **OTHER PROGRAM FEATURES COULD CAUSE EXIT FROM PROGRAM.**
12)	Principle XII (Not Named)	p only if q. Not p. Therefore not q. INVALID	Jane went to the park yesterday Only if she saw her friend Pat yesterday. Jane did not go the park yesterday, Therefore, Jane did not see her friend yesterday.	50 FOR I = 1 to A 60 PRINT "Choose answer 1, 2, 3, or 4" 70 INPUT A$ 80 IF A$ = BS GO TO 200 90 FOR C = 1 to 3 100 IF A$ > 4 GO TO 60 110 NEXT C 120 GO TO 300 : 150 PRINT "Sorry, you're incorrect" : 200 PRINT "You're Right" : 300 END p = question given q = acceptable counter value **A NESTED FOR/NEXT LOOP CAN CAUSE EXIT FROM PROGRAM**

* Principle as Described by Ennis (1965)

section.

Different authors have made observations or delivered opinions on the teaching of BASIC to students. Opinions of BASIC generally fall into two camps: some authors (Bitter, 1981; Luehrmann, 1983) like BASIC because it is easy to learn and is similar to English in its commands; other authors (Bork, 1983; Papert, 1982) feel it is restrictive and teaches poor programming habits. Luehrmann (1983) endorsed BASIC because it can be learned by young children in a few days. It is the language known by more people than any other language and it is the main language of nearly every microcomputer sold recently.

However, Luehrmann identified problems of disproportionate length and complexity when students were assigned longer programs. He recommended that students be shown the principles of structured programming early in their instruction and that they not be shown IF/THEN, or GOTO statements until they are more experienced. Luehrmann favoured BASIC over Pascal because the latter has no immediate mode and has a complex editor and operating system. He felt these impediments were too difficult for an introductory computer literacy course. In an earlier study (Luehrmann, 1981), he expressed the opinion that the purpose of computer literacy courses should be to produce literate doers of computing. Luehrmann recommended that BASIC should be used by seventh and eighth grade students (Ahl, 1981). Evans (1981) offered similar reasons for favouring BASIC over Pascal and decribed changes that would convert BASIC into a more structured language. He did not report on methods for introducing any of these changes to students.

Bork (1983) also advocated a structured approach to programming but did not accept BASIC as a suitable language. He argued that BASIC introduced poor programming habits at an early stage and these habits were difficult to correct at a later stage. Although BASIC has been argued to be easy to learn, Bell (1981) described some teaching methods that assist students in their learning. These were conducted within the context of a computer literacy course at the University of Pittsburgh. Each new BASIC keyword was introduced by analyzing a RUN and LIST of a program containing new and familiar keywords to determine their effect. The students were then assigned a program to incorporate the new keyword. Bell reported that students worked in cooperative groups and learned debugging skills.

Bell also described the personal characteristics that appeared to influence success in BASIC programming. Mathematics majors did not have any inherent advantages for programming. The following characteristics were identified through discussion and personal observation:

1) An ability to think sequentially in small steps (algorithmic thinking ability).
2) Being able to pay attention to details
3) Logical thinking ability

4) Tolerance for frustrations
5) Creativity
6) Above average intellectual ability
7) Perseverance and motivation
8) Independence
9) Organizational ability
10) Self confidence
11) Cognitive abilities of analysis, synthesis, and evaluation, including problem solving ability
12) Initiative.

Battista (1980) tested fifth and sixth grade students to determine any side-effects engendered by programming experience. He reported that students demonstrated a more positive attitude toward computers but they did not show any greater achievement on computer literacy tests. The implication was that teaching elementary school students how to program a computer did not necessarily give the students a sound knowledge of computer capabilities.

Harrison (1982) investigated whether programming experience increased students' understanding of mathematics algorithim. She conducted a quasi-experimental study with three groups to consider three issues:

1) How does programming students' mathematics achievement compare with the mathematics achievement of non-programming students?
2) Do programming students develop better computational skills than non-programming

students?

3) Do programming students develop better problem solving skills than non-programming students?

The mathematics subject content was the law of sines and it was taught by 1) exploring computer assisted instruction on this topic (experimental group) 2) exploring computer assisted instructions programs on this topic (experimental group) and 3) traditonal instruction. Harrison chose to monitor the students' homework rather than affect the teachers' presentation of this topic. She mentioned that there was no attempt to control for a possible Hawthorne effect nor did she identify this as a problem. Harrison found no significant difference in achievement between the three groups.

LOGO

Claims have been made for promoting cognitive advancement through the use of LOGO as a programming language. BASIC was developed as a simple programming language for beginners in computer programming. LOGO was developed by researchers at MIT for the purpose of providing young children with a programming tool that they could control. S. Papert has been the researcher most closely identified with the use of LOGO. He criticized BASIC for the same reasons that other researchers have praised it. BASIC is easy to learn because it has a small vocabulary. However, this small vocabulary limits expression and programs in BASIC often require a labryinthine structure. LOGO allows the child to define his own language within the context of a small number of rules (Papert, 1980). There are similar programming languages available for young children. Robot probe and TI LOGO have been described by Postman (1981), and D'Angelo (1981), respectively. Apple LOGO remains the most popular and widespread version.

Papert (1982) claimed that the use of LOGO will change a teacher's role and will encourage the individual flowering of the children under their charge. The computer helps children grasp sophisticated concepts at a much earlier age than educators now recognize. The computer is able to concretize concepts because it displays the consequences of an action that the student proposes. Williams (1982) interpreted LOGO as being based on the philosophy that children should develop a real understanding of cause and effect and thus progress to a higher level of logical relationships. She identified the most powerful aspects of LOGO as including the use of problem solving tactics and the use of debugging skills. The child has to think ahead to plan a strategy and transfer this strategy to a set of correctly sequenced commands to obtain the desired solution. Although Williams claimed that these processes would enhance logical thinking she did not use a precise definition of logical thinking (reasoning from premises).

Rousseau and Smith (1981) advocated a cautionary view toward Papert's theory. They credited Papert for building upon Piaget's theories but they felt he may have disregarded some of the corollaries of those theories. The crux of Piagetian thought is that a child learns through experience, and develops a framework for dealing with his environment in relatively predictable stages. Experiences that trigger these may occur in a haphazard manner or they may be presented in the school as part of an organized curriculum. Rousseau and Smith suggested that educators should exercise caution when selecting the kinds and sequences of experiences in order to help them develop the framework for more complex types of thinking. The authors disagreed with Papert's implication that children can deal with increasingly abstract ideas at ages earlier than Piaget postulated. Rousseau and Smith asserted the chronological age is linked to the ability to perform specific mental operations. They also stated that children would not handle failure well when confronted with tasks beyond their ability. Papert had said the children would experience a thrill in their own "debugging" processes. Rousseau and Smith further criticized Papert for vague claims about a changing role for teachers and for ignoring parallel research on covert mental operations.

Hill and Barnes (1983) raised similar cautions but they commented on the use of microcomputers by young children, rather than referring directly to Papert. They are inflexible in their thinking. LOGO provides an opportunity to experiment but the child must learn a precise set of instructions before such experimentation can take place. Hill and Barnes posed some general questions including: 1) to what extent are young children capable of the linear sequential thinking required by programming? and 2) does the precision with which one must use a microcomputer help children become reflective and analytical? The authors did not provide answers to these questions but they did recommend that children should be provided with concrete experience before using LOGO. Some answers have been advanced for the preceding questions and they will be examined at the end of this discussion.

Burns (1983) noted that children use rote techniques for programming without understanding what they are doing. Children tend to accept programming techniques for their functions without examining how the techniques fit into the logic of the language. This enables them to use certain programming techniques more easily than adults but ultimately prevents them from understanding the language. Burns found that his students were not progressing as quickly as Papert had suggested. Burns changed his teaching approach from allowing the students to experiment to his lecturing the class at appropriate times. He hesitated in showing students techniques that they did not request. He observed that children still focused on what they wanted the computer to do rather than on why it operated that way.

Burns concluded that he had provided his students with a conceptual framework that would be useful when the children were developmentally ready.

Miller (1983) described greater teacher intervention for the teaching of LOGO than had Burns. Miller attributed his approach to the need for a structured LOGO environment. He maintained that the LOGO environment can accommodate:

1) direct teaching about LOGO programming.
2) structured activities that provide students with models.
3) printed materials distributed by the teacher.

Direct teaching is necessary because teachers cannot assume "modular" thinking is an automatic part of every student's problem-solving repertoire.

Researchers cited so far have reported observations and made claims about students' learning of LOGO. Seidman (1981) performed an experiment studying the effect of learning LOGO on students' learning of logic. Seidman's study provided answers, to some extent, on the questions raised earlier by Hill and Barnes. He worked with fifth-grade students from a Syracuse public school. There was no significant difference in logical reasoning between the experimental and control groups when given a test involving main principles of logic. However, there was a significant difference in achievement for the experimental group when test items for the inversion fallacy principle were examined. It was interesting to note that the control significant difference in achievement for the experimental group when test items for the inversion fallacy principle were examined. It was interesting to note that the control group of the study showed a significant improvement in reading. Seidman used the principles of logic described by Ennis (1965). The inversion fallacy principle is "The denial of the antecedent (p) does not by itself imply the denial of the consequent (q)". He did not offer any mechanisms or explanations by which LOGO instructions would improve mastery of the inversion fallacy principle. With reqard to the differences in reading ability, Seidman suggested that this may have been a consequence of removing the experimantal group from the regular classroom for 30 hours. Seidman concluded with the broad statement that computer programming exposure could have unintended side effects in the achievements for the cognitive and affective domains.

CHAPTER IV

METHOD

Statement of Problem

The review of literature demonstrated that propositional reasoning is a necessary ability for learning many scientific concepts and is also associated with the acquisition of formal operational thinking. Research has indicated no reliable method for encouraging the transition to formal thought or increasing the mastery of propositional logic. Computer literacy has been identified as a recent area of concern to educators. Most computer literacy courses include programming with BASIC language which was described as logical and easy to learn. BASIC statements were shown to have a correspondence with principles of conditional logic. It was suggested that the teaching of BASIC provided an avenue for increasing the conditional reasoning ability of students.

Two hypotheses were tested:

1) Students taught BASIC programming techniques will demonstrate an increased ability in conditional reasoning.
2) Students' conditioning reasoning abilities will be further enhanced if the BASIC programming experience is supplemented by teacher explanation.

Definition of Terms

Class - the instructional grouping of the subjects in their school.

Computer Literacy Instruction - the study of computers excluding practice or discussion of BASIC or any programming languages.

Computer Programming - writing of algorithms, examination and execution of BASIC programming on a microcomputer.

Conditional Reasoning - the type of propositional or sentence logic that used "if", "only if", and "if and only if" as the connective between the parts of as argument. Conditional logic was used as a synonomous term in this study.

Teacher Explanation - didactic instruction in BASIC programming.

Experimental Treatment Groups

Classes and treatments administered are presented in Table 4. A detailed schedule of student activities appears in Appendix A.

Class 1, Treatment 1 - subjects received didactic instruction in computer literacy topics excluding BASIC programming. Topics were: 1) effects of computers in society, 2) nature of a computer, 3) types of computers, 4) parts of computers and 5) [illegible]

Class 2, Treatment 1 - subjects received equivalent

TABLE 4

SUMMARY OF STUDENT GROUPS

	Treatment 1 (Control)	Treatment 2 (Experimental)
Class 1	Research work on computer literacy topics excluding BASIC programming.	Practice in BASIC programming.
Class 2	Research work on computer literacy topics excluding BASIC programming.	Practice in BASIC programming and didactic instruction.

instruction to Class 1, Treatment 1.

Class 1, Treatment 2 - subjects received keyboard experience with BASIC programming with no didactic instruction. Classroom management limited to only settling the class, managing equipment, and giving assignments.

Class 2, Treatment 2 - programming experience supplemented by teacher explanation. The teacher gave a detailed introduction to each assignment, explained the logic of BASIC statements through discussion and flowchart techniques, and discussed programming results with the group.

Description of Sample

Subjects were students in a rural grade school with a population of approximately 500 students from a middle to upper-middle socioeconomic background. The school is organized around a house system with no streaming of students for ability.

The subjects comprised the two grade eight science classes taught by the researcher. Class One consisted of 26 students and Class Two consisted of 29 students. There was no mortality or introduction of new subjects during the students' experimental period. A random number table was used to divide each class into Treatment 1 and Treatment 2 groups.

Procedure

The classes were informed of the broad objectives of the instructional unit but not of the experimental study.

The pretext for dividing the class was that only five computers were available. While the experimental design required two treatment groups, the researcher felt that the subjects should perceive a fair assignment of activities.

The Treatment 1 groups worked on computer literacy activities (excluding BASIC programming) during the experimental period. The activities were judged by the researcher to provide the same level of interest and motivation as did programming experience. The Class 1 Treatment 2 groups worked on microcomputers in groups of three for an average period of 30 minutes every day. The Class 2, Treatment 2 group received teacher explanation of BASIC logic and procedures in addition to the regular BASIC programming activities. The subjects were told that the groups would exchange activities after one month. The activities are identified in Appendix A. A post-test was administered to all groups after a period of one month.

The experimental design categorized according to Campbell and Stanley (1966) is a Design Six. It is a random assignment, control/treatment group with post-test only.

Sources of Error

The two eighth grade science classes of one house in the test school were used as sample groups. They represented found groups and the subjects were the regular academic students of the researcher. The assumption was made regarding the equivalence of the two instructional classes. This assuption was supported by the equivalent scores on the CRT shown by the two control groups. All subjects generally received the same courses and instructors. Several limitations to the study can be identified:

1) The subjects were selected from found classes which limits the generalizability of results for the general population.

2) The activities of the Computer Literacy groups (Treatment 1) were severely curtailed because there were no microcomputers available for them. This may have created a perception of unfair treatment for them.

3) The Programming groups (Treatment 2) had to work with pocket computers instead of full-screen microcomputers during the second and third weeks. Each student had a computer, effectively increasing programming time, but the effect of size difference was not known.

4) The Programming groups (Treatment 2) may have been influenced by the Hawthorne Effect, causing them to perform better.

5) The researcher had to allocate instructional time from the regular science program in order to use full-class groups. This placed a restriction on the length of the experimental period.

6) Treatment groups worked in adjacent science labs to separate their activities. The researcher attempted to give equal time to both groups but that was not always possible.

7) A ninth grade student proctor was enlisted to help

subjects with their programming. He was instructed to assist and answer direct questions, but not to teach. The effect of his role to this study is not known.

Cornell Conditional-reasoning Test

The measuring instrument for this study was the Cornell Conditional Reasoning Test. The Cornell Test is a 72 item multiple choice test with six additional sample questions. The test was developed by Ennis et al (1965) for use as a posttest in one study of the Critical Thinking Readiness Project. It was selected for this study because it is a direct test for the use of propositional logic. Other measuring instruments considered for this study (Canadian Cognitive Abilities Test, Lorge-Thorndike Intelligence Test, and Watson-Glaser Critical Thinking Appraisal) measured propositional logic abilities only in association with other mental abilities that were beyond the scope of this study.

The main advantage of the Cornell Test was that it focuses only on the principles of conditional reasoning. Twelve principles of conditioned logic are measured in the test and it was possible to perform an item analysis of student performance. Another advantage of the Cornell Test was its multiple choice format which allowed easy administration and scoring of the test.

Ennis (1965) reported a test-retest reliabilty estimate of .75 for all grades. Individual grade reliability estimates were given as .76, .65, .78, and .80

for grades 5, 7, 9, and 11 respectively. A split-half correlation was not given because it was not possible to split the test into equivalent halves.

The test was constructed to permit an item-by-item analysis for the twelve propositional logic principles. There were six test items for each of the twelve principles in the 72 items to be completed by the subject. Questions testing each principle appeared in three different content forms. Four of the six items for each prinicple were concrete familiar, meaning that they dealt with articles and qualities that the subjects had experienced. One item was in symbolic form where the propositional argument was developed with symbols such as "x" and "y". The last form, tested one item for each principle, was suggestive where the content was familiar, but the truth status of the argument was not known by the subject. This test construction allowed for a probing analysis of results beyond the main hypotheses.

The Cornell Conditioning Reasoning Test was administered to both classes on the last day of the experimental period. Although it was administered during a 45-minute instructional period, students were allowed extra time to complete the test. All subjects were present and received the test during that testing period.

Statistical Procedure

A two-factor, fixed effects model analysis of variance was employed in this study. Factor I was assignment to class; Factor II treatment given. Random assignment within the classes allowed the assumptions to be made that the two treatment groups within the class were equivalent. The validity of the assumption that the two classes were equivalent depended on the absence of a significant difference in achievement between Treatment 1 groups of the two classes.

The Student-Newman-Kuels multiple comparison test was used to compare the group means. This test was a slight modification of the Newman-Kuels test and it adjusted the pair-wise error rate to keep the error rate equal to p=.05. A subject was randomly dropped from the class 2 treatment 1 group to allow comparison of means between groups. The Student-Newman-Kuels test permitted this comparison between groups if the group sizes were equal or proportional in their differences.

Null Hypothesis

Two null hypotheses were tested in this study:

NULL HYPOTHESIS 1 (Ho)

$$H_0: \mu_{1_T} = \mu_{2_T}$$

NULL HYPOTHESIS 2 (Ho)

$$H_0: (\mu_{11} - \mu_{12}) = (\mu_{21} - \mu_{22})$$

where: U = Expected mean score of the posttest of all subjects

Item Analysis

The Cornell Conditional Reasoning Test contained items testing all of the principles of conditional logic so an item-by-item analysis was conducted to show trends between groups. In a statistical analysis involving comparisons between comparisons the level of uncertainty would rise too high to allow any meaningful results. Therefore, a descriptive analysis showing differences in scores between groups was employed. This procedure had purposes beyond testing the main hypotheses. It indicated the mastery of which logical principle was enhanced through BASIC programming.

CHAPTER V

RESULTS

The results of the ANOVA are presented in Table 5. As well, a descriptive analysis for subjects' mastery of individual principles of propositional logic will be discussed in this chapter.

Analysis of Variance for Treatment

The mean scores for treatment by class are presented in Table 6.

For Class 1, Treatment 1, the mean score on the Cornell Conditional-reasoning test (CRT) was 30.23, compared to a mean score of 38.92 for Class 1, Treatment 2; significant at the $p<.005$ level.

For Class 2, Treatment 1, the mean score on the CRT was 31.73, compared to a mean score of 37.43 for Class 2, Treatment 2. A difference of 8.69, significant at $p< 0.06$, was measured which did not meet the significance level of this study.

The scores of Treatment 1 groups and the scores of Treatment 2 groups were pooled and the results appear in Table 8. The difference between the mean scores of the two groups is significant at the $p<.001$ level allowing rejection of Null Hypothesis 1. On the basis of these results it was concluded that the teaching of BASIC programming enhances conditional reasoning ability as measured by the Cornell Conditional-reasoning Test.

TABLE 5

ANALYSIS OF VARIANCE FOR POSTTEST

DEPENDENT VARIABLE: SCORE (CORNELL CONDITIONAL REASONING TEST)

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR > F	R^2	COEFFICIENT OF VARIATION	ROOT MSE (MEAN SQUARE ERROR)	SCORE MEAN
MODEL	3	725.46	241.82	4.12	.0109	0.198	22.18	7.66	34.55
ERROR	50	2935.87	58.72						
CORRECTED TOTAL	53	3661.33							

SOURCE	D.F.	ANOVA SS	F VALUE	PR > F
TREATMENT	1	696.96	11.87	.0012
CLASS	1	0.023	0.00	0.98
TREATMENT X CLASS	1	28.47	0.48	0.49

TABLE 6

SUMMARY TABLES FOR MEAN SCORES
By Treatment

(Individual Classes)

CLASS = 1

Treatment	N	Mean	Standard Dev.	Standard Error
1	13	30.23	7.67	2.13
2	13	38.92	6.60	1.83

Variances	T	DF	Prob > |T|
Unequal	-3.0966	23.5	0.0050
Equal	-3.0966	24.0	0.0049

For H_0: Variances are equal, F' = 1.35 with 12 and 12 DF
Prob. > F' = 0.6107

CLASS = 2

Treatment	N	Mean	Standard Dev.	Standard Error
1	15	31.73	8.96	2.31
1	14	37.43	6.70	1.79

Variances	T	DF	Prob > |T|
Unequal	-1.95	25.8	0.06
Equal	-1.93	27.0	0.06

For H_0: Variances are equal, F' = 1.79 with 14 and 13 DF
Prob. > F' = 0.3020

Analysis of Variance for Class

The mean scores by treatment are presented in Table 7.

The mean score on the CRT for Class 1, Treatment 1 was 30.23, compared to a mean score of 31.73 for Class 2, Treatment 1. A difference of 1.50, significant at $p<0.64$, did not meet the significance leved of this study.

Class 1, Treatment 2 had a mean score of 38.92 for the CRT, compared to a mean score of 37.43 for Class 2, Treatment 2. The difference of 1.49, significant at $p<0.56$, did not meet the significance level of this study. Null Hypothesis 2 was not rejected and, on the basis of this result, it was concluded that teacher didactic instruction in BASIC programming does not enhance students' mastery of conditional logic.

Evaluation of Null Hypotheses

The analyses of variance for treatment and for calss can now be summarized.

Null Hypothesis 1:

$$H_0 : \mu_{1_T} = \mu_{2_T}$$

-rejected at the $p>.001$ levels of significance.

Null Hypothesis 2:

$$H_0 : (\mu_{11} - \mu_{12}) = (\mu_{21} - \mu_{22})$$

-not rejected at the $p>.05$ levels of significance. Therefore, on the basis of this result, the alternate

TABLE 7

SUMMARY TABLES FOR MEAN SCORES BY CLASS (Individual Classes)

(Individual Classes)

TREATMENT = 1 (Control Groups)

Class	N	Mean	Standard Dev.	Standard Error
1	13	30.23	7.67	2.13
2	15	31.73	8.96	2.31

Variances	T	DF	Prob > |T|
Unequal	-0.4779	26.0	0.6367
Equal	-0.4725	26.0	0.6405

For H_0: Variances are equal, F' = 1.37 with 14 and 12 DF
Prob. > F' = 0.5953

TREATMENT = 2 (Experimental)

Class	N	Mean	Standard Dev.	Standard Error
1	13	38.92	6.60	1.83
2	14	37.43	6.70	1.79

Variances	T	DF	Prob > |T|
Unequal	0.5836	24.9	0.5647
Equal	0.5833	25.0	0.5649

For H_0: Variances are equal, F' = 1.03 with 13 and 12 DF
Prob. > F' = 0.9654

TABLE 8

MULTIPLE COMPARISONS OF FOUR MEANS
(Combined Classes)

VARIABLE: TREATMENT

Grouping	Mean	N	Group
A (Experimental) Class 1 & 2	38.148	27	2
B (Control) Class 1 & 2	30.963	27*	1

VARIABLE: CLASS

Grouping	Mean	N	Group
A (Class 1, Exp & Cont)	34.577	26	1
B (Class 2, Exp & Cont)	34.536	28*	2

* One subject was randomly dropped from Class 2, Treatment 1 to permit comparison between groups.

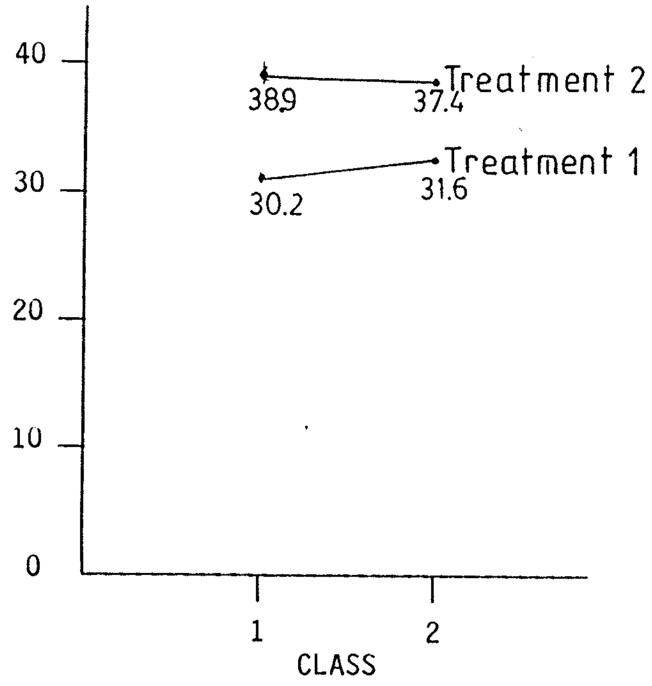
MULTIPLE COMPARISONS OF FOUR MEANS

Class	Treatment	N	Score
1	1	13	30.23
1	2	13	38.92
2	1	14*	31.64
2	2	14	37.42

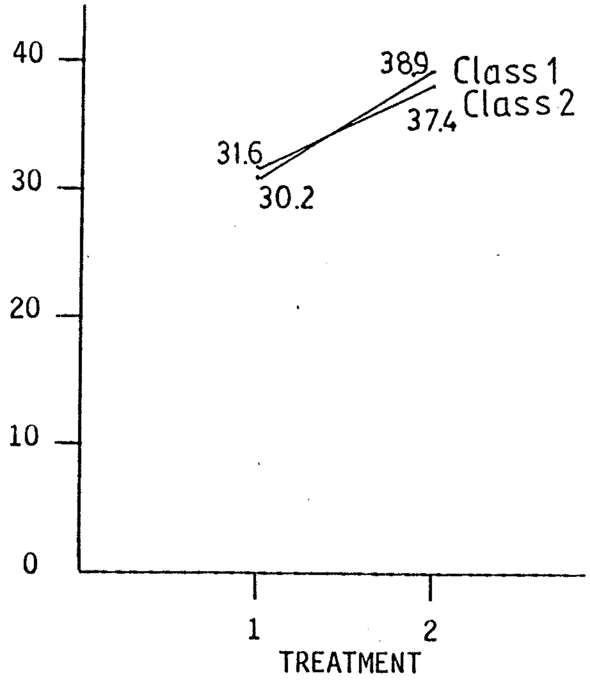
FIGURE 2

SUMMARY GRAPHS FOR MEAN SCORES

GROUP MEAN SCORES FOR TREATMENT



GROUP MEAN SCORES FOR CLASS



hypothesis that teacher didactic instruction in BASIC programming does not enhance conditional reasoning ability was accepted.

Item Analysis of the Conditional Reasoning Test

The Cornell Test of Conditional Reasoning tested twelve principles of conditional logic as described by Ennis (1965). Items for each of these principles were distributed evenly throughout the test and they were phrased in three formats: concrete familiar, symbolic, and suggestive. Group performance on each item was analyzed to determine group achievement for each logical principle. The group performance for each principle is presented in Table 9. A statistical treatment was not used because the number of comparisons necessitated a very high level of uncertainty. Instead, a descriptive analysis was performed by examining student totals for each performance. The totals for both experimental groups (Treatment 2) were compared against the totals for both control groups (Treatment 1). These scores were presented in Table 10.

The combined scores for the experimental groups were markedly higher in concrete familiar items for the logical principles of detachment, reverse negative detachment, forward positive detachment, a combination of detachment and full transitivity principles, and particular full contrapositions. There was a marked difference in group scores for symbolic and suggestive items for particular contraposition, full contraposition, reverse negative detachment, forward negative detachment and full transitivity. It was not observed for detachment and forward positive detachment. Since it was assumed that mastery of a logical principle would not decrease for the experimental groups, the differences between groups for the principle of particular inversion, and particular and full conversion were judged to be anomolous. It was judged that there was no marked difference between groups for the principles of full transitivity, and a combination of detachment and forward negative detachment.

TABLE 10

NONSTATISTICAL COMPARISON OF COMBINED EXPERIMENTAL GROUPS AND CONTROL GROUPS FOR MASTERY OF LOGICAL PRINCIPLES

EXPERIMENTAL GROUPS MARKEDLY HIGHER THAN CONTROL GROUPS

TOTAL SCORE	PRINCIPLE	ITEM FORMAT
98 Exp/80 Cont.	Detachment	Concrete Familiar
89 Exp/78 Cont.	Forward Positive Detachment	Concrete Familiar
78 Exp/68 Cont.	Particular Contraposition	Conc. Familiar, Symbolic, Suggestive
73 Exp/58 Cont.	Full Contraposition	Conc. Familiar, Symbolic Suggestive
93 Exp/79 Cont.	Reverse Negative Detachment	Conc. Familiar, Symbolic, Suggestive
75 Exp/49 Cont.	Forward Negative Detachment	Conc. Familiar, Symbolic, Suggestive
67 Exp/49 Cont.	Detachment and Full Transitivity	Conc. Familiar, Symbolic, Suggestive

CONTROL GROUPS MARKEDLY HIGHER THAN EXPER. GROUPS (ANOMALOUS)

TOTAL SCORE	PRINCIPLE	ITEM FORMAT
24 Cont,/9 Exp.	Particular Inversion	Conc. Familiar, Symbolic
15 Cont./10 Exp.	Particular Inversion	Conc. Familiar
17 Cont./11 Exp.	Full Conversion	Conc. Familiar

NO MARKED DIFFERENCE BETWEEN EXPERIMENTAL AND CONTROL GROUPS

TOTAL SCORE	PRINCIPLE	ITEM FORMAT
74 Exp/65 Cont.	Full Transitivity	Conc. Familiar, Suggestive Suggestive
13 Exp/10 Cont.	Detachment, Forward Positive Detachment	Conc. Familiar, Suggestive

CHAPTER VI

DISCUSSION AND CONCLUSIONS

Main Findings of the Study

The main findings of the study can now be reviewed and discussed in light of earlier research. Limitations of the study and suggestions for further research will be identified. The main hypotheses of the study can be stated in these descriptive terms:

HYPOTHESIS 1- Students exposed to BASIC programming instruction will experience an increase in conditional reasoning ability.

HYPOTHESIS 2- This increase in conditional ability will be further enhanced if the instructor undertakes a directed effort to explain the logic of BASIC programming techniques.

The Effect of BASIC Programming

Since a significant difference was observed between the experimental groups and control groups on a test of conditional reasoning, the Null Hypothesis 1 was rejected at the .001 level of significance. An alternate hypothesis could be proposed and accepted: there will be a significant difference in achievement on a test of conditional reasoning between students performing BASIC programming activities on a microcomputer and students performing other computer literacy activities.

There was no literature available on the cognitive requirements for BASIC programming but an argument was developed that BASIC embodied the principles of conditional logic. It was suggested that since BASIC required a rigorous use of the programming language, students would be compelled to examine their program logic closely. Researchers were not in agreement as to whether propositional logic was a mastery requirement for formal operational thought or just associated with that cognitive stage. Although previous research indicated that formal operational thought could not be imparted through direct instruction, educational activities that provided for equilibration of cognitive dissonance could promote the transition to formal operational thought. The rejection of Null hypothesis 1 provided evidence that BASIC programming could enhance conditional reasoning and perhaps assist the transition to formal thought.

The Effect of Teacher Explanation

There was no significant difference observed between Treatment 2 groups of both classes. This meant that Null Hypothesis 2 was accepted. Two groups were being compared within the framework of that hypothesis. The fact that the two Treatment 1 groups from the two classes showed no significant gain in achievement would have provided evidence that the two larger classes were equivalent. This evidence would have been necessary if it was to be argued that the two experimental groups showed a significant difference due to treatment. However, the difference in achievement between the two experimental groups was not measured to be significant, suggesting that teacher instruction in BASIC programming produced no effect.

Literature reviewed on teacher instruction for computer programming produced mostly subjective reports on pedagogical technique. A pertinent research experiment by Seidman (1981) dealt with the teaching of LOGO to fifth graders and its effects on their logical reasoning. However, the main focus of this study was more on the logical gains made by the subjects rather that the efficacy of the teacher instruction. An underlying assumption for this study was that teacher explanation could provide verbalization for operations that students were performing intuitively. The results of this study provided evidence contradicting this assumption. Precedents for this result were found in studies by Lawson et al (1978) and Ennis (1965) which demonstrated that logical principles could not be taught directly.

Limitations of the Study

The experimental design of this study, design six as described by Campbell and Stanley (1965), was regarded as a useful design for reducing sources of alternate hypothesis. Nevertheless, this study still had design flaws which require examination.

The selection of subjects in found groups has already been discussed and it was recognized that this selection limited the generalizability of the results. A greater concern was the fact that the researcher was the instructor of all the subjects in the study. This situation could have produced the "Pygmalion" effect whose influence cannot be evaluated in this study. A more concrete consequence of the researcher's dual role of experimenter and teacher was the number of procedural annoyances found in most classroom settings. Classes were short, attendance had to be taken, discipline had to be maintained and the researcher/teacher was responsible for management of the instructional classes at all times. This researcher felt that these distractionsinterfered with an ideal administration of the experiment.

No research was available to recommend the most effective technique for teaching programming or computer literacy topics. Various researchers had offered observations but none of those suggestions had been validated. The situation may have existed that teacher explanation of BASIC techniques did enhance logical development but not with the techniques employed by this researcher. The instructional activities for BASIC programming and for computer literacy topics had only face validity. No validation research was available and no validation procedure for the researcher's choice were undertaken. Unanticipated problems with providing adequate numbers of microcomputers were a continual problem during the experimental period. It would have been desirable to reduce the subject numbers on the computer for the experimental group and to provide microcomputers for the control groups, thereby reducing their perception of inequity.

All of these problems contributed to the most pervasive missgivings of the researcher. Although a significant result was obtained for null hypothesis 1, the results may be attributable to a Hawthorne Effect. Every effort was made to provide a balanced treatment of activities and teacher attention for the experimental and control groups. It was still the situation, however, that the researcher observed dissatisfaction amongst subjects in the control group of Class 2. This may have resulted in those subjects not making an honest effort on the post-test, producing artificially low scores for the control groups. Such concerns should be noted by any researcher attempting a similar study.

Suggested Results of the Study

A general increase in conditional reasoning ability for treatment 2 students was demonstrated through the rejection of null hypothesis 1. However, it was also possible to identify suggested improvement for specific conditional logic principles through an item-by-item analysis of treatment group scores. These results were presented in Table 9. Previous researchers had described student mastery of logical principles either through direct measurement or as results from attempts to increase student mastery of those principles. Suggested results from this study were compared to results from previous research.

Students from treatment 2 performed markedly better than students from treatment 1 on most item groups testing logical principles concerning detachment in the Cornell Conditional Reasoning Test. The principle of detachment was the simplest proposition of conditional logic, being phrased as "If p, then q. Given p, ...then q." Students from treatment 2 performed markedly better with the detachment principle as well as its variations of forward positive detachment, forward negative detachment, and reverse negative detachment. Previous research reported a greater increase in mastery for students in the mid-adolescent years than for any other age group (see Tables 1 and 2). The evidence from this study suggests that students' mastery of the various detachment principles was further enhanced.

It was interesting to note that Treatment 2 subjects scored markedly lower than Treatment 1 subjects on items that tested invalid principles. Ennis (1965) reported that mastery of invalid principles such as particular inversion and full and particular conversion were the last to be acquired by adolescent students. BASIC programming did not commonly have situations that embodied invalid principles since it functions with truth-conditions and relations. If BASIC did not provide examples of invalid logical principles, it was expected that Treatment 2 students would perform only as well as Treatment 1 students. The results obtained in this study were anomalous for achievement on invalid principles. The only instance found in previous research where subjects decreased in mastery of logical principles was in the study by Ennis (1965). He observed that grade nine students in his Critical Thinking Readiness study performed less well than students in a control group. Ennis' explanation was that his instruction in conditional reasoning had not yet taken hold, only enough to be confusing to students. Their incomplete mastery may have interfered with their "intuitive feel" of the questions. No explanation for lower scores of Treatment 2 group was advanced and the results were regarded as anomolous.

There was no marked difference between Treatment 1 and Treatment 2 groups for the principles of full transitivity and a combination of detachment and forward positive detachment. All of these interpretations were a post-hoc examination of subject scores and did not receive a statistical treatment. The differences in some principles were marked enough, however, to suggest that BASIC programming enhances the mastery of some specific conditional reasoning principles.

Implications of the Study

The observed results of the study indicate that BASIC programming does, in fact, enhance students' conditional reasoning. Students receiving instruction in computer programming or computer literacy may accelerate their rate of mastery of what was thought to be a developmental process. Sometimes the teaching of BASIC programming is recommended in computer literacy curricula, sometimes it is not. This study demonstrates a tangible benefit with the inclusion of BASIC while justifications for other aspects of computer literacy (preparation for a changing society, familiarity with new technology) represent only anticipated outcomes. This writer recommends the inclusion of programming experience in computer literacy curricula at the junior high level. Another conclusion drawn from the results of this study is that conditional reasoning enhancement occurs without the intervention of the instructor. This raises questions concerning the appropriate role for the teacher of computer literacy. Since the increase in reasoning ability is a consequence of programming experience, students should be given as much time programming as possible. The teacher should act as facilitator helping students with specific problems in programming. If the student is ready to internalize the conditional logic of BASIC, he will apply his own unique strategies. Lecturing on BASIC logic by the teacher will not aid the process.

BASIC is not the only programming language being offered in the context of computer literacy curricula. LOGO is receiving much attention recently, particularly for elementary students. Pascal is being suggested as a replacement for BASIC because it uses structured programming. Seidman (1981) was not able to demonstrate an improvement in general conditional reasoning through experience in LOGO for fifth graders. It may have been with these younger children were not developmentally ready for conditional reasoning. LOGO does have more advanced programming procedures that go beyond screen graphics. However, this writer feels that LOGO statements are not as analogous to conditional logic statements as is BASIC. No research was noted that described the effects of using PASCAL language with students but this writer feels that it is too abstract for young adolescents. BASIC has been criticized for its unstructured statements but its accessibility for adolescents and the increase in logical reasoning it produces are good arguements for retaining it as an introductory programming language.

Speculations can be made to other consequences of learning BASIC. It was not certain whether conditional reasoning was a prerequisite for formal operational thought or merely associated with it. Formal operational thought is a prerequisite for most secondary level science courses. There was no research available to answer whether conditional reasoning was related to overall achievement in school. This writer believes that conditional reasoning advances caused by BASIC will produce an increase in general logical reasoning. Students receiving BASIC instruction may exhibit improvement achievement in science and math courses, and those topics that require critical thinking.

The question whether educators want students with greater reasoning skills deserves passing consideration. This writer believes that an increase in logical thinking ability is a desirable outcome and it will not require any dislocation or accomodation within the present educational system. A school which gives its students a course in ethics and responsibility would probably need to review a repressive policy on student attendance. This writer does not envisage any similar adjustments being required to accommodate more logical students. Science courses may presently be operating beyond the cognitive level of secondary students - an increase in reasoning ability will benefit these students. A widespread delivery of computer literacy courses that include BASIC programming should improve the reasoning ability and achievement of future student populations.

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APPENDIX A

EXPERIMENTATION SCHEDULE, MAY 1982

Day of School Cycle	CLASS 1		CLASS 2	
	TREATMENT 1 (CONTROL)	TREATMENT 2 (EXPERIMENTAL)	TREATMENT 1 (CONTROL)	TREATMENT 2 (EXPERIMENTAL)
4	———	———	Read article, define parts of computer	Parts of computer, how to turn on
5	Read article, define parts of computer	Parts of computer, how to turn on	History of computer	Entering information
6	History of the computer I	Entering information. Assigning line number	History of computer	Assigning line numbers
1	History of the computer II	Program for asking your name [INPUT]	History of computer	Program for asking your name
2	Assignment: 4 generations of computers	Program for asking your name [INPUT]	History of computer	Program for asking your name
3	———	———	Assignment: 4 generations of computers	Program for asking your name
4	———	———	Newspaper assignment. How computers affect society	Program for asking your name
5	Newspaper assignment: How computers affect society	Program for telling a joke [BRANCHED PROGRAM]	Newspaper assignment	Program for telling a joke
6	Newspaper Assignment	Program for telling a joke [BRANCHED PROGRAM]	Newspaper assignment	Program for telling a joke
1	Information - in & out; Storage devices; Memory	Program for multiple-choice test [INPUTS, BRANCHED RANDOMIZER]	Information - in and out	Program for telling a joke

Day of School Cycle	CLASS 1		CLASS 2	
	TREATMENT 1 (CONTROL)	TREATMENT 2 (EXPERIMENTAL)	TREATMENT 1 (CONTROL)	TREATMENT 2 (EXPERIMENTAL)
2	Differences Between Analog and Digital	Program for multiple-choice test [INPUTS,]	Storage Devices Memory	Program for multiple-choice test
3	______	______	Differences Between Analog and Digital	Program for multiple-choice test
4	______	______	Differences Between Analog and Digital	Program for multiple-choice name
5	Project: Different type of Memory,	Program for math test [COMPUTATIONS, RANDOMIZER]	Project: different memories	Program for math test
6	Comparing Micro computers: A) APPLE	Program for math test [COMPUTATIONS, RANDOMIZER]	BASIC Language	Program for math test
1	B) PET	Developing their own program	Comparing Micro-computers	Program for math test
2	C) RADIO-SHACK	Developing their own program	PET Computers	Developing their own program
3	______	______	Radio-Shack	Developing their own program
4	______	______	Radio-Shack	Developing their own program
5	CORNELL TEST	CORNELL TEST	CORNELL TEST	CORNELL TEST

APPENDIX B

SUMMARY OF RAW DATA

CLASS 1	TREATMENT 1 (CONTROL)		TREATMENT 2 (EXPERIMENTAL)	
	SUBJECT	SCORE	SUBJECT	SCORE
	1	29	14	37
	2	19	15	37
	3	19	16	37
	4	34	17	46
	5	35	18	48
	6	39	19	44
	7	38	20	40
	8	36	21	32
	9	34	22	40
	10	25	23	27
	11	34	24	29
	12	17	25	45
	13	34	26	44
	N=13		N=13	

CLASS 2	TREATMENT 1 (CONTROL)		TREATMENT 2 (EXPERIMENTAL)	
	SUBJECT	SCORE	SUBJECT	SCORE
	27	33	42	34
	28	21	43	21
	29	35	44	40
	30	25	45	37
	(31)*	33	46	43
	32	54	47	31
	33	43	48	45
	34	25	49	36
	35	28	50	37
	36	27	51	45
	37	35	52	46
	38	28	53	32
	39	18	54	38
	40	34	55	39
	41	37		

* randomly dropped for statistical comparison.

APPENDIX C

Cornell Critical Thinking Test Series

THE CORNELL CONDITIONAL-REASONING TEST, FORM X

by

Robert H. Ennis
William L. Gardiner
John Guzzetta
Richard Morrow
Dieter Paulus
Lucille Ringel

Fill in the blanks when you are asked to do so:

Print your last name only ______________________

Print your first and middle names ______________________

Your age on your last birthday ______________________ years

Your date of birth: month______ day_____ year_____

Your grade ______________________

Your school ______________________

Your regular teacher at this time ______________________

Today's date: month_______ day_______ year_______

Do not write in this space:

General directions:

This is a test to see how well you do a particular kind of thinking. We call it "conditional reasoning". You will see that you already do some of this kind of thinking. The sample questions make clear what is expected.

DO NOT GUESS WILDLY There is a scoring penalty for guessing wrong. If you think you have the answer, but are not sure mark that answer. But if you have no idea, then skip the question.

There are 6 sample questions, then 72 others. You should work as quickly as you can, but do not rush. This is not a speed test. Once you do the samples, you will be able to move right along.

DO NOT TURN THE PAGE UNTIL YOUR EXAMINER TELLS YOU TO DO SO.

ⓒ 1964 by R. H. Ennis

Published by Cornell Critical Thinking Project, Stone Hall, Ithaca, N. Y.

Answering the questions:

In answering each question, use only what you are told in that question. In order to do this, you should imagine that your mind is blank, because some of the things you are told are obviously false. Even so, you should suppose that they are true--for that question only.

You will be given one or more sentences with which to think. You will then be given another sentence, about which you must decide, using only what you were told.

There are three possible answers. This is what they mean:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

The meaning of the possible answers is given at the top of each page to help you remember. Each question has only one correct answer.

Mark your answers on this booklet by drawing a circle around the right answer. Remember: If you have no idea what the answer is, skip the question and go on to the next. Do not guess wildly, but if you think you know, then answer the question.

Sample questions:

Read the first question and see how it is marked.

1. Suppose you know that

Bill is next to Sam.

Then would this be true?

Sam is next to Bill.

1. A. [✓ YES]
B. NO
C. MAYBE

The correct answer is A, "YES". If Bill is next to Sam, then Sam must be next to Bill. It must be true, so a circle is drawn around "YES".

Here is another sample. This time you circle the answer.

2. Suppose you know that

The sparrow is over the hawk.

Then would this be true?

The hawk is over the sparrow.

2. A. YES
B. NO
C. MAYBE

You should have circled B, "NO". If the sparrow is over the hawk, then the hawk can't be over the sparrow. It can't be true.

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

Circle the answer to this next sample. Be careful:

---

3. Suppose you know that

Jane is standing near Betsy.

Then would this be true?

Betsy is standing near Jane.

3. A. YES
B. NO
C. MAYBE

The correct answer is C, "MAYBE". Even if Jane is standing near Betsy, Betsy be sitting. Betsy might be standing near Jane, but she might be <u>sitting</u> near Jane, or something else. You were not told enough to be <u>certain</u> about it, so "MAYBE" is the answer.

Circle the answer to this next sample question. Remember that your mind is supposed to be blank at the beginning of each question.

---

4. Suppose you know that

California is near New York.

Then would this be true?

New York is near California.

4. A. YES
B. NO
C. MAYBE

The correct answer is A, "YES", even though New York and California are not really near to each other. If California <u>were</u> near to New York, then New York <u>would be</u> near to California. It would have to be true.

Remember. You should suppose that what you are told is true for the question you are answering.

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

So far in the sample questions you were told only one thing. In this one you are told two things. Circle your answer.

5. Suppose you know that

The pit is inside the mouth of the fox.
The cherry is inside the mouth of the fox.

Then would this be true?

The pit is inside the cherry.

5. A. YES
B. NO
C. MAYBE

The correct answer is C, "MAYBE". All you are told is that the pit and the cherry are both in the mouth of the fox. There is no way to be certain whether the pit is in the cherry or not.

Here is the last sample question. This time the letters "X" and "Y" are used. They can stand for anything you like. Circle your answer:

6. Suppose you know that

X is next to Y.

Then would this be true?

Y is next to X.

6. A. YES
B. NO
C. MAYBE

The correct answer is A, "YES", no matter what X and Y stand for. If X is next to Y, then Y must be next to X.

Now that you have done the practice questions you probably understand what is expected. If you have any questions, ask them now.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

---

7. Suppose you know that

If the hat on the table is blue, then it belongs to Joan.
The hat on the table is blue.

Then would this be true?

The hat on the table belongs to Joan.

7. A. YES
B. NO
C. MAYBE

8. Suppose you know that

If the car in the parking lot is Mr. Smith's, then it is blue.
The car in the parking lot is not blue.

Then would this be true?

The car in the parking lot is Mr. Smith's.

8. A. YES
B. NO
C. MAYBE

9. Suppose you know that

If Tom lives in the white house, then his last name is Smith.
Tom does not live in the white house.

Then would this be true?

Tom's last name is not Smith.

9. A. YES
B. NO
C. MAYBE

10. Suppose you know that

Harry is on the football team only if he has his mother's permission.
Harry is on the football team.

Then would this be true?

Harry has his mother's permission.

10. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

11. Suppose you know that

If Mary lives in the white house, then her last name is Brown.
Mary's last name is Brown.

Then would this be true?

Mary lives in the white house.

11. A. YES
B. NO
C. MAYBE

12. Suppose you know that

John is in the kitchen only if there is food in the kitchen.
There is no food in the kitchen.

Then would this be true?

John is in the kitchen.

12. A. YES
B. NO
C. MAYBE

13. Suppose you know that

If the automobile in the parking lot belongs to Mr. Brown, then it is black.
The automobile in the parking lot doesn't belong to Mr. Brown.

Then would this be true?

The automobile isn't black.

13. A. YES
B. NO
C. MAYBE

14. Suppose you know that

Joe's bicycle is not working today.
If Joe's bicycle is not working, then he has to walk to school.

Then would this be true?

Joe has to walk to school today.

14. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

15. Suppose you know that

    There is an X only if there is a Y.
    There is not a Y.

    Then would this be true?

    There is an X.

15. A. YES
    B. NO
    C. MAYBE

16. Suppose you know that

    Dick was not at home yesterday afternoon.
    If Dick was not at the football game yesterday afternoon he was at home.

    Then would this be true?

    Dick was not at the football game yesterday afternoon .

16. A. YES
    B. NO
    C. MAYBE

17. Suppose you know that

    Tom may use paints only if he has cleaned up his clay work.
    Tom may use paints.

    Then would this be true?

    Tom has cleaned up his clay work.

17. A. YES
    B. NO
    C. MAYBE

18. Suppose you know that

    Fred went to a movie last night.
    If Fred does not go to a movie, he feels bad the next day.

    Then would this be true?

    Fred does not feel bad today.

18. A. YES
    B. NO
    C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

19. Suppose you know that

If there is an X, then there is a Y.
There is an X.

Then would this be true?

There is a Y.

19. A. YES
B. NO
C. MAYBE

20. Suppose you know that

Mary will be in the school play only if she likes plays.
Mary will be in the school play.

Then would this be true?

Mary does not like plays.

20. A. YES
B. NO
C. MAYBE

21. Suppose you know that

Tom is playing ball only if he has a ball glove.
Tom does not have a ball glove.

Then would this be true?

Tom is playing ball.

21. A. YES
B. NO
C. MAYBE

22. Suppose you know that

If there is an X, then there is a Y.
There is not a Y.

Then would this be true?

There is an X.

22. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

---

23. Suppose you know that

If whales are birds, then they can fly.
Whales aren't birds.

Then would this be true?

Whales can't fly.

23. A. YES
B. NO
C. MAYBE

---

24. Suppose you know that

If Bill lives on a farm, then he has a pet dog.
Bill has a pet dog.

Then would this be true?

Bill lives on a farm.

24. A. YES
B. NO
C. MAYBE

---

25. Suppose you know that

Jerry was not asked to play ball.
Jerry is not home only if he was asked to play ball.

Then would this be true?

Jerry is not home.

25. A. YES
B. NO
C. MAYBE

---

26. Suppose you know that

If Mary lives in the green house, then her last name is Jones.
Mary doesn't live in the green house.

Then would this be true?

Mary's last name is not Jones.

26. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

27. Suppose you know that

If the coat in the closet is brown, then it belongs to Sue.
The coat in the closet is brown.

Then would this be true?

The coat in the closet does not belong to Sue.

27. A. YES
B. NO
C. MAYBE

28. Suppose you know that

There are black cats only if there are pink cats.
There are black cats.

Then would this be true?

There are pink cats.

28. A. YES
B. NO
C. MAYBE

29. Suppose you know that

If the bicycle in the garage is Bob's, then it is red.
The bicycle in the garage is not red.

Then would this be true?

The bicycle in the garage is not Bob's.

29. A. YES
B. NO
C. MAYBE

30. Suppose you know that

If there is an X, then there is a Y.
There is a Y.

Then would this be true?

There is an X.

30. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

31. Suppose you know that

If mice have five legs, then they run faster than horses.
Mice do have five legs.

Then would this be true?

Mice run faster than horses.

31. A. YES
B. NO
C. MAYBE

---

32. Suppose you know that

If Jane fell off her horse, then she hurt herself badly.
Jane hurt herself badly.

Then would this be true?

Jane fell off her horse.

32. A. YES
B. NO
C. MAYBE

---

33. Suppose you know that

The short pencil is not Bill's favorite pencil.
The short pencil is not Bill's favorite, only if it is dull.

Then would this be true?

The short pencil is dull.

33. A. YES
B. NO
C. MAYBE

---

34. Suppose you know that

If there is an X, then there is a Y.
There is not an X.

Then would this be true?

There is not a Y.

34. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

35. Suppose you know that

If John lives in the white house, then his last name is Smith.
John's last name is not Smith.

Then would this be true?

John does live in the white house.

35. A. YES
B. NO
C. MAYBE

---

36. Suppose you know that

Birds can fly only if they can play the piano.
Birds cannot play the piano.

Then would this be true?

Birds can fly.

36. A. YES
B. NO
C. MAYBE

---

37. Suppose you know that

The car will start.
If the temperature is not below freezing, the car will start.

Then would this be true?

The temperature is not below freezing.

37. A. YES
B. NO
C. MAYBE

---

38. Suppose you know that

There is an X only if there is a Y.
There is an X.

Then would this be true?

There is a Y.

38. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

39\. Suppose you know that

If dogs have four legs, then they have three eyes.
Dogs don't have three eyes.

Then would this be true?

Dogs do have four legs.

39\. A. YES
B. NO
C. MAYBE

40\. Suppose you know that

If Jean goes to the park, she will see her friend Pat.
Today, Jean is going to the Park.

Then would this be true?

Today, Jean will see her friend Pat.

40\. A. YES
B. NO
C. MAYBE

41\. Suppose you know that

If horses are green, then they have two tails.
Horses have two tails.

Then would this be true?

Horses are green

41\. A. YES
B. NO
C. MAYBE

42\. Suppose you know that

The red pencils belong to Sally only if they are on the table.
The red pencils are not on the table.

Then would this be true?

The red pencils do not belong to Sally.

42\. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

43. Suppose you know that

If Paul rides his bike to school, he goes the long way.
Paul rode his bike to school today.
If Paul goes the long way, he gets to school late.

Then would this be true?

Paul was not late for school today.

43. A. YES
B. NO
C. MAYBE

44. Suppose you know that

If the chair is green, then the table is black.

Then would this be true?

If the table is black, then the chair is green.

44. A. YES
B. NO
C. MAYBE

45. Suppose you know that

If there is a blue pencil in the second box, then there is a green pencil in the first box.
If there is a green pencil in the first box, then there is a red pencil in the third box.

Then would this be true?

If there is a blue pencil in the second box, then there is a red pencil in the third box.

45. A. YES
B. NO
C. MAYBE

46. Suppose you know that

If Mrs. Smith entered the flower show, then she entered her roses.

Then would this be true?

If Mrs. Smith didn't enter her roses, then she didn't enter the flower show.

46. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

47. Suppose you know that

Bill will see Audrey, if and only if he goes to Montreal.
Bill will not see Audrey this year.

Then would this be true?

Bill is going to Montreal this year.

47. A. YES
B. NO
C. MAYBE

48. Suppose you know that

If Gary sees Sharon, he goes to Canada.
This winter Gary saw Sharon.
Gary goes skating only if he goes to Canada.

Then would this be true?

This winter Gary went skating.

48. A. YES
B. NO
C. MAYBE

49. Suppose you know that

If there is an A, then there is a B.
If there is a B, then there is a C.

Then would this be true?

If there is an A, then there is a C.

49. A. YES
B. NO
C. MAYBE

50. Suppose you know that

If birds can fly, then they have six legs.

Then would this be true?

If birds don't have six legs, then they can't fly.

50. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

51. Suppose you know that

If the bus goes to town, then it passes the old stone church.
The bus goes to town.
If it passes the old stone church, then it goes over the new bridge.

Then would this be true?

The bus doesn't go over the new bridge.

51. A. YES
B. NO
C. MAYBE

52. Suppose you know that

If the school team loses this game, Brighton High will win the league pennant.
If Joe does not hit a homer on this pitch, the school team will lose this game.

Then would this be true?

If Joe does not hit a homer on this pitch, Brighton High will win the league pennant.

52. A. YES
B. NO
C. MAYBE

53. Suppose you know that

If Jean goes shopping, she goes to Chicago.
Last Saturday Jean went shopping.
Jean visits her aunt only if she goes to Chicago.

Then would this be true?

Last Saturday Jean visited her aunt.

53. A. YES
B. NO
C. MAYBE

54. Suppose you know that

Tom will go skating, if and only if he can borrow Frank's jacket.
Tom is not going skating.

Then would this be true?

Tom can borrow Frank's jacket.

54. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

55. Suppose you know that

If Sam misses the bus, he will walk to school.
If Sam walks to school, he will cross the bridge.

Then would this be true?

If Sam misses the bus, he will cross the bridge.

55. A. YES
B. NO
C. MAYBE

---

56. Suppose you know that

If Bob did not buy a new baseball glove, then he played basketball today.

Then would this be true?

If Bob did not play basketball today, then he did buy a new baseball glove.

56. A. YES
B. NO
C. MAYBE

---

57. Suppose you know that

If Bill has an apple in his lunchbox, then Sally has a cracker in her lunchbox.

Then would this be true?

If Sally has a cracker in her lunchbox, then Bill has an apple in his lunchbox.

57. A. YES
B. NO
C. MAYBE

---

58. Suppose you know that

Betty is going to the movies.
Betty is not going to the movies, if and only if Ann is going to the movies.

Then would this be true?

Ann is going to the movies.

58. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

---

59. Suppose you know that

If there is an X, then there is a Y.

Then would this be true?

If there is a Y, then there is an X.

59. A. YES
B. NO
C. MAYBE

---

60. Suppose you know that

Elephants are pink, if and only if they are large.
Elephants are not pink.

Then would this be true?

Elephants are large.

60. A. YES
B. NO
C. MAYBE

---

61. Suppose you know that

If there is an X, then there is a Y.

Then would this be true?

If there is not a Y, then there is not an X.

61. A. YES
B. NO
C. MAYBE

---

62. Suppose you know that

If John has the red chalk, then he is making a poster for the play.
John has the red chalk.
If John is making a poster for the play, then he is in the library.

Then would this be true?

John is in the library.

62. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A. YES It must be true.
B. NO It can't be true.
C. MAYBE It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

---

63. Suppose you know that

That bicycle belongs to John, if and only if it is red.
That bicycle does not belong to John.

Then would this be true?

That bicycle is not red.

63. A. YES
B. NO
C. MAYBE

---

64. Suppose you know that

If a dog can stand on its front legs, then it is a puppy.

Then would this be true?

If a dog is a puppy, then it can stand on its front legs.

64. A. YES
B. NO
C. MAYBE

---

65. Suppose you know that

If there is an X, then there is a Y.
There is an X.
There is a Z only if there is a Y.

Then would this be true?

There is a Z.

65. A. YES
B. NO
C. MAYBE

---

66. Suppose you know that

If Kate is in Mrs. Jones' class, then she is out on the playground.
If Kate is out on the playground, then she is jumping rope.

Then would this be true?

If Kate is in Mrs. Jones' class, then she is jumping rope.

66. A. YES
B. NO
C. MAYBE

Here is a reminder of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be <u>certain</u> whether it is "YES" or "NO".

---

67. Suppose you know that

If there is an X, then there is a Y.
There is an X.
If there is a Y, then there is a Z.

Then would this be true?

There is not a Z.

67. A. YES
B. NO
C. MAYBE

68. Suppose you know that

If Jane did not go to the movies yesterday, then she saw her friend Pat.
Jane went to the park yesterday only if she saw her friend Pat.
Jane did not go to the movies yesterday.

Then would this be true?

Jane went to the park yesterday.

68. A. YES
B. NO
C. MAYBE

69. Suppose you know that

If Nancy bought a new dress, then she went to the shop on Main Street.

Then would this be true?

If Nancy didn't go to the shop on Main Street, then she didn't buy a new dress.

69. A. YES
B. NO
C. MAYBE

70. Suppose you know that

If John is not in school, then he has a cold.

Then would this be true?

If John has a cold. then he is not in school.

70. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

71. Suppose you know that

If Sally is writing a report at home, then the library is closed.
Sally is writing a report at home.
Dick is using the classroom dictionary only if the library is closed.

Then would this be true?

Dick is using the classroom dictionary.

71. A. YES
B. NO
C. MAYBE

72. Suppose you know that

If there are no blue pencils in the first box, then there is a green pencil in the second box.
If there is a green pencil in the second box, then there is a red pencil in the third box.
There are no blue pencils in the first box.

Then would this be true?

There are no red pencils in the third box.

72. A. YES
B. NO
C. MAYBE

73. Suppose you know that

If an animal is a turtle, then it can fly.
If an animal can fly, then it has feathers.

Then would this be true?

If an animal is a turtle, then it has feathers.

73. A. YES
B. NO
C. MAYBE

74. Suppose you know that

If there is a yellow marble in the first box, then there is a blue marble in the second box.

Then would this be true?

If there is not a blue marble in the second box, then there is not a yellow marble in the first box.

74. A. YES
B. NO
C. MAYBE

Here is a reminder of the meaning of the possible answers:

A.	YES	It must be true.
B.	NO	It can't be true.
C.	MAYBE	It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO".

---

75. Suppose you know that

If people have fins, then they live in water.
People have fins.
People can swim only if they live in water.

Then would this be true?

People can swim.

75. A. YES
B. NO
C. MAYBE

---

76. Suppose you know that

If this animal is a dog, then it can fly.
This animal is a dog.
If an animal can fly, then it has feathers.

Then would this be true?

This animal does not have feathers.

76. A. YES
B. NO
C. MAYBE

---

77. Suppose you know that

If John is on the volleyball team then he is good at volleyball.

Then would this be true?

If John is good at volleyball, then he is on the volleyball team.

77. A. YES
B. NO
C. MAYBE

---

78. Suppose you know that

There is a Y, if and only if there is an X.
There is not a Y.

Then would this be true?

There is an X.

78. A. YES
B. NO
C. MAYBE

END OF TEST. GO BACK AND CHECK YOUR ANSWERS.

RE:ml
M/HP18

APPENDIX D

CORNELL TEST OF CONDITIONAL REASONING ANSWER KEY

1.
2.
3.
4.
5.
6.
7. a
8. b
9. c
10. a
11. c
12. b
13. c
14. a
15. b
16. b
17. a
18. c
19. a
20. b
21. b
22. b
23. c
24. c
25. b
26. c
27. b
28. a
29. a
30. c
31. a
32. c
33. a
34. c
35. b
36. b
37. c
38. a
39. b
40. a
41. c
42. a
43. b
44. c
45. a
46. a
47. b
48. c
49. a
50. a
51. b
52. a
53. c
54. b
55. a
56. a
57. c
58. b
59. c
60. b
61. a
62. a
63. a
64. c
65. c
66. a
67. b
68. c
69. a
70. c
71. c
72. b
73. a
74. a
75. c
76. a
77. c
78. b

MY LETTER

Rm. 8-231 MECA
Ontario Institute for
Studies in Education
252 Bloor St. W.
Toronto, Ontario, M5S 1V6
October 1, 1985

Illinois Thinking Project
University of Illinois at Urbana-Champaign
College of Education
Bureau of Educational Research
188 Education Building
1310 South Sixth Street
Champaign, Il. 61820

Dear Sir/Madam:

I would like permission to include a copy of your copyright Cornell Conditional Reasoning Test (1964) in my 1983 M.Ed. Thesis entitled "The Effect of Exposure to BASIC Programming upon Students' Conditional Reasoning."

I regret that my request is, to some extent, after the fact. Because I was rushed and I did not know any better, I have in fact, included one copy of your test as a second appendix in the only bound version of my thesis which presently resides in an office at the Faculty of Education, University of Manitoba. The School of Graduate Studies, University of Manitoba will not release any copies of my thesis for the Education Library, the Curriculum Department, or their own library until I obtain permission to include your test. My personal copy of the thesis is more or less being held as ransom until I settle this matter and some researchers here in Ontario have asked for soft-bound copies. I would be most grateful if you could grant my request and help me out of this muddle.

Yours sincerely,

Terry Fogg

University of Illinois
at Urbana-Champaign

**Department of Educational
Policy Studies**

360 Education Building
1310 South Sixth Street
Champaign
Illinois 61820

College of Education

217 333-2446

HIS LETTER

October 8, 1985

Mr. Terry Fogg
Room 8-231 MECA
Ontario Institute for
Studies in Education
252 Bloor Street W.
Toronto, Ontario, M5S 1V6
Canada

Dear Mr. Fogg:

You have my permission if you will send me a copy of your thesis.

Sincerely,

[redacted]

Professor of Philosophy of
Education

RHE:mkm