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THE EFFECTS OF LEARNING LOGO ON THE ABILITY OF CONCRETE OPERATIONAL STUDENTS TO LEARN ABSTRACT CONCEPTS

A Dissertation Presented

By

ARNOLD GLIM

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

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Education

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ABSTRACT

The Effects of Learning Logo on the Ability of Concrete
Operational Students to Learn Abstract Concepts

(May, 1987)

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This study examines the effects of learning the computer language Logo on concrete operational students. It sought to determine if a sample of such students were taught to program in a Logo, they would then be able to learn abstract concepts rather than a similar sample of students who were not taught Logo.

To do this study, a sample of 33 eighth grade students who were tested as concrete operational were divided into control and treatment groups. Each group was pre-tested on their knowledge of abstract physics concepts which were to be taught as part of a self-contained physics unit.

The treatment group then received 14 weeks of instruction in Logo, as part of a specially-designed Logo learning environment. Following this, both groups were taught a three-week long physics unit. This unit was designed to teach a variety of abstract physics concepts, some strongly related to the Logo taught to the treatment group, and the rest either unrelated or weakly related to the Logo taught.

Both groups were then post-tested on their knowledge of the physics taught. A t-test analysis of the physics pre- and post-test results was done to see if the treatment group made significantly greater improvement in test scores than the control group. A further analysis was done with respect to individual test items to see if the treatment group made significantly greater improvement on test items which were judged strongly related to Logo.

The results of these analyses indicated that there was no evidence that concrete operational students who are trained in Logo do any better at learning abstract physics concepts than students who were not trained in Logo. This was true even when the abstract concepts involved were strongly related to the Logo concepts taught.

To conclude, this study does not support the hypothesis that Logo can help concrete operational students think abstractly and learn abstract science concepts any better than traditionally taught students. Considering this, it would seem unwise to take time from teaching these students traditional science, in order to teach them Logo.

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CHAPTER I

INTRODUCTION

The teaching and learning of science has, in recent decades, become a matter of national concern. Our nation's fear of losing its technological edge in defense and industry, due to lack of proper science training, has been the focus of many educational reports and studies. In fact, those in the science education field were, and still are, greatly influenced by the U.S.S.R.'s launching of the first space satellite, which spurred on the development of many national-level science curricula.

Programs, such as Physical Science Study Committee (PSSC) physics, Biological Science Curriculum Study (BSCS) biology, Earth Science Curriculum Project (ESCP) earth science, Chem Studies, Introductory Physical Science (IPS), etc., were initiated in the late 1950s and early 1960s as a direct reaction to the perceived need to do something about science education in this country. Whether or not faulty science education was the actual reason for our falling behind the Russians in space exploration and missile development, our reaction was forthright. Teachers, university professors, and scientists put together new science curricula which were designed to bring science education into the "space age" by emphasizing science process, problem solving and scientific reasoning. That these programs influenced practically every aspect of science teaching cannot be denied. Even today, though many science teachers have stepped back from these original programs, their influence can be seen in terms of content and method.

Students reacted to our nation's need for scientists and engineers with enthusiasm, but after an initial surge, science enrollment began a steady decline. Many students perceived the new science programs as too difficult to learn and understand, and were frustrated in their efforts. These frustrations, in fact, increased steadily as students progressed through their academic careers. In a recent study of schools, Goodlad cites statistics that show that while most elementary school students found science easy or "just right" and generally liked the subject, senior high students found it their most difficult subject and liked it only a shade better than foreign language which was their least liked subject.[1]

Why many students find learning science so difficult is a question well worth asking, and it has been asked by a number of educational researchers. Some of these researchers have attempted to relate the inability of many students to learn science to Piaget's theory of intellectual development, which suggests that children undergo a transition through intellectual stages as they mature. According to Piaget, children, as they go through these stages, think not only less efficiently than adults, but think qualitatively differently.[2] Research into Piagetian development seems to indicate that most secondary school children cannot handle abstract concepts effectively, and, in fact, an early synthesis of relevant data in this area by E. L. Chiappetta indicates that 77-83.4 percent of junior high school students, and 22-85.85 percent of high school students cannot be considered as formal reasoners, i.e., could not be expected to reason abstractly.[3] Furthermore, it is suggested that these students who cannot reason abstractly cannot learn abstract concepts except by rote or in a mechanical way. Clearly, if it is abstract process they must deal with, they will be at a loss.

Most of these non-abstract thinkers would be characterized by Piaget as being at the concrete operational stage of their development. During this stage, a student can solve complex problems, but needs reference to familiar actions and objects. Unfortunately, most high school science courses are presented on an abstract level, and deal with very abstract concepts. In fact, most science curricula today, including those at the middle school level, assume the level of operations that Piaget describes as formal.[4] Even those programs which are designed for slower students with low reading levels contain highly abstract concepts.

Teaching abstract concepts in the study of science is probably unavoidable. This presents no great problem to students who have reached Piaget's stage of formal operations; even those students who are at a transitional stage between concrete and formal operations can be eased into formal thought patterns, especially if concrete examples are used to aid this transition. However, Piaget points out that students who are fully concrete operational thinkers cannot be indefinitely accelerated into formal patterns of reasoning by means of stimulus-response type learning, or any other traditional technique.[5] Research suggests that the ability to think abstractly "develops" in a Piagetian sense rather than being acquired as a consequence of direct or short-term teaching.[6]

Purpose of the Study

The field of science is by nature conceptually abstract, and is becoming increasingly more so at an ever-accelerating pace. Science students are now being challenged with such abstract concepts as atomic and nuclear theory, unseen forces, curved space and relativistic time, biochemical interactions, genetic engineering, and so on. It has taken thousands of years for man to discover and try to fathom these concepts, yet we ask our children to understand and assimilate them in a relatively brief span of time.

It is understandable, then, that one of the major challenges facing curriculum decision making is to create conditions where students are not frustrated in their attempts to learn, understand and apply these concepts. This is especially true when one considers that many, if not most, of these students are not developmentally able to effectively deal with abstractions.

Considering, then, the abstract nature of most secondary school science and the concrete operational ability of most secondary school students, can a way be found to teach science to these students effectively?

A growing number of educational researchers believe that it is the computer which will provide the flexibility needed to bridge the gap between concrete and formal learning patterns.[7] Computer software, for example, has been developed that will simulate specific learning environments which allow students to more fully interact with what they must learn. Learning situations could be developed which would be difficult, if not impossible, to develop without the use of the computer.

But perhaps the most promising method of using the computer to learn abstract concepts involves student writing of computer programs. Seymour Papert and his associates at the Massachusetts Institute of Technology feel that this is, in fact, the best way of bridging the gap between concrete and abstract learning operations.[8]

Papert points out that computer languages, including the most commonly used language, BASIC, are themselves highly abstract. To learn to program in these languages, in any but the most surface fashion, calls for formal reasoning ability. In response to this problem, Papert and his associates developed Logo, an advanced computer language designed specifically as a "learning language." Logo, Papert has stated, allows even young children to program in such a way that insight into the programming process is gained.

Papert's ideas are based, in part, on the Piagetian theory of intellectual development. Piaget pointed out that all of us, including highly abstract reasoners, revert to concrete mental operations to understand new and unfamiliar ideas. One tends to use mental models which have been "concretized" by our own experiences, and absorb new ideas in terms of these mental models.

In general, the concrete thinker does not have sufficiently developed mental models to use in this process. Piaget believed that until the concrete thinker has developed these mental "structures," he will not be able to absorb abstract ideas.

According to Piaget, Logo allows students to develop and concretize mental models which will hasten a student's transition from the concrete to abstract stages of development. For example, through the use of Logo Physics, students who would normally view Newton's laws of motion as highly abstract ideas will now be able to understand them because they have developed concrete mental models which form the basis of understanding the concepts involved.

The purpose of this study, then, was to determine whether or not Papert is essentially correct, and that the learning of Logo does in fact aid the concrete operational learner to learn abstract concepts better than similar learners who have not learned to program in Logo. That is, the researcher wished to see if concrete operational students, who have been taught to use the computer language Logo as part of an educational program designed to give these students a variety of mental models for "concretizing" abstract ideas, learn new abstract materials more effectively than similar students who have not been taught to use Logo.

Furthermore, the researcher wished to examine whether or not it makes a significant difference for the abstract material being learned to be directly related to the Logo educational program as compared to material which is unrelated to the Logo educational program.

Two hypotheses will guide this research:

Hypothesis 1: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics than similar students who have not been taught to program in Logo.

Hypothesis 2: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics which are directly related to the Logo concepts learned, than similar students who have not been taught to program in Logo.

Definition of Terms

This section defines the key technical terms referred to in this study. The purpose of these definitions is to provide a common understanding of the terms which are essential to the understanding of the study.

Abstract Concepts: Concepts, often abstruse, which are disassociated from any particular state or thing.

Selected Abstract Concepts in Physics: Concepts taken from the study of physics, which are by nature abstract and thought to require the level of mental development known as formal operational, in order that they be well understood by the learner; or concepts which relate to abstract content area, and are, therefore, considered abstract. For example, to understand the concept of "density," the learner must understand proportional reasoning, which is intrinsic to the understanding of this concept. As proportional reasoning is considered a formal operation, the concept of density, according to this definition, must be considered abstract. As a second example, consider the concept of projectile motion, such as a bullet fired through the air. To completely understand this concept, the learner must understand the concept of inertia. Since the concept of inertia is disassociated from any particular state or thing, and is quite difficult to understand, it is considered abstract. As the content of projectile motion relates to an abstraction, projectile motion will be considered an abstract concept.

Concrete Concepts: Concepts which are characterized by or belonging to immediate experience of actual things or events.

Developmental Stages: Refers to periods of time through which a child's intellectual development evolves as the child matures. Each stage is characterized by different psychological structures which help the child to adapt to his or her environment. Piaget theorized four major stages of development, each representing a major step in the hierarchy of mental development.

Concrete Operational Learner: Refers to the third major stage in a child's development. During this stage of operation, the learner has difficulty dealing with abstract concepts and needs reference to familiar actions and objects.

This level of operation ranges for the average child, between 7 and 11 years of age. However, many researchers feel that this level of operation may go well beyond age 11, in fact, many adults have been tested as concrete operational learners.

Formal Reasoner: Refers to what Piaget believed to be the fourth and last major stage of human intellectual development. Beginning at about 11 years of age or older, the formal reasoner has the ability to reason abstractly. That is, he or she: can deal with complex problems in a logical way; can imagine many possibilities inherent in a situation; can deal with hypothetical propositions, theories and idealized models. Furthermore, the formal reasoner can compensate mentally for transformations in reality, where the concrete reasoner would have to actually manipulate the objects of the situation.

Mental Operations: These are internalized actions which modify the object of knowledge and are reversible in their application. That is, the child performs this action mentally, and is able to perform its opposite action which leaves him or her where he or she started. For example, if the learner has developed the mental operation of "conservation," he or she understands that a pint of water completely poured from a tall, narrow container into a short, wide container has not lost any substance, and that if it is poured back again, it will all be there. This particular operation is well developed for the completely concrete operational child so that it is obvious that the water in our example is conserved. On the other hand, this would not be at all obvious to the child who is not yet concrete operational, so that he or she would expect that water poured from the tall container would be lost when it is put in the short container (or gained, depending on the individual child's perception at the time).

Logo: The computer language developed at the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology. It is the language used to communicate with the "turtle" (originally a remote controlled robotic device which moved along the floor trailing an ink marker in response to programmed commands, and now described by Papert[9] as computer-controlled cybernetic animals that live on computer screens). Watt[10] describes it this way: "Logo isn't just something you learn. It's something you learn with."

Significance of the Study

A good deal of money, time and effort has already been invested in computer education. According to a 1980 survey by the National Center for Educational Statistics (NCES) of the U. S. Department of Education, about one-half of the nation's school districts provide students with access to at least one microcomputer or to a terminal attached to a large computer. Furthermore, every indicator points to even increased acquisition of computers and computer related materials.

It is generally recognized that while the technology is here, methods are still in question. C. Evans, in his book The Micro Millennium, points out ". . . that to develop a technology capable of providing interactive personal teaching is far less difficult than to determine the best methods for doing so and to ascertain just how effective these methods will be when put into practice."[11]

What is needed is basic research into the educational process as it relates to the development of powerful and effective teaching programs.

The study which is being done here is important because it will assess an important theory of epistemology with the development of computer language and an educational program based on this theory. If it is true that Papert and his MIT Logo group has developed a computer method for teaching abstract concepts to the concrete operational student, progress will have been made toward the understanding of ideas associated with Piaget's theory of intellectual development and important progress will have been made toward more effective teaching.

Recent research indicates that more students and adults in general think on a concrete operational level than was previously suspected. Kohlberg and Gillison have found evidence of widespread concrete thought in persons from 10 to 50 years of age.[12] Renner and

McKinnon have shown that 50 percent of Oklahoma's entering freshmen and 66 percent of its high school seniors still occupy the concrete operational stage of intellectual development.[13]

The author's own research in this field indicates that only 47 percent of students studying physics and chemistry at Brattleboro High School, Brattleboro, Vermont, are fully formal reasoners. Eight percent of these students have been tested to be at the concrete operational level. These students by and large represent Brattleboro's best students, and it is most probable that an even larger percentage of Brattleboro's remaining students are operating on a concrete or less than formal level. Reaching these concrete operational and transitional students is an important part of the educational process. Helping them to develop a heuristic approach to problem solving so that they are capable of dealing with a world which is becoming increasingly complex, cannot help but be beneficial to them and to the society in which they live.

Delimitations of the Study

Robert Taylor, the editor of The Computer in the School: Tutor, Tool, Tutee, points out that there are three modes of using computing in Education.[14] First, as a tutor, the computer is programmed to present subject material to a student. To develop programs effectively requires many hours of expert work for relatively few hours of good tutoring. However, these programs may be designed to accommodate individual differences to an extent which seldom occurs in the normal classroom situation.

Second, as a tool, the computer is used to aid in calculations, store and process information, analyze experimental data, and so forth. Time and intellectual energy may be saved for more rewarding use.

The third mode of computer use involves the programming of the computer, which is in effect the "teaching" of the computer. Taylor suggests that there are several important benefits to doing this. These benefits include a greater understanding of the subject being "taught" to the computer, since you cannot teach what you do not understand. In addition, learners gain new insights into their own thinking through learning to program, and teachers have their understanding of education enriched as they observe the educational processes involved.

It is this third mode which differs most from traditional educational methods, and, in my opinion, offers the greatest opportunity for educational progress. This study will, therefore, be restricted to that mode of computer education which involves students learning a computer language and writing their own programs.

Choosing a computer language out of the several which are available involves some difficult choices. The most commonly used computer language for educational purposes is BASIC.

BASIC is an easy to use language in that it has relatively few commands and it is good at computational type problems. Unfortunately, because it has relatively few commands, the writing of an even mildly complex program usually involves a clumsy manipulation of these commands that are difficult to design and even more difficult to follow. To use a rough analogy, it is like trying to write a well thought out essay while being restricted to fifty or so words. Furthermore, since BASIC is algebraic in nature, it does not lend itself well to using words, making it a rather abstract language to learn and fully understand.

Since this study was primarily aimed at the concrete operational student, BASIC would be a poor choice, as it is doubtful that these students could handle the intrinsically abstract nature of the BASIC language.

Other languages which might have been considered include:

(1) PILOT, which is a dialogue-oriented computer language that, as J. W. Dean describes in an article adapted for the Journal of the National Education Association, deals nicely with words and text.[15]

(2) PASCAL, another high-level computer language, is described as designed to lead to more efficienty programming, fewer errors, and easier revision. While PASCAL is described as not difficult to understand, to become proficient in using it takes considerable time and effort.

Though these languages offer excellent possibilities for further study, it is the language developed the the MIT Artificial Intelligence Laboratory called Logo which is most directly related to Piaget's theory of intellectual development. The developers of Logo describe it as a "user-friendly," easy-to-learn language which they hope will teach students to deal with highly abstract concepts.

It is for these reasons that Logo was chosen for use in this study. Although there are many methods of using the computer for educational purposes, it is the use of Logo in the "tutor" mode which offers, it is felt, the best chance of getting the concrete operational reasoner to learn abstract materials.

Design of the Study

This study is designed to test whether the researcher may accept or reject the following two hypotheses:

Hypothesis 1: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics than similar students who have not been taught to program in Logo.

Hypothesis 2: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics which are directly related to Logo the concepts learned, than similar students who have not been taught to program in Logo.

To do this study, eighth grade students who were enrolled in a general science course at Brattleboro Union High School were tested with respect to their level of reasoning. A modified form of the Lawson Classroom Test of Formal Reasoning was used to determine each student's reasoning level. As these students had been described by their science teacher as average, it was expected that there would be a range of cognitive levels among them, but most of these students were found to be at the concrete operational level of reasoning. The achievement of those students who were found to be reasoning at a higher than "concrete operational" level served as a standard of the level of achievement that could be reasonably expected. The reasoning level test was not scored until the completion of the teaching parts of this study to preclude its influencing the researcher who was both tester and teacher of these students.

The students that took part in this study were scheduled into two classes of 20 and 23 students respectively, by a computer which is programmed to consider time and space availability only. As these students had not been tracked into ability groups, it was unlikely that there were other than random differences between groups.

One group, chosen arbitrarily on the basis of available computer laboratory space, was used as a control, while the other was used as the "treatment" group. Both groups were pre-tested as to their knowledge and understanding of fairly abstract areas of physics. While this material is considered abstract, it is not overly mathematical in nature. That is, most of these eighth grade students should have been able to understand and apply the mathematics involved. The control group then followed their traditional course of study, which included demonstrations, class recitation, laboratory activities, audio-visual material, etc.; and the treatment group was taught to program in Logo.

After a period of fourteen weeks, when the Logo group had completed the Logo course of study, both groups were taught a three-week "self contained" physics unit which dealt with the abstract concepts which had been pre-tested. Some of the material taught was directly related to concepts developed through the Logo course of study, and some was unrelated. Furthermore, much of the material studied in this unit was different from other material studied in the general science course. After this unit had been taught, both groups were post-tested.

To test the first hypothesis, the researcher determined the statistical means of percentage points difference in the pre- and post-physics tests for the control and treatment groups. A t-test was then used to determine if these means were significantly different. If this hypothesis was to be accepted, it must be shown that no significant differences existed at the .05 level between means for these groups.

If a significant difference was found in the means of percentage points difference in test scores between control and treatment groups, the first hypothesis must be rejected. A rejection of this hypothesis would imply that if the treatment group's mean scores were higher than the control group's, learning Logo does help concrete operational students learn abstract concepts in general.

To test the second hypothesis, it was necessary to first identify those questions in the physics test which test concepts that are strongly related to Logo concepts included as part of the Logo curriculum, and those questions which are only weakly related or unrelated. The researcher then scored each category (Logo related and unrelated) of questions separately. After which, the statistical means of the percentage points difference in scores for each category were subjected to a t-test for significant differences between control and treatment groups.

To accept the second hypothesis, it must be shown that no significant differences exist at the .05 level in the means of percentage points difference in scores for those questions on the pre- and post-physics test which were judged to be strongly related to concepts learned in the Logo educational program, as compared to those questions which were judged weakly related or unrelated to the concepts learned as part of a Logo educational program, between the control and treatment groups.

If a significant difference were found in the means of percentage points difference in scores between treatment and control groups for those questions which test concepts that were judged strongly related to concepts learned as part of the Logo educational program, but not found for those questions that were judged weakly related or unrelated to Logo concepts, it would be necessary to reject the second hypothesis. A rejection of the second hypothesis would imply that if treatment group students scored higher than control group students on Logo related questions, the learning of Logo helps concrete operational students learn abstract concepts which are related to Logo concepts.

If only the second hypothesis were rejected, the implication would be that while the learning of Logo does not help in the learning of abstraction physics concepts in general, it may have helped in the learning of Logo related abstract concepts.

Curriculum

The curricula used for this study is made up of two parts. The first part is the Logo curriculum, and the strategy used to teach this curriculum.

The second part is the selected abstract concepts in physics curriculum, and the strategy used to teach this curriculum.

Logo Curriculum--Objectives and Teaching Strategy

The question of whether or not the Logo content and teaching procedures used here reflects the philosophical and pedagogical essence of Logo is a weighty one. If it does not, can one make any justifiable claims concerning the results of the experimental research done here? Certainly, one could expect criticism on these groups at the very least.

The problem, then, is to make certain that the Logo used represents what is generally thought of as appropriate for what must be done here. But as the development of Logo is relatively new and is still in the process of evolving, one finds differing opinions on how Logo should be taught. Papert, in his persuasive book Mindstorms, speaks of children "learning without being taught" or "Piagetian learning." He believes the classroom is ". . . an artificial and inefficient learning environment," and that the computer should be used to modify the learning environment so that the child will learn "painlessly," just as he or she learns to talk. Logo, then, should not be taught as simply another computer language, a "Logo environment," where students explore and discover new intellectual structures to help them interact with the world. Logo, he feels, should provide a medium for children to think about thinking, an environment for "epistemological reflection." While Papert feels that Logo could be used to help teach a traditional curriculum, he sees it as a vehicle for Piagetian learning, which to him is learning without a curriculum; but, that teaching without a curriculum does not mean spontaneous, free-form classrooms or simply leaving the child alone. It means supporting children as they build their own intellectual structures with material drawn from the surrounding culture.

Others, however, are not so sure. According to Stanley Pogrow, Associate Professor of Educational Administration at the University of Arizona and a Logo consultant, as cited in an article by C. Euchner,[16] "programming in Logo for Logo's sake" does not teach problem solving to any but the brightest pupils. Most students, he said, need to be shown how Logo principles apply to other subjects. And Dan Watt, author of the book Learning With Logo and a contributing editor of Popular Computing magazine, quoted in the same article, cautions that the use of Logo and research on problem solving are in the very early stages. "Logo," states Watt, "is not magic. It takes a lot of planning and good educators to make it work."

Considering the problems involved in developing a good Logo unit, it was decided that borrowing heavily from the well-established written works of recognized experts in the field, such as Watt's Learning With Logo,[17] Abelson's Apple Logo,[18] and Abelson and diSessa's Turtle Geometry,[19] and others, would be appropriate. Furthermore, considering the age and abilities of the student subjects, it was felt that the "graphics" aspects of Logo would be the primary vehicle of instruction, as the more sophisticated aspects of Logo might be too abstract.

In addition, the researcher was aided in the development, and advised on the teachability of this unit by several Logo experts, including a number of elementary and secondary school teachers of Logo. The version of Logo used here was the first edition of Apple Logo.

Trying to take a middle ground between lack of structure and too much structure, a number of goals and objectives were developed along with a brief outline of procedures and student projects. Students were allowed a great deal of latitude to explore various avenues of interest within a guided framework.

Achievement of student objectives was evaluated on the basis of successful completion of assigned projects, including some which were graded in terms of knowledge of Logo concepts, sophistication of technique, and creativeness of approach. In addition, written examinations were given periodically to determine the student's ability to write simple Logo programs, correct program errors and interpret programs.

The purpose of this evaluation was to determine the extent of each student's knowledge of Logo at the completion of this unit. This information was considered, along with student developmental level and ability to learn selected abstract concepts in physics in the analysis section (Chapter IV) of this study.

As part of this Logo curriculum, concepts, such as vector addition and dynaturtle physics, were purposely included to provide material related to the selected abstract concepts in physics to be taught after the completion of this unit. This was done in order to help test the second hypothesis of this study.

It may be noted that the Logo curriculum developed for this study is divided into seventeen lessons. It was not meant that these lessons be taught in equal periods of time. The time spent on any one lesson depended on the complexity of the lesson and the time needed for students to achieve the objectives of that lesson.

The following is a list of the student objectives hoped to be achieved by the completion of the Logo curriculum used. (See Appendix B for a complete listing of the Logo curriculum and lesson procedures used in this study.)

Logo Objectives. The student will be able:

1. To start up and load the Logo program.
2. To use the following commands:

PRINT	(PR)	HIDETURTLE	(HT)
FORWARD	(FD)	SHOWTURTLE	(ST)
RIGHT	(RT)	CLEARSCREEN	(CS)
BACK	(BK)	PENERASE	(PE)
LEFT	(LT)	PENUP	(PU)
		PENDOWN	(PD)

3. To use these commands to draw simple geometric figures.
4. To understand how angles are used in constructing these figures.
5. To understand how side length and angle size determine shape of simple figures.
6. To define a Logo procedure using TO and END.
7. To correct mistakes using:

    <- delete character to left of cursor.
    -> moves cursor to right without deleting characters.
    [A] moves cursor to beginning of line.
    [B] moves cursor to left without deleting characters.
    FULLSCREEN or [L] to give full graphic screen.
    TEXTSCREEN or [T] to give full text screen.
    SPLITSCREEN or [S] to give mixed screen.

8. To use the REPEAT command to draw simple geometric figures (e.g., REPEAT 4 [FD 50 RT 90]).

9. To use [G] to stop a Logo execution.

10. To go into edit mode and edit a Logo procedure using:

EDIT	"NAME.
[C]	exits editor with text processed.
[G]	exits editor with text unprocessed.
->	at end of line to move to next line.
[A]	moves cursor to beginning of line without deleting.
[B]	moves cursor back without deleting, and at beginning of line to move to end of previous line.
<-	at end of line to combine line with next line.
[N]	to move down to Next line.
[O]	to Open new line at cursor position.
[P]	to move cursor up to Previous line.
[V]	to scroll forward one screenful.
[ESC]	to scroll back one screenful.
[L]	to scroll cursor line to center of screen.

11. To define more than one procedure at a time.

12. To save a procedure to disk using SAVE "NAME.

13. To catalog disk using CATALOG command.

14. To load saved procedures using LOAD "NAME.

15. To print hard copy using .PRINTER #

16. To manage workspace using:

PO "NAME	(prints out definition of NAME)
PO [NAME OTHERNAME]	
POALL	(prints names and procedures)
ERASE (ER) "NAME	(erases file called "NAME)

17. To use commands learned so far to draw a more complicated picture.

18. To use the following screen commands:

HOME	to clear screen and move turtle to center position.

CLEAN to clear graphic screen without moving turtle.

19. To set pen colors using:

    SETPC # (0-black, 1-white, 2-green, 3-violet, 4-orange, 5-blue)

20. To set background using:

    SETBG #

21. To reverse pen colors using:

    PENREVERSE (PX).

22. To understand what is meant by a variable.

23. To use Logo variables and inputs in Logo procedures (e.g., TO SQUARE :S --> SQUARE 100).

24. To perform arithmetical operations on variables (e.g., using 2 * S in SQUARE :S procedure).

25. To understand what is meant by recursion.

26. To use recursion in procedures.

27. To use recursion and variables to draw designs.

28. To understand the infinite nature of recursive procedures.

29. To use the following predicates with the following conditional expressions:

    >, <, =.

30. To control recursion with conditional expressions.

    Example: IF :X > :Y [STOP]

31. To define a regular sided shape.

32. To write a procedure which draws regular sided shapes.

33. To understand that only certain angles will produce regular sided shapes.

34. To apply knowledge of polygons to construct circles.

35. To understand angular relationships with circles and other polygons.

36. To understand nature of infinity and approximations of infinity.

37. To use HEADING to control poly program.

38. To use the MAKE command in a procedure. For example:

```
MAKE "APPLE 50
PRINT :APPLE
50
```

39. To understand that a conditional stop command must be inserted in the logically correct place in a procedure to work properly.

40. To construct circles using the radius of a circle.

41. To construct arcs of various sizes.

42. To include procedures for arcs and circles in designs.

43. To understand what a "frame of reference" is.

44. To define Cartesian frame of reference.

45. To move the turtle by specifying x,y Cartesian coordinates using the SETPOS command, e.g., SETPOS [30 40].

46. To move the turtle horizontally by using the SETX command.

47. To move the turtle vertically by using the SETY command.

48. To set the direction of the turtle using the SETHEADING, (SETH) command. Rotates turtle clockwise with zero directed straight up, e.g., SETH 180.

49. To understand what a random number is and use RANDOM # in a procedure.

50. To define what a vector is.

51. To use Logo commands to construct vectors.
52. To add and subtract vectors.
53. To resolve vectors into components.
54. To understand force as a vector quantity.
55. To understand motion in terms of vector quantities.
56. To understand the dynamics of motion using the dynaturtle program.
57. To understand the dynamics of circular motion.

Selected Abstract Concepts in Physics Curriculum--Objectives and Teaching Strategy

The abstract material chosen for this study comes from the discipline of physics. That much of this discipline is abstract and difficult to learn has long been recognized by physics teachers and their students. John Renner, Professor of Science Education at the University of Oklahoma, points out an assumption often made is that as students accumulated information about physics, intellectual development would occur, and that the only indication that the general topic of intellectual status was ever considered is that it is generally taught to twelfth grade students.[20]

The physics covered in this unit is quite abstract, especially if the student is expected to go beyond rote manipulation of formulas. An analysis of the subject matter and methodology shows that while some of it could be understood by the concrete operational student, most of it is either based on concepts which are considered formal operational, such as proportional or propositional reasoning, or deal with abstract content area, such as "unseen forces."

Because the students used in this study are eighth graders and are expected to be concrete operational, the material will be presented in as qualitative a way as possible. Nevertheless, it is very likely that these students will have difficulty understanding or applying the concepts they will be studying.

During the process of developing this unit, a variety of literature dealing with physics, abstract reasoning, problem solving, and Piaget was reviewed.[21] In addition, several university professors with expertise in this area of study were consulted. (See proposed curriculum in Appendix B.)

The following is a list of student objectives for the selected abstract concepts in a physics unit which is expected to be achieved.

Selected Abstract Concepts in Physics Objectives. The student will:

1. Know the definition of a force.
2. Know the definition of a vector.
3. Know that forces have vector properties.
4. Understand how to add vectors.
5. Know that unbalanced forces will cause objects to speed up, slow down, or change direction.
6. Know that friction is an "invisible" force which can act on a moving or standing object.
7. Understand the relationship between unbalanced forces and motion.
8. Know that motion is a change in position over an interval of time, the rate of which is called speed.
9. Know that velocity is an object's speed in a given direction.

10. Understand and apply the formula for velocity as it relates to distance and time.

11. Understand what is meant by instantaneous velocity.

12. Understand the meaning of accelerated motion.

13. Understand how unbalanced forces produce accelerated motion.

14. Know what is meant by a frame of reference.

15. Understand why position is given with respect to a frame of reference.

16. Understand relative motion.

17. Understand the concept of inertial motion.

18. Understand the effects of force on moving objects.

19. Understand the effect of gravity on an object's motion.

20. Understand how applying a force to an object may lead to curved or circular motion.

21. Understand the centripetal nature of the force causing an object to move in a circle with constant speed.

22. Know that there are forces such as the gravitational or electromagnetic forces that do not seem to push or pull by direct contact.

23. Know that these forces may act through the exchange of "invisibly" small particles, called respectively gravitons and photons.

24. Understand that these "unseen" forces influence the space surrounding them.

25. Understand the "field" nature of this space in terms of these forces.

26. Understand some of the properties of field in space such as the inverse proportional nature of the force emanating from a point.

27. Apply these properties to explain observed phenomena.

Instrumentation

Two instruments will be used in this study. The first instrument was designed to measure the Piagetian development stage of each of the participants of this study. The instrument used here has been well described in the literature, and is considered to be valid and reliable for the situation in which it will be used.

The second instrument is basically an achievement test which was specifically designed to test the knowledge and understanding of some selected abstract concepts taken from the discipline of physics. As this instrument is new and specific to this study, it is hoped that content validity and reliability can be demonstrated.

Reasoning Level Test

The modified Lawson Classroom Test of Formal Reasoning will be used in this study to determine the reasoning levels of the students involved.

This test was used in place of "classical" Piagetian tasks, as these tasks were very time consuming and call for a level of expertise beyond the experience of most teachers.

The Lawson test uses a demonstration format combined with a test booklet of instructions and questions. Fifteen demonstrations based on classical Piagetian tasks include: conservation of weight and displaced volume, proportional reasoning, controlling of variables, combinational reasoning and probability.

Lawson estimated the reliability of the test, using the Kuder-Richardson 20 formula, to be 0.78. He felt that this represented an adequate degree of Reliability.[22]

The test was also found to have face validity as judged by a panel of six experts in Piagetian theory. In addition, it was found to have convergent validity as judged by the high correlation ($r = 0.76$) between the Lawson test results and results obtained by administering two Piagetian tasks using the classical interviewing method. A third measure of validity, factorial validity, was found through an analysis of elements of the Lawson test as correlated to similar elements of a four-task interview test.[23]

The author's own modification of this test consisted of videotaping the demonstrations to maintain a higher degree of consistency in giving the test. During a trial run of this test (1981), one-half of Brattleboro Junior High School's seventh grade was given the Lawson test and the other half was given the modified version. No significant difference was found between the means of scores of the Lawson and the modified Lawson tests.

Results of Lawson's test indicated that three identifiable psychological parametrics were being measured. Lawson interpreted these three factors as: (1) formal reasoning, (2) concrete reasoning, and (3) early formal or transitional-formal reasoning. Students were scored 12 or better on their 15-question test could be considered formal reasoners, while those who scored 5 or less were considered concrete reasoners. Students whose scores ranged from 6 to 11 were considered to be transitional. (The questions asked as part of this test may be found in Appendix C.)

Pre- and Post-Test of Knowledge and Understanding of Selected Abstract Concepts in Physics

The pre/post-test consists of a variety of questions which range in type from fairly concrete to very abstract.

To assess the validity of the test for the purposes of this study, evidence was sought to demonstrate that the test's questions evaluate the objectives of this unit, and that many of these objectives are abstract in nature. Furthermore, evidence was sought to demonstrate that some of the objectives to be evaluated are directly related to concepts learned in the process of mastering the Logo unit, while others are unrelated. In other words, evidence of the content validity of this test was sought.

To provide the evidence needed, a careful analysis of the test questions was made with respect to the stated physics objectives to see if they, in fact, test these objectives. Furthermore, an analysis of the physics objectives was done to see whether or not they met the criteria for being abstract. And, finally, an analysis was made to show the relationship between physics objectives Logo concepts taught.

After this analysis was completed, a number of University of Massachusetts professors, with expertise in this area, were asked to judge the content and face validity of this instrument. These professors agreed that this instrument was valid to that extent.

The reliability of this test was assessed by use of the split-half method of reliability determination. To do this, the test was divided into two equal half-tests made up of 15 even and 15 odd numbered questions. It was expected that this method of selecting questions made it likely that each half-test contained questions which are equally abstract and varied in content.

The half-tests were then graded for each student in our sample, so that a coefficient of reliability could be determined. To determine the reliability coefficient, the Kuder-Richardson 20 formula Correlation was found, and then modified by means of the Spearman-Brown formula.

As the same questions asked on the pre-test was used on the post-test after a period of approximately 17 weeks, the question of whether or not the pre-test will affect post-test results should be considered. To begin with, due to the nature of the material to be tested, it is very likely to be completely unfamiliar, and more than likely was forgotten within a very short period of time. In any case, as all students will be exposed to the same material, any effect should be averaged out for our sample. (The test of selective abstract physics concepts may be found in Appendix D.)

NOTES

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CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this review is to lay the theoretical and empirical foundation of this study. It will examine a theory of intellectual development and a learning model based on this theory. The review will establish the relationship between the intellectual development model and the philosophy of education for which the learning model is based upon. In doing so, it will establish the basis for testing an important aspect of this learning model.

This review will be divided into four basic parts which will consist of:

- Literature which describes the Theory of Intellectual Development as proposed by Piaget and others associated with this theory. Emphasis will be placed on those aspects of the Piagetian theory which discuss the developmental transition through intellectual stages. Research which supports or contradicts this theory will be considered with respect to the aspects of the Piagetian theory for which this study is based.
- Literature which deals with an analysis of the underlying abstract nature of concepts needed to learn physics, with respect to the Piagetian theory of formal reasoning.
- Literature dealing with the philosophy, development and use of the computer language Logo as an aid to the

educational process. Emphasis will be placed on research which measures the effectiveness of this language in helping students in the learning of abstract concepts.

- Literature which describes the educational philosophy of the "Logo environment" as it relates to the development of a Logo curriculum.

Piaget's Theory of Intellectual Development

Description of Piagetian Model of Intellectual Development

The Piagetian model of intellectual development is, in an important sense, based on a theory of evolution. In this evolutionary scheme, it is the mind that is evolving as the individual develops. Piaget hypothesized the existence of mental structures whose function was to organize the environment so that an organism can function effectively.[1] As basic biological and intellectual structures develop, they serve as a guide to an organism behavior as long as its interactions with the environment are successful. Environmental contradictions to these mental structures produce a need for the organism to change and adapt to new conditions, so that its mental structures evolve into a more sophisticated form.

Piaget referred to himself as an epistemologist. His interest in epistemology, i.e., the study of knowledge, and his training as a biologist formed the basis of his interest in intellectual development.

Piaget integrated his biological and epistemological interests by first pursuing the psychology of human intelligence in terms of an organism's adaptation to its environment; and, secondly, by focusing on the process of intellectual growth in the individual. He believed that a full understanding of human knowledge could be gained only through the study of its formation and evolution in childhood.[2]

This study of the formation and evolution of knowledge in the child led to the development of a model of intellectual development which suggests that children undergo a transition through intellectual stages as they mature; and although the time needed to attain a specific stage varies significantly from one child to the next, the basic sequencing of the stages is invariant. Research suggests that ability "develops" in this Piagetian sense rather than is acquired as a consequence of direct and short-term teaching.[3]

A significant development of Piaget's work was the recognition that children were not merely miniature replicas of adults who thought less efficiently, but thought differently as well. Intellectual development had to be conceived in terms of evolution through these qualitatively different stages of thought.[4]

To begin with, Piaget defined intelligence as a particular instance of biological adaptation, which allows the individual to interact effectively with the environment at a psychological level. Piaget, borrowing the concept of equilibrium in physics, uses it to describe the direction which successive adaptations and exchanges between the organism and its environment take. In this case, equilibrium refers to a balance between an individual's cognitive structures and his environment. Piaget explains that while the balance may be disturbed, the individual can perform actions to restore this balance. The types of actions the child is capable of using changes as the child develops, and this changes the resulting equilibrium as well.[5]

Furthermore, the difference between high IQ children and those with lower IQs is the rate at which these children move through a particular stage. A high IQ child might master in several months a level of cognition for which an average child might take two years. However, even the high IQ child cannot be pushed into the next stage before being biologically ready.[6]

Research, most notably done and reported by H. T. Epstein, in neuroscience suggests that there is a neurological basis for this development in terms of brain growth spurts. This research indicates that 85 to 90 percent of all youngsters of average and above-average ability experience brain growth spurts at some point during the ages of 2-4, 6-8, 10-12, and 14-16+, with growth patterns in-between.[7] Although some of this research has been criticized as poorly done,[8] others point out that though there were inconsistencies with Epstein's data and problems with his interpretation, his predictions generally hold.[9] Data showing electroencephlograph measurement of brain waves and cognitive activities, for example, show systematic development with age. This data, derived from several studies of brain-wave development, indicated "spurts" did occur at approximately the same ages found for brain growth spurts.[10]

Piaget, whose clinical observations do not depend on neurological research for validation, postulates that all species inherit two basic tendencies: organization and adaptation.

Organization refers to the tendency for all species to systematize their processes into coherent systems. For example, fish have gills, a particular circulatory system, and temperature mechanisms which allow them to live in water.

At the psychological level, Piaget suggests there are mental structures present which are systematized by the organism. For example, the very young infant has available the separate behavioral structures of either looking at objects or of grasping them. He or she does not initially combine the two, but after a period of development, he or she organizes these two separate structures into a higher-order structure which enables him or her to grasp something while holding it. Organization, then, is the tendency to integrate structures into higher order systems or structures.[11]

Adaptation refers to an organism's tendency to adapt to the environment by the processes described by Piaget as accommodation, which is an individual's tendency to change in response to environmental demands; and assimilation, the process by which the individual deals with an environmental event in terms of his or her own current mental structures.

As the individual tends to organize his or her behavior and thought, he or she develops, according to Piaget, a number of psychological structures which take different forms at different ages. Piaget describes four major stages of intellectual growth: The Sensorimotor Stage, which begins at birth; the Preoperational Stage, which begins at about two years; the Concrete Stage, which begins at about seven years; and the Formal Stage, which begins at about eleven. Some researchers believe that there is a fifth (and last) stage which begins at about age fifteen years.[12]

The stated ages are only approximate and different aspects of how stages proceed at different rates, and what remains invariant is the sequence of these stages. That is, in order to proceed to a new stage, the child would have had to develop certain structures which are part of the former stage. Even then, the development of a structure to deal with a certain task at one age may not work for a different, but similar, task. In fact, while one child may be able to accomplish some task before another similar task, a second child may reverse the order. This ability lag between similar tasks within a developmental period was called horizontal decalage by Piaget.[13]

As an example of horizontal decalage, a child may develop the ability to conserve the number of discontinuous quantities, such as marbles, at the age of six or seven, but cannot conserve the concept of weight until age nine or ten, and volume until age eleven or twelve.

Leone Pascual and his co-workers have been critical of Piaget's attempt to explain horizontal decalage through "resistance" to assimilation, presumably related to content of the task.[14]

The effect of content on the ability of a subject to do a specific task is another source of criticism of Piaget's work. Marcia Linn, for example, maintains that while Piaget was concerned with "content-free" structures for his developmental-based mechanisms and structural models of reasoning, in the real world of practice (especially in the science classroom), many factors are not addressed by Piagetian theory. These include factual knowledge, uniqueness of formal reasoning, field dependence/independence, individual attitudes, diagnosis of specific errors, sex differences, and instructional intervention, to name a few. She suggests that these factors do play a role in influencing performance and that they deserve more careful scrutiny.[15]

In fact, Leone Pascual and R. Case have put forth neo-Piagetian theories which take into account the role of factual knowledge. Both models include the role of working memory as a factor in reasoning. Leone Pascual has worked out a transition rule for Piaget's developmental stages which correspond to a regular bi-yearly increase in the capacity of working memory.[16]

Description of Piagetian Stages

During the sensorimotor stage of development, as described by Piaget, the child is unable to "think," but performs overt actions which show organized behavior. The child then develops into the preoperational stage in which problems are solved by "thinking them out." (Piaget defines "operation" as internalized actions which modify the object of knowledge.) Then follows the concrete operational stage in which the child can solve complex problems, but needs reference to familiar actions and objects. And then we have the formal operations stage in which operations are carried out on verbal propositions rather than directly on objects and their representations. Also, formal thought is hypothetico-deductive and proceeds from what is possible to what is real, through the application of a mental structure, which Piaget calls a "combinational system," that makes possible the listing of propositions systematically in all possible ways. It is this combinational system that provides the basic set of operations that allow subjects to examine data to verify hypotheses.[17]

At the secondary school level, we are primarily concerned with the latter two stages of Piagetian development. Piaget[18] and his associates describe some of the characteristics of concrete and formal operational students as follows:

1. For students who have attained the concrete stage of development, we should expect a "decentration" of thought. That is, the child should be able to focus on more than one action at a time when the action involves objects. Concrete operational students often cannot do this in the absence of concrete objects. Furthermore, the child should be able to visualize the transformation from the beginning of an event to its end result, and then be able to reverse the process.

We should also expect the concrete operational child to be able to apply conservation reasoning, e.g., understand that a liquid completely poured from a tall, narrow container into a short, wide container has not lost any substance. Conservation reasoning should not only apply to substance, as in the preceding example, but number, length, and weight as well. (Conserving displaced volume gives the concrete operational child difficulty, and volume may not be completely conserved until formal operations.)

In grasping these concepts, he or she will be able to use the argument of "identity," i.e., if you take nothing away, you must keep the same amount; the argument of "negation," i.e., if you return the substance, you still have the same amount; and arguments of "compensation," i.e., the loss of one characteristic is compensated by the gain of another.

He or she should be able to grasp ordinal relationships so that he or she would be able to establish one-to-one correspondences and arrange data in increasing or decreasing serial sequence. He or she can arrange objects using "vicariant" order, and can construct numerically equivalent sets.

He or she would still have difficulty if the A implies B and B implies C and therefore A implies C variety (twice removed implications). This problem stems from an inability to think simultaneously about several aspects of a situation in the abstract. This explains why concrete operational students have so much trouble with ratios.[19]

Classification is a mental process with roots in the sensorimotor period of development. It continues to develop and be refined through the period of formal operations. The progression of classification skills is both sequential and hierarchical. As children become involved in higher-level classification tasks, they become involved with higher-level thinking.[20]

Classification is the ability to sort or group a collection of objects according to a specified rule, or in a systematic way. To be able to classify fully one must know more than just the name of the object; one must also know its properties and characteristics.

Classification involves the separation of a set of subsets. These activities fall into two general categories--simple and multiple classification:

- Simple classification involves subsets that disjoint, with no common elements, and is often accompanied by negation, e.g., red and not red.

- Multiple classification involves non-disjoint or overlapping sets which have elements in common.

This is often a source of confusion and needs a higher level of thinking. The child must be able to perceive an object in two different ways simultaneously.[21]

We could expect the concrete operational student to be able to make simple classifications and successfully relate systems to subsystems and classes to subclasses, and to be able to produce a hierarchical arrangement of classes when working with concrete objects. Classification of abstract concepts, on the other hand, would give the concrete operational child difficulty.

The concrete operational student, while quite capable of experimentation on a surface level, would be limited to empirical results. Typically, he or she would much rather see the actual outcome of an experiment than have to consider the abstract possibilities. He or she uses little planning or foresight, does not consider all possibilities, and fails to make consistent use of variable control. While he or she is capable of observing results accurately, he or she often draws incorrect conclusions from observations. (Chances for drawing successful conclusions improves with greater familiarity with subject.) When confronted with several factors which might influence the results of an experiment, he or she usually tests each alone, but fails to consider all of them in combination.

2. Students who have attained the formal stages of operations have reached a high degree of equilibrium. Their thought is effective and is

characterized by flexibility. They can deal with complex problems in a logical way, which imagines many possibilities inherent in a given situation. They can deal with hypothetical propositions, theories, idealized models, and compensate mentally for transformations in reality.

We should expect them to understand concepts defined in terms of other concepts or through abstract relationships, such as mathematical limits; imagine all possible combinations of conditions even though not all may be realized in nature; use theories or idealized models; and be able to recognize and apply functional relationships, such as direct or inverse proportion.

His or her ability to classify extends to abstract concepts, and he or she has no difficulty conserving displaced volume. Furthermore, when experimenting, he or she is able to systematically isolate variables, can make distinction between necessary and sufficient cause, and can consider the hypothetical outcomes and possibilities of the experiment.

He or she uses operations to solve problems and is unlikely to be confused by unexpected results because he or she has perceived beforehand nearly all of the possibilities. Furthermore, he or she understands the nature of probability and recognizes its implications for experimental design and data analysis.

In contrasting experimentation ability of the concrete and formal reasoning student, Piaget explains that the concrete operational subject, when dealing with complex explanations, appears limited to proceeding in a step-by-step fashion without relating each partial link to the others. The formal operational subject, on the other hand, appears to view an experiment from the start in terms of a total set of possibilities and in terms of necessary relations between propositions. In reasoning, each partial link in an explanation is grouped in relation to the explanation as a whole. Therefore, reasoning moves continuously as a function of a "structured whole."[22]

Piaget's Model as It Relates to Learning

Learning, in the narrow sense, according to Piaget,[23] involves the acquisition over time of new responses and is restricted to specific situations. Mental growth, however, involves not only learning, but intellectual development as well. By intellectual development, Piaget meant the acquisition of new structures of mental operations as a reaction to four ongoing processes. These processes are:

1. Maturation. This involves physical brain growth and maturation, which, as previously pointed out, has been found by some researchers to spurt and plateau during periods roughly correlated to Piagetian stages.
2. Logical-Mathematical. This involves experiences which are directly experienced by the learner. This is not merely a physical experience, but one in which the learner acts to order, count, etc.
3. Social Transmission. This involves the transmission of information and experiences through social interaction; that is, attending school, having a parent explain something or being read to, etc. It should be pointed out that Piaget believes that social

transmission can only be effective if the child is prepared (has the mental structures) to understand the conveyed information.

4. Equilibration (Self Regulation). This involves the integration of the other three factors and refers to the self-regulatory process which controls the exchanges between an open system and its surroundings. Equilibration is an intellectual system that deals with these surroundings in terms of the present structures of the organism, i.e., it allows for assimilation. It can also result in self-modification that allows the organism to deal with environmental demands through the process of accommodation. The tendency to equilibrium between organism and environment is the result of this process. That is, disequilibrium is succeeded by greater equilibrium. For example, incomplete understanding or confusion is replaced by greater understanding.

Piaget describes this intellectual progression in terms of strategies and the probability of adopting a particular strategy. As an example, consider the child who conserves the quantity of a liquid in terms of its height in a container. He or she may decide to change his or her strategy and consider width to be the most important consideration. This may occur because he or she sees it in a new container, short and wide instead of tall and narrow. Or he or she may be dissatisfied with always using the same old solution without being certain of its correctness. He or she may then jump between one solution and the other, until he or she begins to consider the two factors (height and width) simultaneously. It is only then that true conservation of substance can develop.

It is unlikely that the child will come up with the last strategy without going through the earlier stages first. That is, it is likely that the child will go through the sequential probability of development, which is unlikely to happen before the child has the necessary mental equipment to make use of the new experience. Only then, feels Piaget, can learning occur. If the child is not ready, he or she will either change the experience into a form that he or she can assimilate, or he or she will weakly respond to a specific situation which he or she does not have the ability to generalize.

The learning process, then, involves four phases through which the child progresses. In the first phase, the child can keep to modes of reasoning without perceiving any conflict between modes. The child then becomes aware of the conflict during the second phase, and undergoes disequilibrium as a result. He or she tries to reconcile the conflict in some way, usually coming up with a "compromise solution" which uses some illegitimate method to resolve the conflict. This third phase shows the child mentally developing an accommodating structure which indicates equilibration is going on. Finally, in the fourth phase, the child develops a legitimate means of coordinating the two schemes--an act which involves a certain amount of compensating.

It is felt, then, that the child will only profit from training when the initial developmental level of the child is high enough to allow it. That is, the child has to be ready, or at least near-ready to learn. Those children who are in a transitional stage of development can have their progress considerably accelerated by being put into disequilibrium situations.

In considering Piaget's model as it relates to the learner, one sees the difficulty in teaching abstract ideas to students who, as a result of their developmental level, are not capable of learning. The subject of physics is based, for the most part, on abstract concepts. Teaching students who operate on a formal level is no great problem. However, many high school physics students are not fully formal operational, and may even be concrete operational. Many of these students fall by the wayside if they are held strictly accountable for learning these abstract concepts. The challenge then is to find a method of moving these students to a higher level of thinking and learning. In the next section of this review, the abstract nature of physics concepts will be examined to see how they relate to formal and concrete learners.

The Abstract Nature of Physics

Can students grasp physics? This question was asked by researchers J. W. Renner and R. M. Grant[24] in an article by that name. It was asked with respect to the abstract nature of physics concepts and the knowledge that many students, including students of physics, are not fully abstract reasoners. They refer to Piaget's theory that non-abstract thinkers operate on "objects" and not yet on verbally expressed hypotheses.[25] Such thinkers, they point out, would insist, for example, that a model built on an assumption is wrong or impossible if the truth of the assumption is not known. On the other hand, an abstract reasoner is one who thinks beyond the present and forms theories about everything, delighting especially in consideration of that which is not.[26]

Using Piaget's concrete and formal thought model, Anton Lawson describes concrete concepts as those whose meaning can be developed from firsthand experience with objects or events. And formal concepts are those whose meanings are derived through position within a postulatory-deductive system.[27] These definitions shall be used as part of an evaluation of the physic concepts to be taught as part of the author's study.

To evaluate whether or not a particular concept is concrete or formal, Renner provides some examples of type of concept as commonly found in physics textbooks.[28] The following are concrete:

- Light beams bounce back evenly off mirrors;
- Steel balls bounce back evenly off steel plates;
- Real images are formed by concave mirrors;
- Light beams come to a point after reflection from a curved mirror.

In each of the preceding examples, real objects or events were referred to.

The following are examples of formal concepts:

- The energy states of hydrogen can be described by the combined picture of waves and particles;
- It is the smallness of the atom that makes atoms so difficult to detect with the unaided senses. On the other hand, it is the smallness of size and almost unlimited number which enable us to explain all the wonders of matter.

In each of these examples, the concept is defined in terms of a postulatory-deductive theory--the quantum theory in the first case and atomic theory in the second.

Renner found that in six secondary school textbooks examined there were 130 major concepts which could be classified as formal, while the concrete concepts found were always minor. Even many of the minor concepts developed were formal. This clearly indicates that the typical physics curriculum is highly abstract in nature, and it is likely, then, that only formal thinkers have a reasonably good chance at learning the subject.

A number of studies over the past decade have looked into the question of how students learn physics. Some of these studies in the field of mechanics were summarized in an article by Lillian C. McDermott, titled "Research on the Conceptual Understanding in Mechanics."[29] McDermott points out that while some researchers used physics for examining cognitive processes, and others investigated conceptual understanding in particular areas of physics, the results indicate that similar difficulties occur among students of different ages and ability, and that the persistence of these difficulties suggests that they are not easily overcome.

The studies looked at were organized by topics in mechanics and include: "passive" forces, gravitational force, velocity and acceleration, and force and motion. These topics are particularly interesting to the author of this study, as many of these topics were included as part of the "abstract concepts in physics" used here.

Passive Forces

These are forces, such as tension in a string, which respond to an applied force by adjusting its own magnitude or strength. Many students, apparently, do not recognize the existence of these forces.

In a study conducted by Svein Sjoberg and Svein Lie[30] in Norway, over one-thousand students, including secondary school students, future teachers, university students and physics graduate students, were asked a number of questions regarding passive forces, including one in which they had to indicate the forces acting on a stationary and a swinging pendulum. For the stationary pendulum, about 50 percent of the secondary students who had had one year of physics omitted the tension in the string. About 40 percent of the future teachers omitted the force as well. Even about 10 percent of the graduate students failed to indicate the force due to the string. For the swinging pendulum, quite a few students had the common misconception that a force existed in the direction of motion.

Other studies, done in the United States, point out that misconceptions concerning "normal" forces, that is, the upwards force exerted by such things as a chair in response to the weight of someone sitting in it, for example, are quite common at all levels. Part of a class discussion on this topic by junior high school students was recorded by Rosalind Driver,[31] as part of one of the first descriptive studies of student conceptual understanding in physics, indicated a common misconception with the following statement made by a student:

> That chair does not push up. If it did, when you got off, it would go 'whoop.' [Indicates upward motion with hand.] . . . These things [tables, chairs] are offering resistance.

> . . . They are not pushing up. . . . Those things, the chair, can't do anything. They are not alive.

Grativational Force

A study conducted by Audrey Champagne, Leopold Klopfer, and their collaborators,[32] involving twelve academically-talented seventh- and eight-grade students, gives us some insight into student ideas about gravity, which generally confirmed findings from other studies. The results of this study indicated that while students realize that the speed of a freely falling object increases, they also thought that speed was roughly proportional to gravitational force. It was apparent that many students confused the concepts of mass and weight and velocity and acceleration.

In another study, using older students, Richard Gunstone and Richard White,[33] at Monash University in Australia, found that when college physics students were shown a bucket of sand attached to a rope supporting a block of wood on the other side of a pulley with the bucket being placed markedly higher than the block, and asked to compare the weights of the two objects, about 30 percent of the 400 students asked had failed to state that the weights were equal.

Many of the incorrect responses implied that the block was heavier because it was nearer the floor. This is a common response found in a number of other studies, including those with younger students.

Velocity and Acceleration

In a study probing student understanding of motion,[34] it was found that many students:

- Could not distinguish clearly between the concepts of speed and position with a particular instant;
- Did not discriminate between velocity and change in velocity;
- Neglected to consider the time intervals during which changes in velocity took place.

In a number of studies concerning relative motion,[35] vector concepts of motion,[36] and projectile motion,[37] it was found that many students:

- Thought that velocity was an intrinsic property of an object, independent of reference frame;
- Did not recognize that the propulsion system of a boat is independent of the speed of a current in a river;
- Believed that when the horizontal force is removed from a projectile, the horizontal velocity ceases abruptly and the object falls vertically.

Force and Motion

The relationship between force and motion is widely recognized as misunderstood by those untrained in physics. The idea that a force is always necessary to sustain motion, even at steady speed, is an example of a common misconception. McDermott, in her review, points out that researchers have found that this and similar ideas are not readily abandoned, but are retained together with the accepted scientific view.

Many of the difficulties arise from the difference in meaning ascribed to many technical terms by the physicist and the layman. Words such as "force" and "acceleration" are often used indiscriminately by the layman, who often interchange such words as "force" and "momentum."

In a study involving curvilinear motion and trajectories by M. McCloskey, A. Caramazza, and B. Green at John Hopkins University,[38] about 50 undergraduates were asked to trace the path a pendulum bob would follow if the string were cut at each of four different positions along its path. They found that only one-fourth of the students gave an essentially correct response for all four situations. In many cases, the students ignored the velocity of the bob at the instant the string was cut, indicating the bob would move in a direction the researchers believed constituted a model of motion reminiscent of the medieval theory of impetus, i.e., the object will continue moving in its original manner until the initial "force" that set it in motion is "used up."

John Clement, at the University of Massachusetts, examined how pre-engineering students perceived the relationship between force and motion[39] by administering a written examination early in the course and at the end. The same written tasks were also presented to a smaller number of students during individual interviews that were videotaped. One task involved drawing a force diagram for a coin just after it had been tossed in the air. A typical response indicated that "force from your hand gradually dies away as it pushes on the coin."

Clement listed a number of characteristics, which he grouped together and labeled the "motion implies a force" misconception. This model includes the concept that all motion, even at constant velocity, implies a force in the direction of motion that is greater than any opposing force, and that changes in motion can be accounted for by forces that "die out" or "build up."

L. Viennot,[40] at the University of Paris, tested about 2,000 French, British, and Belgian students from the university and secondary school levels with respect to their understanding of the relationship between force and motion. From their responses, Viennot constructed a model for how students think about force. According to this model, students hold both Newtonian and non-Newtonian conceptions of force. If the motion is not directly accessible, either through direct observation or from a diagram, students use the correct Newtonian force in solving the problem. If, however, the motion is obvious, it depends on whether or not the motion is in the same sense as the force acting on it for the student to use the correct Newtonian explanation. If the student believes there is a conflict between the motion and the direction of acting force (as in the case of a force acting in a direction opposite to the velocity), he or she will attempt to account for the motion by introducing a non-Newtonian force. This new force: is in the direction of the motion; is proportional to the velocity instead of the acceleration; and is not well localized in time and space.

In another study, the computer was used to investigate student conceptual difficulties concerning the force-motion relationship. Andrea diSessa and Barbara White,[41] at the Massachusetts Institute of Technology, designed tasks in which students used keyboard commands to move a simulated object on a screen.

DiSessa developed a series of games to explore student understanding of force and motion which were used by students of different ages. The games featured a "dynaturtle" that moved according to Newtonian laws of dynamics, and the students were asked to make the dynaturtle move with different speeds and directions in response to the application of suitable "kicks."

White designed computer games to address conceptual problems she had previously identified through written pre-tests administered to high school students taking PSSC physics. Students maneuvered a simulated spaceship through a frictionless, idealized environment which provided experience and immediate feedback. She found significant improvement on written post-tests followed the playing of these games.

These and other studies described by McDermott point out that many students emerge from their study of physics without a functional understanding of some elementary but fundamental concepts, and the difficulties these students have are related to the abstract nature of these concepts, as well as the intuitive preconceptions the students may have.

Many of the difficulties students have learning physics concepts are based on the same reasons that they have difficulty learning chemistry. J. Dudley Herron,[42] of Purdue University, notes that: "Over the years, I have observed that any concept which involves a ratio is extremely difficult for many students; density, velocity, acceleration, molarity, and reaction rate are names for a few of those concepts." He indicated that while students are able to memorize an algorithm for making numerical calculations of these qualities but appear to have such poor comprehension of the idea, they are unable to apply the concept to any problem different from those analyzed and discussed in class. Herron cites, as an example, students who have learned how to calculate density from mass and volume data are frequently unable to answer simple questions such as, "Water has a density less than that of sulfuric acid. Which would have the greater volume, 100 g of water or 100 g of sulfuric acid?"

Testing the theory that students who were formal reasoners would do better in Herron's chemistry course than concrete operational students, he selected a random sample of 20 students. Seventeen of the sample who were available for testing were given a battery of Piagetian tasks administered by three science students in science education. Scores on this battery of tests were then correlated with the total points earned in the course using the Pearson product-moment correlation. The best estimate of the correlation obtained was 0.8.[43]

Herron was not certain as to what extent this relationship would hold for other chemistry courses, but he thought it would be high. Thirty-three students from a number of freshman courses were given this same battery of Piagetian tasks. Scores on this battery were correlated with scores on a chemistry placement test. Although these students were not representative of the students in the chemistry classes since a large proportion of them were among the better students which would result in an estimate of correlation lower than what actually exists, the correlation was still a substantial 0.7.[44]

While Herron believes that formal concepts are not really accessible to students who are not formal in their thought, he feels that it would be impossible to make chemistry any less abstract than it is without returning to ". . . a course based on blind memorization of a catalog of descriptive chemical facts is as repugnant to me as the continuation of courses based on the blind memorization of inscrutable theory."

If chemistry is considered a highly abstract subject, certainly physics, which is filled with abstract models and concepts, must be considered abstract as well. However, in a study done by H. D. Cohen, D. F. Hillman, and R. M. Agne, only a weak correlation was found between the level of physics course taken and final course grade.[45] In this study, 195 undergraduate students at the University of Vermont were randomly chosen to participate in the study. Students were drawn from four introductory physics courses, each course representing an increased level of sophistication.

All the students took a battery of tests which included at least one Piagetian task at the very beginning of their respective courses. One hundred eighteen students participated during the first round of testing and were given three Piagetian tasks (Floating, Pendulum, and Shadows) to accomplish. The remaining 77 students participated in a second round of testing and were given one Piagetian task (Chemicals). After the first round of testing, it was concluded that two of the Piagetian tasks were inappropriate (Floating and Pendulum) for the subjects involved, as a large number of the subjects had been exposed to the precise content of these tasks during high school science courses.

The researchers found that the correlation between course level and Piagetian level was "just significant" and that the correlation between student grades, averaged over a two-year period with two different instructors, of 53 students from the lowest level course was also just significant. Additionally, the researchers found that when Piagetian level was compared with course grade, which was also found by averaging over a two-year period with two different instructors, for the top level course no correlation existed. Their conclusion was that their data showed little correlation between course grade and Piagetian level.

This, they felt, was most true for the most advanced courses which were likely to be the most formal.

It is interesting to note that a careful reading of Cohen and his associates' paper indicates that the researchers used only one Piagetian task to test each student's Piagetian level. As the individual task used could only test one aspect of the student's formal reasoning ability, it would seem unlikely to be a reliable measure. When you then consider that in testing a population of college physics students, especially in a higher-level class, you would not expect to find much of a range in reasoning ability. Expecting to find strong correlations then would seem not very likely.

W. T. Griffith,[46] of Pacific University, also investigated the relationship between Piagetian cognitive level and performance in introductory physics courses. In this study, Griffith uses a test of formal reasoning developed by Griffith and Weiner which they call the Science Logic Test (SLT).

The SLT is a pencil-and-paper test of some of the logical operations identified by Piaget as components of formal thinking. The 12-item test includes two or three items from each of five subscales: proportional reasoning, probalistic reasoning, combinatorial reasoning, hypothetical reasoning, and control of variables. The selection criteria for these items included difficulty level, correlations with test total, item-item correlation, and correlations with performance on interview-style Piagetian tasks. An important feature of the test, Griffith points out, is that it covers a wide range of formal operations. He cautions that any test involving just three or four items usually would not cover a wide enough range to be a reliable predictor.

Course grade was based primarily on examinations given throughout the term. By prior agreement, 25 to 30 percent of the questions asked were qualitative and conceptual in nature. These conceptual questions took a variety of forms, including explanations of physical concepts, interpretation of graphical information, and prediction of physical effects in qualitative terms.

The results of the study indicated that the SLT was an important predictor of performance in their introductory physics courses and that it was an even better predictor of performance if only qualitative or conceptual items were considered as the basis of determining student performance.

In another study dealing with physics concepts, this time with 10 to 13 year-olds, M. Shayer and H. Wylam indicate that: "It has been possible not only to show a unitary relationship between estimates of Piagetian stages of development and levels of understanding in a wide variety of Heat concepts, but also to report the findings in the form of an addition to the body of cognitive development findings already published by Piaget."[47]

In summary, the preponderance of evidence seems to indicate that much of what is studied in physics is abstract in nature and difficult to learn. Furthermore, there is a correlation between performance in physics, especially when performance is based on ability to understand the conceptual aspects of the subject, and Piagetian developmental level.

Use of the Computer Language Logo

Learning the abstract concepts of physics, as indicated in the preceding section, is generally a challenge. For those of us who do not reason in the formal sense, as defined by Piaget, learning these abstractions may be beyond reach. Certainly there are a large number of researchers who feel that the ability to learn abstract concepts is directly related to one's stage of intellectual development.

A number of researchers and educators have tried to design educational programs based on Piagetian theory. An example of one such program was developed by R. Karplus, A. Lawson, W. Wollman, et al., to aid educators to understand the large differences in the abilities of students to learn science concepts, and to aid teachers to respond effectively to the learning problems associated with these differences.[48] While the methods described are interesting, they do not appear that different from methods presently used by many good science teachers, which have met with varying degrees of success. Their approach emphasizes extended exploration of a phenomenon before the introduction of formal concepts related to the phenomenon, and then followed by a period of concept application.

But in the last ten years or so, there has been a virtual explosion of computer use for educational and personal purposes. With the increased availability of the computer, educators and researchers have had the opportunity to examine a number of novel approaches to education which uses the computer as its main point of focus.

While there are a number of promising computer techniques and computer languages available, the language called Logo has apparently captured the imagination and interest of an increasingly large number of educators and school systems. A few years ago, only a handful of teachers ever heard of the language, and now there are very few teachers, especially in the elementary schools, who have not.

Toby Tentenbaum and Thomas Mulkeen, in an article titled "Logo and the Teaching of Problem Solving: A Call for a Moratorium,"[49] point out that during the year 1982 alone, the use of Logo in schools jumped from less than a dozen sites to hundreds; and it is expected to involve thousands of classrooms with tens of thousands of students within the following year. They believe that: "Logo's appeal lies not as much in its programming capabilities as in the claim that it is a language for learning how to think. Its proponents believe that along with its introducing the concepts for programming, Logo promotes meta-cognitive skills, like planning and problem solving." Tentenbaum and Mulkeen believe that the excitement Logo has generated comes not so much from a perceived value to program per se, but from a belief that through learning to program in Logo, children's cognitive capacities will be greatly expanded and they will develop higher-level cognitive skill which will generalize or transfer to other content areas.

In what way, then, is Logo considered to be different? To begin with, as Harold Abelson,[50] one of Logo's developers, points out, those who designed Logo do not look at it so much as a programming language, but ". . . rather as a computer-based learning environment, where activities are just as integral as the programming tools used." The best kind of Logo activity, says Abelson, is a ". . . synthesis of programming, mathematics, aesthetics, and, above all, the opportunity to explore."

But perhaps the most outspoken advocate of Logo is another of its developers, Seymour Papert. Papert, an MIT mathematician who trained with Piaget in Geneva, believes Logo is an educational innovation that could make a vast difference in the way children learn. His reasons for believing this is expressed in his book Mindstorms.[51]

Papert writes that there are two fundamental ideas that run through his book. The first is that it is possible to design computers so that learning to communicate with them can be a natural process, more like learning French by living in France than like trying to learn through the unnatural process of American foreign-language instruction in classrooms. Second, learning to communicate with a computer may change the way other learning takes place.[52]

The type of learning that Papert is referring to he calls "Piagetian learning," learning without being taught--the vast quantity of knowledge children gain long before going to school; and he wonders why some learning takes place so early and spontaneously while some is delayed many years or does not happen at all without deliberately imposed formal instruction. Papert agrees with Piaget that the child builds mental structures as he or she learns, but is at variance with him or her as to the role the surrounding culture plays at supplying the materials for building these structures.

"In some cases, the culture supplies them in abundance, thus facilitating constructive Piagetian learning," says Papert. ". . . But in many cases where Piaget would explain slower development of a particular concept by its greater complexity or formality, I see the critical factor as the relative poverty of the culture in those materials that would make the concept simple and concrete."[53]

In an article called "Computer as Mudpie,"[54] Papert clarifies his view by explaining that Piaget believed that specific kinds of learning only happened after the age of 10 or 11 years. The learning that begins at this time is called "formal learning." Things learned at the "formal" stage are not rooted in real life, that is, in the social, affective, natural life and cultural environment of the child. According to Piaget, the child has to learn such things by formal instruction.

On the other hand, Papert believes Piaget was wrong in his ideas that particular skills and pieces of knowledge must be learned formally while others must be learned naturally. Instead, he believes that what is learned during the natural stage and what is learned during the formal stage depend upon the world in which we live. "The fundamental question is: How can we create a culture, an environment for the child, that is rich in natural learning?"

He indicates that to many in the teaching profession, "education" means "teaching," particularly classroom teaching, and the goal of educational research is finding out how to improve classroom teaching. The model of successful learning is the way a child learns to talk. This process, says Papert, takes place without deliberate and organized teaching.

Papert believes the classroom is an artificial and inefficient learning environment that society has been forced to invent because its informal environment fails in certain learning domains, such as writing or grammar or school math. His interest is in developing "object-to-think-with," objects which serve as an intersection of cultural presence, embedded knowledge, and the possibility for personal invention. The Logo "Turtle," he believes, serves no other purpose than to be good to program with, and good to think with.

The Logo environment, explains Papert, teaches children to think by having them teach a computer how to think. ". . . Thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults." The computer can "concretize" and personalize the formal, and is unique in its ability in providing the means for addressing what Piaget and others see as the obstacle which is overcome in the passage from child to adult thinking.

The computer, says Papert, "by providing a very concrete down-to-earth model of a particular style of thinking . . . can make it easier to understand that there is such a thing as 'style-of-thinking.'" Giving children the opportunity to choose one style of thinking or another gives children the opportunity to develop the skills necessary to choose between styles; and that learning to program in Logo provides the basis for this new way of learning. Programs are constructed to become building blocks that enable a child to create hierarchies of knowledge, and powerful intellectual skills are developed in the process.[55]

In order to learn something, you have got to make sense out of it. This type of learning is what Piaget referred to as "syntonic learning"--the acquisition of acceptable ideas. Turtle geometry is an example of syntonic learning. It allows the student to develop strategies for problem solving by subdividing the problems into simpler problems by turning the abstract elements of the problems into concrete procedures.

Papert refers to mathetics, which is the guiding principle that governs learning, as being to learning as heuristics is to problem solving. Logo learning is based on two important principles of mathetics which state:

1. Relate what is new and to be learned to something you already know.
2. Take what is new and make it your own.

These ideas are reflected in Piaget's study of spontaneous learning, in which Piaget found that the child absorbs the new into the old in a process he calls "assimilation," and the child constructs his or her knowledge in the course of actively working with it.

But Papert points out that there are roadblocks in this process. New knowledge contradicts old, and effective learning requires strategies to deal with such conflict. Sometimes the conflicting pieces of knowledge can be reconciled, sometimes one or the other must be abandoned, and sometimes the two can be safely maintained in separate mental compartments. These learning strategies are evident when formal theory of physics enters into sharp conflict with common sense, intuitive ideas about physics.

One of the simplest of such conflicts, Papert points out, is raised by the fundamental tenet of Newton's physics: A body of motion will, if left alone, continue to move forever at a constant speed and in a straight line. This principle of "perpetual motion" contradicts common experience and, indeed, older theories of physics, such as Aristotle's.

People who want to learn Newtonian physics may not be able to apply mathetic principles. They may not possess any knowledge to which the physics can be effectively related. Also, one may not be able to apply the Newtonian physics easily.[56]

However, by using the Logo "dynaturtle," which has the property of momentum, as the building block for learning formal physics, the Newtonian principle can be made concrete. As the child works with the dynaturtle, he or she assimilates its properties and can develop the means of applying the concepts assimilated; and this can all be done without the prerequisites normally needed to learn them.

In the absence of direct and physical experience of Newtonian motion, teachers are forced to give students indirect and highly mathematical experiences of Newtonian objects. There movement is learned by manipulating equations rather than manipulating the objects themselves. The experience, lacking immediacy, is slow to change the students' intuitions.

"Dynaturtle, instead of making students wait for equations, can motivate and facilitate the acquisition of equational skills by providing an intuitively well-understood context for their use." In this way, students use Newtonian turtles to make Newton their own.[57]

As far as dealing with the counterintuitive aspects of Newtonian physics is concerned, Papert goes on to say that: "Everyone knows the unpleasant feeling evoked by running into a counterintuitive phenomenon where we are forced, by observation or by reason, to acknowledge that reality does not fit our expectations."

Papert feels that when our intuition cannot be trusted, we have to improve our intuition; but the pressure is on us is to abandon our intuition and rely on equations instead. When the student tells his or her teacher that he or she cannot "believe" the phenomenon he or she may have just seen, the teacher responds by writing the equations which prove it is so. But equations are not what the student needs. He or she already knows that it is true, but his or her knowledge conflicts with his or her intuition. What he or she needs, says Papert, is a better understanding of himself or herself, and not the phenonemon. He or she needs to know how to work on his or her intuitions in order to change them.[58]

The computer can help the student understand counterintuitive ideas in two ways. First, the computer allows, or obliges, the child to externalize intuitive expectations. Papert believes that when the intuition is translated into a program, it becomes more obtrusive, and more accessible to reflection. Second, computational ideas can be taken up as materials for the work of remodeling intuitive knowledge.

While Papert's ideas are much influenced by Piaget, he is not concerned with Piagetian stages; what children at certain ages can and cannot do. Instead, he is concerned with Piaget, the epistemologist, as his ideas relate to the knowledge-based theory of learning that Papert describes. This theory of learning does not "divorce the study of mathematics learned from the study of mathematics itself."[59]

The epistemological aspects of Piaget's thoughts have been underplayed until now because they offered no possibilities for action in the world of traditional education. This will not be the case, says Papert, in a computer-rich educational environment. Piaget's stage theory tends to emphasize what children cannot do, says Papert, and he strives to uncover the Piaget whose epistemological ideas might expand the known bounds of the human mind. These Piagetian ideas will be placed in a theoretical framework drawn from a side of the computer world artificial intelligence, or AI.[60]

AI is concerned with getting a machine to perform "intelligently." Part of this process is to design "learning" capacity into the machine. To do this, it is necessary to probe deeply into the nature of learning which moves AI research from the realm of advanced engineering to the cognitive science area--to epistemology. AI theories and methodology, says Papert, especially those drawing heavily on theories of computation, are being used to reinterpret Piaget. It is giving concrete form to ideas about thinking that previously might have seemed abstract, even metaphysical.

Papert believes that Piaget, the epistemologist, is really talking about the development of knowledge when he talks about the developing child. And while the psychologist studies the laws that govern the learner rather than on what is being learned, Piaget believes it is a mistake to separate the learning process from what is being learned.[61]

Piaget, says Papert, stressed the theoretical aspects of the internal events within the learner's mind as it interacted with the external world, while his perspective is more interventionist. His goals relate to education, not just understanding. He places an emphasis on two dimensions which are implicit, but not elaborated in Piaget's own work: an interest in intellectual structures that could develop as opposed to those that, at present, actually do develop in the child; and the design of learning environments that are resonant with them.[62]

The claims made by Papert and his associates concerning Logo's ability to revolutionize educational thought have had some glowing testimonials. For example, an article by W. Higgins, of Queen's University, describes some early observations Higgins and the Education department faculty at Queen's University made on the use of Logo, titled "Leading Fish to Water: Early Observations on the Use of Logo."[63] These observations, which are rather qualitative in nature, describe the interaction of faculty members and others with small groups of children (in some cases their own) who were being taught to use Logo.

They found that Logo appeared to touch something quite fundamental in children's learning procedures irrespective of the "school ability" of the child, and that the speed at which the group of self-confident 10 year-olds in an afternoon enrichment class grasped ideas was quite impressive.

"The unforced way in which powerful ideas emerge from the turtle geometry microworld," says Higgins, "is in stark contrast to the struggles of traditional teaching. The old riposte 'you can lead a horse to Euclid but you can't make him think' did not seem to apply." Higgins felt that the naturalness of the children's responses to questions that emerged from Logo situations made him feel that he was bringing fish, not horses, to an educational pond.

But as research on Logo increased, some doubt, and a certain amount of equivocation, concerning the widespread adoption of Logo began to surface.

Tentenbaum and Mulkeen, for instance, in a previously-mentioned article ("Logo and the Teaching of Problem Solving"),[64] remind us that the idea of Logo expanding cognitive skills which are transferable to other content areas was believed of the study of Latin by earlier generations. Unfortunately, evidence from Thorndike[65] suggested that the study of Latin did not further this goal, and subsequent research failed to find appreciable transfer from training on one task to success on another.

Examination of existing research and study of the use and benefits of Logo indicates some widely different opinions and findings. Dan Watt, in an article titled "Logo in the Schools," gives a description of some of this research, including one of the earliest studies of Logo in a school situation, which took place in Brookline, Massachusetts.[66]

The Brookline Project[67] was a collaboration between the Brookline school system and the MIT Logo Group and was sponsored by the National Science Foundation (NSF). The emphasis of the research was the observation and documentation of what a group of sixth graders actually learned during their study of Logo, rather than assess whether or not they achieved pre-planned objectives.

Fifty sixth-grade students were given the opportunity to learn Logo in a computer laboratory. The work of 16 of these students, representing a full range of academic ability and interests, were selected for study. This included monitoring, analyzing, and documenting what these students learned, what learning styles they used, and what types of choices they made.

While introductory turtle geometry projects were stressed at the beginning of the project, students could then choose a variety of activities, such as math and word games, computer conversations, animations, tic-tac-toe, and dynamic action games. Students were expected to make their own choices while teachers helped them to accomplish their goals.

The results of the project indicated that the Logo learning environment was suitable for a wide range of students, with both gifted and "poor" students being successful in their Logo class.

The Brookline Project was not very successful in obtaining "objective" data about the learning gains made by the students. Standardized tests were rejected as irrelevant to the goals of the project, as such things as the ability to do turtle geometry are not measured by sixth-grade math tests. The problem-solving tests and mathematical tests devised and administered by the project staff had inconclusive results. The problem of developing objective tests in such areas as problem solving or procedural thinking is still an open question for educational researchers. The project was also limited by the need for extremely sensitive and knowledgeable teachers, with a great deal of time to consider the needs of each student.

A second project undertaken by the MIT Logo Group was done in collaboration with the Lamplighter School,[68] a private school in Dallas, Texas, and the Texas Instrument Company, which supplied the necessary computers for the project. In this project, 400 students between three and nine years of age were put in a setting in which student access to computers would not be a limiting factor. A goal of the project was to see what students could accomplish under these circumstances.

The project was responsible for training teachers, providing computers, and developing a Logo environment. But with a few minor exceptions, the research studies that were expected to be part of the project did not materialize, and some of the anticipated results of the project never happened. For example, the students have not used computers for creative writing, and Logo had not been integrated into the school's curriculum as had been planned.

Another project at the Lamplighter School, which is described by Henry Gorman of the University of Texas Psychology Department in an article titled "The Lamplighter Project,"[69] was to determine if Logo could be used by students to learn better thinking, problem-solving, and learning skills.

Gorman points out that it is quite complicated to measure thinking, problem solving, and learning skills; as no one test, and no single study, can do more than explore these skills and the change in them as a result of students using Logo. To perform the experiment, students in the third grade at Lamplighter School were randomly assigned to one of three homerooms which had two computers each. Five more computers were located in a shared space between the two rooms.

After homeroom, students went to classes with each of the third-grade teachers. Two of the third-grade homeroom teachers elected to insure that each pupil received one-half hour of Logo a week and the other teacher set a one-hour-a-week minimum for her students. This difference existed from the start of the school year through the last week in April when students from all three classes were given the task of learning the "condition rule" taken from the cognitive psychology test called the Rule Learning. In this test, students are shown a series of pictures, usually with one of several shapes in several colors, with size of the shape shown either small, medium, or large; and with one, two, three exact replicas of the shape present. In rule learning, students are told which feature to pay attention to and are required to learn what combination of relevant features satisfies the binary rule chosen by the experimenter. To solve a rule-learning task, students have to be able to symbolically manipulate the features, ignore irrelevant features, process information, and combine that information with their memories from previous pictures. For third graders, the conjunctive and disjunctive rules are fairly simple, but the conditional rule is much more difficult for them, and the biconditional rule harder still.

It was found that the students from the one-hour Logo homeroom performed significantly better than the two other groups, and Gorman believes that "what is most important about these results is that children were not taught to the test; rather, their extra Logo sessions improved a more general problem-solving skill."

In another project described by Watt, this one in Edinburgh, Scotland,[70] the objective of the project was to discover whether students' ability to do mathematics and talk about their mathematics was changed by exploring mathematical problems through Logo programming.

The project lasted two years, during which the students attended a Logo laboratory at the University. For the first year, students taken from the lowest math level group worked through graded worksheets to learn the basic elements of Logo. For the second year, they did special Logo exercises designed to teach topics selected from their regular mathematics curriculum. The project was highly structured in several respects. The students' learning experiences were structured by means of assigned worksheets that they worked through in order, at their own rate. During the second year of the project, Logo activities were drawn from such mathematical topics as areas of rectangles, factors and multiples, positive and negative numbers, and plotting coordinates on graphs.

Students were given standardized tests in mathematics before and after the project. Their progress was compared with that of a control group drawn from boys in the second lowest level group. Both groups of boys, as well as their teachers, were given a series of questionnaires designed to measure their attitudes toward mathematics.

The results of the project on student achievement were not very dramatic. Over the two-year period, the experimental group improved a bit more than the control group on a "basic math" test, but the reverse was true on a "math attainment" test. The most interesting finding had to do with the teachers' perception of the students in both groups. Teachers found that students who had taken part in the Logo classes were more willing to "argue sensibly about mathematical issues." This may have depended as much on the teaching approach used by the Logo teachers--and on the individual assistance the Logo students received--as it did on the Logo activities themselves.

While the results of the Edinburgh Project was not convincing, at least one point seems clear: The highly-structured methods of teaching Logo used here do not follow the discovery-learning pedagogy advocated by the developers of Logo.

In another research project, this was undertaken by Roy D. Pea and his associates at the Bank Street College of Education in New York.[71] In this study, the discovery-learning approach to the teaching of Logo was used.

The purpose of this study was to test "this idea--that programming will provide exercise for the highest mental faculties, and that the cognitive development thus assured for programming will generalize or transfer to other content areas." That is, is the claim that programming is the "Wheaties of the mind" true?[72]

Pea points out that much of the evaluation of the empirical validity of the claims made by Papert and his colleagues are based on qualitative studies. While these studies were interesting, they did not directly address the ". . . widely touted claims for the development of thinking skills that transcend the programming context, for which case-study methods are inappropriate."

The research done by Pea and his colleagues was designed to test student ability to understand Logo commands, write Logo programs, and find errors in pre-written programs with two classes of 25 children. One class consisted of 8 and 9 year-olds, and the other was made up of 11 and 12 year-olds.

The results of this study indicated that the older children understood Logo commands significantly better than the younger group. Pea found that the performance on the command comprehension task was revealing: out of 100 possible points, the mean score for commands understood in terms of this measure was 34, with a large deviation of 25, and only three out of the 50 students scored between 75 and 95.

In a second study, it was found that even the best programmers often displayed production without comprehension.

A third study involved a longitudinal pre-post investigation of groups of children who were provided with extensive opportunity to program in the Logo language over a school year. Matched with non-programming students, they showed no differences in planning strategy or plan "debugging" a classroom chore-scheduling task. Pea found that this study did not demonstrate that learning Logo helped students to develop strategies for solving dissimilar problems.

Pea also found that while entry level Logo did not present conceptual problems for the school-aged child, its procedurality which allows one to define new procedures and use them as building blocks in increasingly complex programs, its control structures that allow very brief recursive programs that can solve quite difficult problems, present deeply challenging conceptual problems to children. "Logo," says Pea, "is cognitively complex beyond its early steps, and quite difficult to learn without instructional guidance, even if students are intellectually engaged with that learning."[73]

Pea and his colleagues conclude that with thoughtful instruction, which will require developmental research for its design, they expect that Logo may provide a good window for the child into important computational concepts. "With accompanying instruction in thinking skills, perhaps using Logo or other programming languages as a vehicle for discussing heuristics and problem-solving methods, developments in planning skill may in fact be achieved."

As one can readily see, most of the qualitative studies reviewed here seem to view Logo learning in quite favorable light, while the more quantitative, objective studies are rather less than favorable. Clearly, objective studies dealing with cognitive concepts are difficult to design and difficult to carry out; and there really has not been a sufficient number of them to come to any decisive conclusions.

The Logo Environment

The learning environment in which a child finds himself or herself is almost certainly an important factor in just how much that child is going to learn. The environment for learning Logo is no exception. In fact, according to the developers of Logo, it is a critical factor.

In an article titled "Creating a Logo Environment," Tim Riordan examines the elements of what he believes is an appropriate Logo environment. He begins by indicating that while it is necessary that the teacher must be trained in the Logo language, the training is not sufficient. He states: "Most teachers need not only to learn the language but also how to implement Logo--how to create a Logo environment in the classroom."[74]

A Logo environment, he says, needs more than computer stations; it needs psychological and physical space as well. It must take into account the interaction between students and adults.

For example, the teacher must watch the students work, and seeing a student encounter an unexpected result, may ask whether the student has a theory about what caused that result; and perhaps share this interaction with the entire class. Students not only interact with the teacher, but among themselves. Some students may become "experts" on some aspect of Logo. Students who are having problems should be able to seek the help of these experts.

Invariably, students will discover different ways of accomplishing a task. The teacher does not try to coerce the student into adopting another method, as each procedure is valued. The teacher is sensitive to accepting different intellectual styles.

In general, Riordan indicates a number of qualities which he feels are important for a teacher of Logo to have, so that the appropriate Logo environment can exist. These include:

- Being sensitive to whether or not students are headed for frustration.
- Having in mind a sequence of Logo concepts and a large repertoire of Logo project ideas.
- Often considering the teaching role not as a repository of answers but as a midwife helping students to discover answers by theorizing about problems and unexpected results.

A Logo environment, says Riordan, has many of the attributes of a democratic classroom. Authority is distributed; sharing and cooperation are promoted; students look to their classmates as legitimate sources of information; because students make project choices, variety rather than uniformity is the norm; rewards are intrinsic; differences in working styles are valued; and, there is a sense of shared learning.

In answering the question of why such an environment should be set up in the classroom, Riordan refers to Seymour Papert's belief that children can learn many important things without formal instruction. Just as children learn their own language from a language-rich environment, Riordan points out that "a Logo environment must be a . . . mathematics-rich environment, a context including not only a computer, walls and floors with project ideas, but also how students and the teacher interact with each other in an environment where mathematics objects and ideas are joyfully shared, played with, discussed and encouraged, mathematical intuitions and language will be learned without excessive formal instruction. What lies behind this is a Piagetian view of children who learn because they naturally make and revise theories about things they are interested in."[75]

Riordan points out that the question of scope and sequencing is problematic, and that the inventors of Logo ". . . fear that publication of a scope and sequence will invite the belief that students should be accountable for learning Logo concepts. This will inevitably lead to evaluation of student learning. This will lead to Logo being a joyless, unnatural learning activity. Logo was not meant to be taught, and the kind of learning that occurs was not meant to be evaluated like other school learning!"

Having said that, Riordan presents the following scope and sequence:

- Moving the turtle around the screen and the REPEAT command

- Saving pictures on disks

- Creating procedures -- TO command
- Saving procedures on disks
- Editing procedures -- moving the cursor around the editor
- Problem-solving strategy -- take it, walk it, turtle talk it
- Placing designs on screen -- RANDOM and SETXY primitives
- Using variables
- Doing and printing arithmetic
- Using procedures in other procedures
- Analyzing designs -- repeated but slightly changing patterns
- Dynaturtle
- Making a "hot" keyboard (individual keys make things happen)
- Music procedures
- Printing numbers, words, and lists -- WORD, SENTENCE primitives
- Superprocedures and subprocedures
- Planning a game
- List processing commands -- FIRST, BUTFIRST, LAST, BUTLAST primitives

Dan and Molly Watt, in an unpublished grant proposal summary titled "Collaborating With Teachers to Evaluate Critical Aspects of Logo Learning,"[76] indicate some concern with respect to many educators' interpretation of Papert's emphasis on "natural learning." They believe that these educators take Papert to mean Logo can be learned by children simply interacting with the computer, with a minimal amount of instruction. They believe that Papert's goal of putting the child in control of the computer has been taken by some teachers to mean that the teacher should just stand back and let the student discover the powerful ideas embedded in Logo entirely on their own.

However, they say that they found the opposite to be true. They envision Papert's Logo as an open-ended learning environment in which learners (adults as well as children) can take a large share of the responsibility for their own learning. It requires a teacher with a deep understanding of critical aspects of Logo learning, a large collection of ideas for supporting student projects, and probing student understanding.

Commenting on this question, Alan Altman, in an article titled "Pulling in the Reins on Freewheeling Logo,"[77] felt that he needed to have some control over students' free exploration. As a result, he developed certain restriction strategies which, in combination with free exploration time, he felt would lead to a rich and balanced Logo experience. The purpose of using these restriction strategies was to focus student attention on aspects of Logo which would be useful to them during their free exploration time.

During the activities, the students could only work on assigned tasks, for which new Logo primitive structures were introduced. Students were then encouraged to incorporate these ideas into their free exploration.

These strategies include:

- Pattern Search Strategy: The goal of this strategy was to get students to organize their data and think about possible mathematic relationships.

- Group Project Strategy: The purpose of this strategy was to get students to focus their energy on a specific programming problem.
- Modules Modification Strategy: In this strategy, students are given a secure starting point for their activities by outlining a simple framework for the type of procedure they were to work on. The class then modified and elaborated on this framework.
- Practice Game Strategy: In this strategy, games are used to focus the student's attention on a specific task, and to give them practice in accomplishing this task.
- Classroom Management Strategy: The goal of this strategy is to maximize student access to the computer.

Reining in the perceived notion of a freewheeling, completely spontaneous Logo teaching situation is a matter which Papert refers to himself. He discusses the problems associated with a Logo curriculum in Mindstorms when he refers to the "Piagetian curriculum or Piagetian teaching methods," and indicates that he sees these phrases as a contradiction in terms. He states, "I see Piaget as the theorist of learning without curricula and the theorist of the kind of learning that happens without deliberate teaching. To turn him into the theorist of a new curriculum is to stand him on his head."[78]

But, he says, that teaching without curricula does not mean spontaneous free-form classrooms or simply leaving the child alone. It means supporting children as they build their own intellectual structures with materials drawn from the surrounding culture. In this model, educational intervention means changing the culture, planting new construction elements, and eliminating noxious ones.

"The Logo teacher will answer questions, provide help if asked, and sometimes sit down next to a student and say: 'Let me show you something.' But what is shown is not dictated by a set syllabus."[79]

The instructor in a Logo environment does not provide an answer for the child who demands: How can I make the Turtle draw a circle? but rather introduces the child to a method for solving not only this problem but a large class of others as well.

Molly Watt, in an article titled "What Is Logo?" states that the role of a Logo teacher will include being a demonstrator, teacher/lecturer, teller, time structurer, problem setter, management solver, arbitrator, decision maker, challenger, helper, collaborator, process sharer, question asker, idea extender, observer, documenter, admirer, enjoyer, time provider, technician, and model learner.[80]

Furthermore, his or her students are required to keep a journal of process notes, questions, and descriptions of problems encountered. He or she reads these and responds to them regularly.

During the time his or her students are at the computer, he or she takes the time to "wander, watch, listen, and answer." He or she feels that the words he or she uses are important. Instead of solving a problem for a youngster by telling or showing the solution immediately, he or she usually asks the student to describe the problem, or tell him or her what happens, or asks the student to try it and show him or her. Some Logo teachers, she says, asks the student to teach them what they did.

Watt indicates that this type of response is important because giving a description is a matter-of-fact task which can diminish emotion and allow the describer to see what actually happens clearly. If after the student describes the problem and neither of them knows how to solve it, they write a plan together in "plain English words."

Invariably, errors will be made in writing computer procedures. Papert believes that "school teaches that errors are bad; the last thing one wants to do is to pour over them, or think about them." But in the Logo environment, the children learn that these errors are part of the learning process, and that everyone can learn from their mistakes.[81]

In a Logo environment, these errors are not looked upon as "mistakes," but rather as a natural part of writing computer programs. These errors are known in computer parlance as "bugs," for historical reasons going back to the pioneering work in the computer field.

A "bug" occurs, according to Robert Lawler, when the result of a procedure turns out to be different from what was expected. "But sometimes the surprising result is a better one than what you first intended. That's a 'new discovery' bug." He believes it to be one of the best kind. "Any bug," says Lawler, ". . . which makes your procedure do the unexpected--if you bother to figure it out--leads to an increase in knowledge. Although a bug may hinder your objective, the bugs in your procedures will offer the best guidance on what to learn in order to master the Logo programming environment."[82]

Clearly, it is believed that in a Logo environment errors are not only not bad but they may be good. Therefore, a very important part of writing a computer program is the process of "de-bugging" it, and Logo's emphasis on debugging allows it to become part of a learner's cognitive style. It helps students to develop and articulate language which focuses on their problem, so they know just how to ask for help when it is needed.

Molly Watt, in an article titled "De-Bug Collection," points out that "debugging is a programming skill rather than a nuisance to be avoided." She goes on to explain that the debugging tools provided within Logo are designed to teach how to correct errors. "There is no shame involved in having a bug," she says. Examining what does not work and figuring out how to correct it could be considered a most important and transferable skill.[83]

Part of being a Logo teacher is understanding one's own problem-solving strategies and being able to talk about them. It means being with students when they do not know what is wrong, and supporting them in the process of them finding and correcting their own errors.

Another important part of the Logo environment is the computer-based microworld. In an article titled "Designing Computer-Based Microworlds,"[84] R. W. Lawler describes the microworld as a "task domain" or "problem space" designed for virtual, streamlined experience where objects and processes can be understood. Microworlds do not focus on problems, but rather on "neat phenomena"--phenomena that are inherently interesting to observe and interact with.

A well-designed computer microworld embodies the simplest model which represents an entry point to a richer knowledge. But if a microworld lacks "neat phenomena," it will not justify a child's involvement. Microworld design shifts the accountability from students, who are often criticized for not liking what they must learn, to teachers, who believe their ideas and values are worth perpetuating.

These microworlds should be constructed around a powerful idea which is worth the teacher's time to develop and the student's time to explore. The teacher must decide which ideas are "powerful" and worth developing, and the student, by accepting or rejecting these ideas, will determine their worth. Lawler cites Papert for guidance in selecting powerful ideas: They should be simple, general, useful, and "syntonic."

Reality, says Lawler, dictates the candidates for powerful ideas. Society also declares what ideas are important. But it is one's own mind, insights and experiences which allow the formulation of these ideas. An idea is powerful if it gives form to one's understanding of life. "It follows," states Lawler, "that you cannot inspire others with an idea unless it has first inspired you."

As an example of a microworld, Lawler uses the three-line Logo procedure called POLYSPI (from "polyspiral"). POLYSPI generates polyspiral designs by changing any of the three variables: DISTANCE, ANGLE, and CHANGE (in distance). The procedure draws designs by going forward a specified distance, turning at the specified angle, then increasing the distance by the specified change, going forward for the incremented distance at the specified angle, and so on. By stepping up each or any of these variables, strikingly different designs may be generated.

Some of the designs are pretty, mainly because of the surprising spiral patterns which emerge under certain conditions. The variability of POLYSPI procedure sometimes permits even a beginner to surprise more expert users (as well as himself or herself) with the discovery of beautiful designs.

The procedures for POLYSPI and its designs comprise a microworld. The objects of the microworld are all the designs that the procedure can generate, which defines the domain for exploration. But more important, says Lawler, the designs are a class of "neat phenomena" whose generation can be made comprehensible with the following ideas. First, the POLYSPI procedure provides a crisp model of variable separation in which each of the three variables are each used once, and used differently, in a simple procedure text. Second, the difference in relative potency of the variables is obvious and striking.

"The POLYSPI microworld," says Lawler, "reveals the stepping of variables as a powerful idea." By stepping variables, he means changing one variable at a time and examining the results while holding the other variables constant. In short, this microworld provides a clear model of variation of dimensions and their effects.

Variable stepping, says Lawler, is a powerful idea because it is universally useful, and crucial to the process of scientific investigation--an idea, judged by Piaget, to be an essential component of formal operational thought.

Another example of a Logo microworld was previously mentioned in an earlier context. This is the Newtonian physics microworld which features the Dynaturtle. This microworld is described by Andrew diSessa and Barbara White in an article titled "Learning Physics From a Dynaturtle."[85]

DiSessa developed the dynamic turtle as a microworld in which children could experience physics painlessly while pursuing personally-satisfying activities. The dynamic turtle, which is called a dynaturtle, obeys Newton's laws of inertia and momentum. It remains at rest or travels in a straight line except when it is acted upon by an unbalanced force. These forces are little pushes or kicks which are specified by the student via the keyboard. Depending on the direction of these kicks, the dynaturtle may be sped up or slowed down, or have its direction changed.

Experience with elementary students, they say, proved that even simple activities were both motivating and instructive. For example, the deep-seated misconception that the students had that an object moves in the direction it is pushed is challenged by the behavior of the dynaturtle. When they translated this belief into hitting a target, they would inevitably miss it.

Students were able to see that pushing the dynaturtle only adds to its existing momentum so that it is typically only deflected. With practice and feedback, they gain a better understanding of how forces affect the motion of an object.

By developing games and posing the appropriate problems, students could explore a physics microworld which its developers felt was "strikingly successful" at eliminating basic misconceptions and improving overall understanding of the physics of motion. Clearly, this microworld fulfills the criteria of containing powerful ideas and "neat phenomena."

The Logo environment, with its powerful ideas, microworlds, and learning strategies, represents crucial aspects of the teaching of Logo. It is evident that the developers of the language do not see it as just another computer language, but rather a vehicle for "natural learning."

Simply teaching children the elements of Logo procedures will not do. Logo, then, seems more of an educational philosophy than a computer language--an important point to consider when designing an evaluation of Logo's effectiveness.

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CHAPTER III

RESEARCH PROCEDURES

Chapter III describes the research methods used in this study. The purpose of this chapter is to describe the procedures and processes involved in the selection of the sample; the development of the research instruments; an analysis of these instruments; the development of the learning and teaching environment of the experiment; and the collection, reporting, and analysis of the data. Information concerning the reliability and validity of the research instruments used will also be reported in this chapter. The data base of this study includes the test scores on a battery of tests taken by 43 eighth-grade students involved in a controlled experiment performed at a Vermont junior high school.

Sample Selection

The procedure used in obtaining the study sample involved the choosing of two eighth-grade science classes which consisted of 43 students drawn from the 181 eighth-grade student population at a small town Vermont junior high school. The students in these classes were computer scheduled on a random basis into their respective classes as it fit their schedules.

The classes used in this study were chosen primarily on the basis of when they were scheduled with respect to availability of the school's computer laboratory and that they were scheduled with the same science teacher.

While science students are not ability tracked at this school, students are ability tracked in their mathematics classes. This inevitably leads to a less than random distribution of ability levels in all classes. The effect of this, in this case, was to cream off some of the more able students in both of the classes used in this experiment.

Nevertheless, both classes used were judged fairly comparable on the basis of the science teacher's judgment. (Students had been studying science with this teacher for a semester before this study began.) Furthermore, each student was tested with respect to their developmental reasoning level, with only those students who were judged to be concrete operational chosen as subjects for this study. This procedure effectively matched populations, and, in fact, the creaming off of more able students from both classes left a larger sample of concrete operational students to work with.

Description of Sample

The students used in this study were a rather homogeneous group which fairly well represented the social, racial and ethnic makeup of the community. They were all Caucasian, except for one Black student who was the adopted child of a Caucasian family.

Within the classes, there was a range of ability and school achievement which seemed fairly normal. Some of the students, in each of the classes, were considered good students, while others were not so good. Some were well behaved, while others were not so well behaved. Two of the students, both in the treatment class, had serious social problems--one tended to be violent, and the other was on medication to help control his behavior.

None of these students had volunteered to be in this study, and only two of them had any computer exposure to speak of--and that was not much. Most, if not all, of the students seemed eager to take part in the study, especially the group that was told they were going to learn how to program. The parents of the control group, since their children were to have their normal science class routine interrupted for a period of several months, were informed that their children would take part in a "field testing" of a computer curriculum which would be integrated with the study of science. They were given the opportunity to withdraw their children from the study. None chose to do so. Many indicated they were pleased that their children would be working with computers.

Development of the Research Instruments

There were two instruments used in this study. They are the Modified Lawson Classroom Test of Formal Reasoning, which was used to determine the Piagetian stage of development for each student in the study; and the Physics Evaluation Instrument, which was used as a pre/post test. In addition, three Logo evaluation tests were given as part of the process of evaluating student knowledge of Logo concepts.

The Modified Lawson Test of Formal Reasoning

Testing for the Piagetian developmental level of a child has, in the past, been somewhat difficult to do. Piaget and his associates used a clinical approach to accomplish this testing, but it required individual interviews and careful training of the interviewer. The child was asked to do a number of Piagetian tasks which required special materials and equipment and generally proved too time consuming for practical classroom use.

A number of attempts were made to develop group-administered tests with a variety of formats, which are described by A. Lawson in an article titled "The Development and Validation of a Classroom Test of Formal Reasoning."[1] The objective of these tests was to keep as many of the positive aspects of the clinical view as possible yet allow one test to be administered to an entire group of students. Furthermore, it would be advantageous with respect to ease of administering the test to eliminate the need for special materials. Decreasing the skill required to administer and interpret this test would also prove advantageous.

While a variety of paper-and-pencil type tests had been developed, which eliminated the need for special materials, their drawbacks included loss of motivating aspects which arise from the reality of physical materials and equipment. Also, paper-and-pencil tests increase the reading and writing skills which are not directly related to Piagetian operations.

A number of researchers developed testing formats for which all students were provided with a set of materials and a test booklet of instructions and questions, but this method required large amounts of equipment and proved quite time consuming. To get around this problem, a class demonstration format was tried, where students could see the physical materials and hear the teacher's questions, but would still record their answers in individual test booklets.

Lawson improved upon these methods by adding to the number and variety of demonstrations and formal-level questions asked. His present format includes 15 demonstrations which include a range of developmental levels. Each item involved a demonstration using some physical materials and/or apparatus. For each item, the demonstration was used to pose a question or call for a prediction. The booklets contained a number of possible questions with a number of possible answers. Students were instructed to choose the best possible answer and explain why they chose that answer. To be scored correct, the student had to choose the right answer and give an adequate explanation for the answer chosen. A brief description of the 15 items follows:

Item 1: The Conservation of Weight. This item involves two balls of clay of identical size, shape, and weight. The students are shown that the clay ball weighs the same by placing them on opposite ends of a balance beam. One of the balls is flattened into a "pancake" shape and the students are asked about the relative weights of the pieces.

Item 2: Displaced Volume. Using two solid cylinders of equal size but different density, the students are shown the level of water displaced by the lighter cylinder and asked to predict the level of the water displaced by the heavier cylinder.

Item 3: Proportional Reasoning-1. Using two plastic cylindrical containers of equal height but with different diameters, the students are shown that a given quantity of water 4 units in the wide container and rises a corresponding 6 units when poured into the narrow container. They are then asked to predict how high a given quantity of water that rises 6 units in a wide container would rise if poured into the narrow container.

Item 4: Proportional Reasoning-2. Using the same plastic containers, 11 units of water are poured into the narrow container and the students are asked to predict how high the water would rise if poured into the wide container.

Item 5: Proportional Reasoning-3. Given a balance beam and hanging weights, the students are asked to predict where a 5-unit weight should be hung to balance a 10-unit weight which is hung 7 units in length from the fulcrum.

Item 6: Proportional Reasoning-4. Using the same balance beam, the students are asked to predict where a 10-unit weight should be hung to balance a 15-unit weight which is hung 4 units of length from the fulcrum.

Item 7: Controlling Variables-1. Using three pendulums (two of equal length but with bobs of 50-grams and 100-grams, the third longer with a 50-gram bob), the students are asked to predict which of the pendulums should be used in an experiment to find out if the variable of length effects the period of the pendulum.

Item 8: Controlling Variables-2. Using the same three pendulums, the students are asked to select which pendulums should be used to find out if the weight of the bobs effects the period of the pendulum.

Item 9: Controlling Variables-3. Using the ramp and three metal spheres, the students are shown a light sphere rolling down the ramp from a low position, striking and then displacing a target sphere which has been placed at the bottom of the ramp. The students are then asked to select the correct sphere (light or heavy) to release from a high position to find out if the variable of release position effects how far the target sphere will travel after it has been struck.

Item 10: Controlling Variables-4. Using a ramp and three metal spheres, the students are shown an experiment in which two metal spheres (A and B) roll down the ramp from the same starting position and strike two target spheres of different densities. They are then asked to decide whether or not the experiment constitutes proof that metal A can displace a target further than metal B.

Item 11: Combinational Reasoning-1. Given a metal box with four color-coded switches and a light, the students are shown that the light can be turned on by flipping a certain combination of the switches. They are then asked to list all the possible combinations of the four switches that they would have to try to discover which combination or combinations will turn on the light.

Item 12: Combinatorial Reasoning-2 "Permutations". Using four objects which represent four stores (a barber shop, a discount store, a grocery store, and a coffee shop), the students are told that the stores are going to be arranged side by side on the ground floor of a new shopping center. The students are asked to list all of the possible ways in which the stores could be arranged side by side.

Item 13: Probability-1. Three yellow squares are placed in a sack. The students are asked to predict the chances of drawing out a red square on the first draw.

Item 14: Probability-2. Three red squares, four yellow squares, and five blue squares are placed into a sack. Four red diamond-shaped pieces, two yellow "diamonds," and three blue "diamonds" are also placed into the sack. The students are asked to predict the chances of drawing out a red piece on the first draw.

Item 15: Probability-3. Using the same wooden pieces as in Item 14, the students are asked to predict the chances of drawing a red or blue "diamond" on the first draw.

In order to determine the validity of the group test (i.e., assure that the group test measures the same psychological parameter(s) as an individually administered battery of four Piagetian tasks), a subsample of the group tested by Lawson were randomly selected and individually administered a battery of four Piagetian tasks by three trained interviewers. Lawson found that an analysis of correlations factorially validated the classroom test.

Lawson sought three types of evidence to assess the validity of the classroom test as a measure of formal reasoning. The first type concerned face validity. A panel of six judges, who were considered experts due to their involvement of Piagetian research, responded with 100 percent agreement that the test items appeared to require concrete and/or formal reasoning. It was concluded that the test has face validity.

The second type of evidence concerned the relationship between the classroom test total score and the level of subject response for the individually administered Piagetian tasks. Pearson product-moment correlations between the classroom test scores and level of responses on these tasks were 0.76 ($p < .001$). This high correlation between the measures indicates that the classroom test has convergent validity.

As a third type of evidence of the classroom test's validity, the classroom test and the Piagetian tasks were submitted to a principal components analysis, with the results showing that the test measures aspects of formal reasoning as well as some aspects of concrete reasoning and reasoning that could be considered intermediate. This supports the hypothesis that the classroom test does, in fact, measure these aspects, and could therefore be said to have factorial validity.

Reliability estimates of the Piagetian tasks were found to be high. Test-retest correlation coefficients ranged between 0.48 and 0.78. Cronbach's Alpha coefficient, a modification of the KR-20 formula for scalable items, was 0.86.

An analysis of test scores indicated there were three levels of intellectual development which could be classified by score. Those who received a score of 0 - 5 were classified as concrete reasoners, while those whose score was 12 or better were considered formal reasoners. Those who received scores between 6 and 11 were considered at a transitional stage between concrete and formal reasoning.

The modified version of the Lawson test used in this present study consisted of showing a videotape of the demonstration rather than live demonstrations, as it was felt that there would be a greater consistency from one administration of the test to another. In an earlier unpublished study made by the author and his associates, 187 seventh-grade students were randomly divided into two groups. One group was tested using live demonstrations, while the other watched a videotape of the demonstrations. Students watching the videotape could view a rerun of any particular demonstration if it was needed for clarification. Students were also permitted to ask questions concerning the demonstrations for clarification, just as they were for the live demonstrations.

The results of this experiment indicated that there were no significant differences between scores ($p < .005$).

The Physics Evaluation Instrument

This test was developed by the author of this present study to evaluate achievement of the major objectives of the physics unit taught. Questions were designed to evaluate specific objectives, while keeping the level of mathematics within appropriate limits. A number of these questions are relatively concrete in nature, however most are abstract. Some of the questions are directly related to the Logo unit taught, while others are either weakly related or unrelated to this unit. The following is an analysis of these questions with respect to the level of operations needed to fully understand the question's concepts, and the degree of relatedness to Logo concepts taught as part of the Logo unit.

Question 1: Which of the following statements are examples of force being applied?

(a) A girl tries to lift a heavy weight, but can't budge it.

(b) A boy spends five minutes thinking about solving a math problem.

(c) A girl pedals her bicycle.

Answer:

(1) A and B

(2) B and C

(3) A and C

(4) C only

This question tests knowledge of the definition of a force as a push or a pull. To get this question right, the student has to understand that the application of a force requires a physical action, but that it does not necessarily result in movement.

Because of the familiarity with the concept of what it means to push or pull, concrete operational students should be able to answer this question.

While the use of a force was part of the Logo dynaturtle microworld, the concept was not strongly related to the Logo unit.

Question 2: Which two words best belong in the blanks?

To describe a force, we must know its
_______________ and _______________.

Answer:

(1) speed, power

(2) type, direction

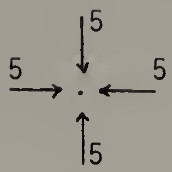
(3) magnitude, direction

(4) cause, start

This question calls for the knowledge that a force is a vector quantity, and that vectors are described in terms of magnitude and direction. Although the answer choices for this question use terms often used incorrectly by students describing force, it can still be understood on a concrete operational level.

An important part of the Logo curriculum used here dealt with the concept of a vector; therefore, this question is related to the Logo curriculum.

Question 3: Four forces act on a point, as shown in Figure 3.



(Figure 3)

The resultant of the four forces is:

(1) 0

(2) 5

(3) 14

(4) 20

This question requires that a student understand the meaning of a force resultant, and the method of vector addition.

Because the vector addition required to be able to answer this question calls for a fair understanding of what vectors are, and that vectors are inherently abstract representations of the physical world, this question should be considered abstract in nature.

Vector addition was an important part of the Logo curriculum, and, therefore, this question should be considered Logo related.

Question 4: Two forces of 10 and 20 pounds act on a point at some angle other than 0° or 180° between them. Which one of the following forces, when applied to this point at some angle, might be able to balance these two forces?

(1) 10 pounds

(2) 28 pounds

(3) 30 pounds

(4) 35 pounds

To answer this question, the student would have to have an excellent understanding of vectors and vector addition. As a result, for the reasons given in the explanation in Question 3, this question should be considered abstract in nature.

For the same reasons as given in Question 3, this question should be considered Logo related.

Question 5: A man pushes a book along a table from point A to point B with a force of 5 pounds. The force of friction acting on the book is also 5 pounds. Which statement best describes the book's motion?

(1) It comes to a sudden stop.

(2) It moves along with constant speed.

(3) It speeds up.

(4) It slows down.

Question 6: The man in problem five suddenly stops pushing the book. Which statement best describes the book's motion?

(1) It stops immediately.

(2) It slows down.

(3) It keeps going.

(4) It speeds up.

Question 7: The man now pushes the book with 10 pounds of force, while the force of friction remains at 5 pounds. Which statement best describes the book's motion?

(1) It stops immediately.

(2) It moves with constant speed.

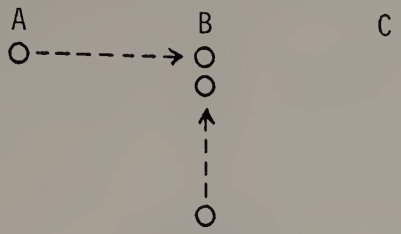
(3) It slows down.

(4) It speeds up.

Questions 5-7 relate to two highly abstract concepts, namely, the force of friction and the concept of inertial motion; and should, therefore, be considered abstract in nature.

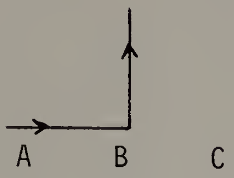
The concept of friction is unrelated to the Logo curriculum, but the concept of inertia is related to the dynaturtle microworld; however, in the context of these questions, the relationship is weak.

Question 8: A marble rolls along a straight line from point A to point B, as shown in Figure 8. Which picture best describes how the marble moves after it was hit directly on center by a similar marble at point B?

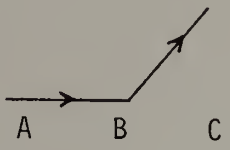


(Figure 8)

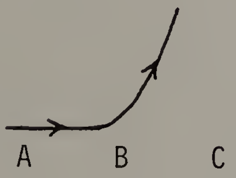
(1)



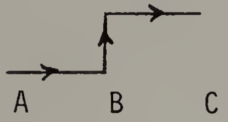
(2)



(3)

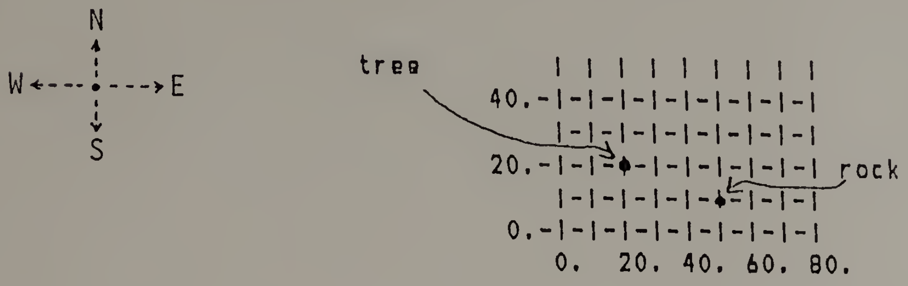


(4)



To answer this question, the student must have a good grasp of inertial motion, and is therefore an abstract in nature. Since an important part of the Logo curriculum dealt directly with the properties of inertial motion, this question should be Logo related.

Question 9: To find a pirate's treasure on the map in Figure 9, you must start digging at a point 10 feet north of the tree and 20 feet east of the tree. Describe the location of this treasure using the rock as a starting point instead of the tree.



(Figure 9)

(1) 10 feet north and 20 feet east

(2) 10 feet west and 20 feet north

(3) 10 feet south

(4) 20 feet north and 10 feet east

To be able to describe the location of the treasure from a new reference point, the student must understand how a coordinate system works well enough to make the mathematical translation. This task is abstract in nature, as we are dealing with what is fundamentally a mathematical abstraction, and then asking that the abstraction be manipulated mentally.

Plotting points in a coordinate system was an important part of the Logo curriculum and, therefore, this question is Logo related.

Question 10: A train moves north along a straight track at 50 m.p.h. A bug walks south along the floor of the train at a speed of 2 m.p.h. How fast is the bug moving with respect to the train tracks?

(1) 2 m.p.h.

(2) 48 m.p.h.

(3) 50 m.p.h.

(4) 52 m.p.h.

Question 11: How fast is the bug in Question 10 moving with respect to one of the train's seats?

(1) 2 m.p.h.

(2) 48 m.p.h.

(3) 50 m.p.h.

(4) 52 m.p.h.

Question 12: How fast is the bug moving with respect to a boy on the train who is walking 2 m.p.h. south?

(1) 0 m.p.h.

(2) 50 m.p.h.

(3) 48 m.p.h.

(4) 54 m.p.h.

Questions 10-12 dealt with relative motion. The concepts involved relate to making mathematical translations with respect to motion calculations. These concepts, especially as they relate to the manipulation of hypothetical situations, are abstract in nature.

Relative motion was not part of the Logo curriculum used here. While knowledge of coordinate systems gained through the study of Logo might have been helpful, it would have, at best, been a very indirect aid; therefore these questions are not strongly Logo related.

Question 13: A bicycle rider travels 20 miles down a stretch of road. How fast is the rider moving if it takes 45 minutes to travel that far?

(1) 10 m.p.h.

(2) 20 m.p.h.

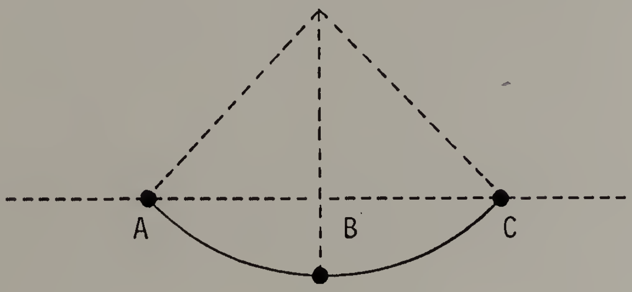
(3) 26.66 m.p.h.

(4) 32 m.p.h.

To answer this question, the student need only to have memorized the algorithm for doing speed-time problems of this sort, and be able to recognize that 45 minutes is three-fourths hour. This question could have easily been answered by a concrete operational student, and is, therefore, concrete in nature.

Problems of this kind were not covered as part of the Logo curriculum; therefore, this is not a Logo-related question.

Question 14: A pendulum is swung from point A through point B at the bottom of its swing to point C and back again to point A, as shown in Figure 14. At the exact instant the pendulum is passing point B it:



(Figure 14)

(1) is not moving.

(2) is speeding up.

(3) is moving at maximum speed.

(4) is slowing down.

Question 15: As the pendulum in problem 14 moves through point B, the only forces acting on the pendulum (ignore friction or air resistance) are the upward pull of the string and the downward pull of gravity. The resultant of these forces:

(1) acts downward.

(2) is zero.

(3) acts upward.

(4) acts towards point C.

Question 16: At the exact instant the pendulum in problem 14 reaches point C, the pendulum is:

(1) moving with constant speed.

(2) moving with non-constant speed.

(3) slowing down.

(4) not moving.

Questions 14-16 relate to knowledge of instantaneous speeds, accelerations, and dynamic equilibrium, which are all rather abstract concepts. These questions, then, are abstract in nature.

Although knowledge of infinitesimal steps and forces in equilibrium was gained through the study of Logo, this knowledge is not directly useful in the context of these questions. These questions could not, therefore, be considered strongly Logo related.

Question 17: A coin is thrown directly up into the air. While the coin is moving up, the only force(s) acting on the coin (ignoring air resistance):

(1) is the pull of gravity.

(2) is the upward projecting force.

(3) are the upward projecting force and the pull of gravity.

(4) is the internal force of the coin.

This question relates to inertial motion and the "unseen" force of gravity. Both of these concepts are abstract in nature and, therefore, this is an abstract question.

While inertial motion was studied as part of the Logo unit, the application of knowledge of inertia would be only slightly helpful, if at all, in this context. Furthermore, gravity was not at all part of the Logo unit, and, therefore, this question is not strongly Logo related.

Question 18: The resultant of the forces acting on the coin in problem 17:

(1) acts sideways.

(2) is zero.

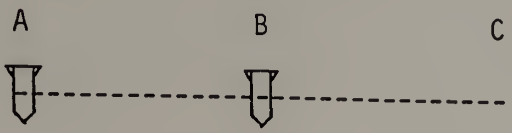
(3) acts upwards.

(4) acts downward.

This question deals with the same abstract concepts mentioned with respect to Question 17 and adds the concept of force resolution as well. It should, therefore, be considered abstract in nature.

The concept of vector resolution was studied in the context of learning Logo, but the other factors involved in the answering of this question renders this knowledge of little use. This question, then, for reasons similar to ones given for Question 17, is not strongly Logo related.

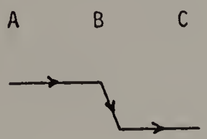
Question 19: A rocket is moving along sideways in deep space with its engine off from point A to point B, as shown in Figure 19.



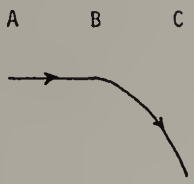
(Figure 19)

It is not near any planets and there are no other forces acting on it. If the engine is fired for an instant (an instant being as brief a period of time as you can imagine) at point B, which of the following paths will it take?

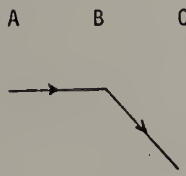
(1)



(2)



(3)



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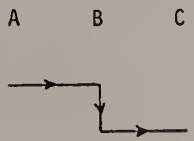
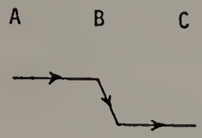


Question 20: If the engine of the rocket in problem 19 is fired for 10 seconds at point B, which of the following paths will it take?

(1)



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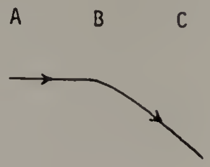
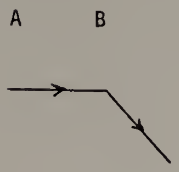
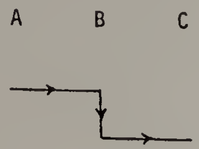


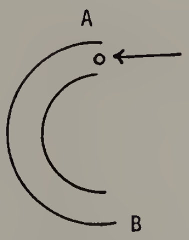
(3)



(4)

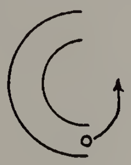


Question 21: A fast rolling ball enters a curved guide on a table top at point A and leaves at the other end, point B, as shown in Figure 21. Which of the following paths will it take?

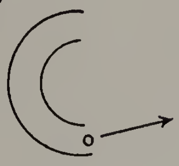


(Figure 21)

(1)

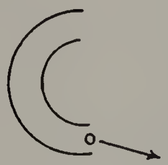


(2)



(3)

(4)



Questions 19-21 all relate to inertial motion and Newtonian mechanics. As these concepts are highly abstract, these questions should be considered abstract as well.

These questions relate to the dynaturtle microworld which was part of the Logo curriculum used here, and as such are strongly Logo related.

Question 22: A car travels 10 miles north, then 3 miles east, then 2 miles north, and then another 2 miles east. How far has the car been displaced from its starting point?

(1) 0 miles

(2) 10 miles

(3) 13 miles

(4) 17 miles

Question 23: A car travels 20 miles east, then 10 miles north, then 5 miles west, then 10 miles north, then 15 miles west, and then another 20 miles south. How far has the car been displaced from its starting point?

(1) 0 miles

(2) 25 miles

(3) 50 miles

(4) 70 miles

Questions 22 and 23, though somewhat complex in terms of written instructions, are well within the grasp of the concrete operational students who are quite capable of following straightforward instructions. Therefore, these questions should be considered concrete.

Part of the Logo curriculum consisted of having work with displacements of varying length and direction, which are similar to what students would be required to do to answer these questions. Therefore, these questions should be considered strongly Logo related.

Question 24: A racing car travels around a circular track at a constant speed of 120 m.p.h. The force needed to keep the car moving in a circle is:

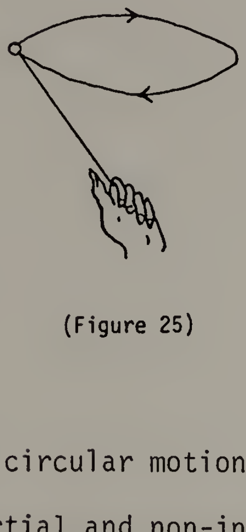
(1) constant in magnitude but changing in direction.

(2) constant in both magnitude and direction.

(3) changing in magnitude but constant in direction.

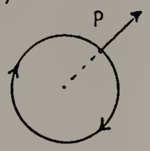
(4) changing in both magnitude and direction.

Question 25: A rock attached to a hand-held string is twirled overhead so that it moves as shown in Figure 25. Which path will be taken by the rock if the string is released at point P? (paths viewed from above)

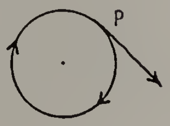


(Figure 25)

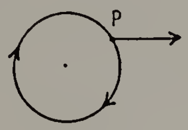
(1)



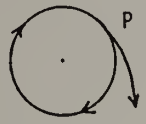
(2)



(3)



(4)



To understand circular motion, the student would have to have a clear grasp of inertial and non-inertial motion, and that an object does not necessarily move in the direction of the force applied to it. As these are abstract concepts, questions based on these concepts are abstract as well. It might be argued, however, that students could memorize the correct responses to these questions without having much understanding of them. While this is certainly correct, it has been found that students have a great deal of difficulty remembering information they do not understand.

Circular motion and dynamic motion were studied in some detail as part of the Logo curriculum. These questions, then, should be considered strongly Logo related.

Question 26: The distance separating the earth and a rocket heading for the moon is twice as great as it had been. The earth's gravitational force on the rocket during this time:

(1) remains the same.

(2) doubles.

(3) becomes half as great.

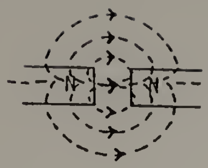
(4) becomes one-fourth as great.

This question deals with gravitation, an abstract "unseen" force; and the inverse square proportional relationship. As both of these concepts are abstract in nature, this question should be considered abstract as well.

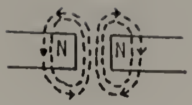
The Logo curriculum did not touch on gravitational forces or inverse square relationships. This question, therefore, should be considered non-Logo related.

Question 27: Two bar magnets with their north poles facing each other are separated by a short distance. Which diagram best represents the magnetic lines of force around the magnets?

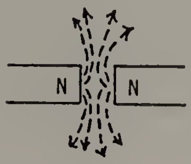
(1)



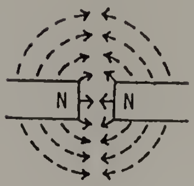
(2)



(3)



(4)



Question 27 relates to magnetic forces which act through distance and are rather abstract in nature. While it is true, the teaching of this concept is made more concrete by demonstrating the magnetic effects on iron filings, for example, as was done in this study. Nevertheless, the nature of the pattern and the directions of the force lines are sufficiently abstract to consider this an abstract question.

Magnetism or force fields were not covered as part of the Logo unit. This question should, therefore, be considered non-Logo related.

Question 28: As the electric charge on the surface of a hollow ball increases, the electric field inside the ball:

(1) increases.

(2) decreases.

(3) remains the same.

This question deals with the abstract concept of the electric field, and the equally abstract concept of the inverse square law of electric force. As it deals with abstract concepts, it should be considered an abstract question.

This question dealt with concepts which were not covered in the Logo curriculum, and should be considered non-Logo related.

Question 29: A heavy cannon ball and a marble are dropped from the same height at the same time. Which of the following statements is true?

(1) The cannon ball will land much before the marble.

(2) The marble will land much before the cannon ball.

(3) The cannon ball will land a short while before the marble.

(4) They will both land about the same time.

This question deals with a highly abstract concept; namely, the concept of gravitational mass and its relationship to gravitational force; and the compensating effect of inertial mass. In addition, the student must overcome some highly ingrained misconstrued ideas about the physics of falling bodies. While it may again be argued that the student will simply remember that objects of different weights fall at the same rate, one should consider the difficulties non-abstract reasoners have learning even recall-type information about abstract concepts.

The concepts involved here were not taught as part of the Logo curriculum and, therefore, this question should be considered non-Logo related.

Question 30: The subatomic particle which takes part in the electromagnetic interaction is the:

(1) meson.

(2) graviton

(3) neutron.

(4) photon.

This question relates to a highly abstract theory of matter and as such should be considered abstract in nature.

The subject matter of this question was not part of the Logo curriculum; therefore, the question should be considered non-Logo related.

The results of the preceding analysis are summarized with respect to whether or not a question is abstract and/or Logo related in the following table. In addition, the last column of the table indicates which of the listed physics concepts taught (see Physics Curriculum) are evaluated by the question.

The curricular validity of the physics evaluation instrument is determined by the observable relationship between the test and the instructional objectives of the physics curriculum. To determine the curricular validity, then, the test must closely evaluate the stated objectives of the physics unit. To this end, an analysis of each question asked was made with respect to the stated learning objectives. This analysis indicates that each physics learning objective is tested at least once, and usually more than once, by the questions asked. Furthermore, the analysis indicates that many of these questions fit this studies criteria for being abstract, and a number of the questions are strongly related to the Logo unit taught. (See Table 1.) This indicates that the test does measure what is being taught, and that it is, therefore, a valid instrument.

Further evidence of the test's validity is based on the judgments of two people who, on the basis of their research and publications in

TABLE 1

ANALYSIS OF PHYSICS TEST QUESTIONS

Question Number	Abstract	Logo Related	Concept Number(s) Evaluated
1.	No	No	1
2.	No	Yes	2,3
3.	Yes	Yes	1-4
4.	Yes	Yes	3,4
5.	Yes	No	4-6
6.	Yes	No	4-6
7.	Yes	No	4-6,13
8.	Yes	Yes	17,18
9.	Yes	Yes	14,15
10.	Yes	No	9,10,14-16
11.	Yes	No	9,10,14-16
12.	Yes	No	9,10,14-16
13.	No	No	10
14.	Yes	No	7,11,12,19
15.	Yes	No	7,11,12,19
16.	Yes	No	7,11,12,19
17.	Yes	No	19,22
18.	Yes	No	3,4,7,17
19.	Yes	Yes	17,18
20.	Yes	Yes	17,20
21.	Yes	Yes	17,20,21
22.	No	Yes	4
23.	No	Yes	4
24.	Yes	No	8,20-21
25.	Yes	No	17,20,21
26.	Yes	No	19,22,25-27
27.	Yes	No	25-27
28.	Yes	No	25-27
29.	Yes	No	19
30.	Yes	No	23-25,27

the fields of physics, developmental psychology and Logo, are considered experts in these areas. Each agreed that the test basically measures what it was trying to measure and is, therefore, valid to that extent.

Reliability estimates for this instrument are relatively high. Using the Spearman-Brown formula to correct an odd-even split half correlation for the combined control and treatment groups physics pre-test scores, the reliability coefficient was found to be 0.6 (see appendix for test scores). The Kuder-Richardson 20 formula was also used to determine the reliability coefficient of the instrument. This turned out to be a slightly lower 0.5, which is understandable considering that the physics pre-test was not highly homogeneous.

The Logo Evaluation Instruments

The other instruments used in this study consist of three Logo tests which were developed on an ad hoc basis to evaluate student progress in learning Logo. (The Logo tests used in this study may be seen in Appendix E.) Students were asked to write short Logo programs, interpret Logo instructions, and correct "bugged" Logo programs. As these tests were specifically designed to evaluate student progress, and were based on Logo concepts studied, they should be valid indicators of student progress.

The Logo tests were not used directly as part of this study, but rather as an indicator of student learning of Logo (along with evaluation of student projects). It was felt that student participation in a Logo environment was not sufficient reason to assume learning had gone on. To this end, the Logo tests were developed to see which students learned Logo and to what degree the Logo was learned.

The Learning Environment

This section describes the learning environments for the control and treatment groups. Only the treatment group was taught Logo, but both groups were taught physics.

The Logo Learning Environment

Developing a "Logo environment" in a public school setting can be a difficult task. One cannot set off in an entirely new direction without the cooperation of the school and community. This cooperation is generally limited by a variety of constraints. For example, in this study, the Logo and physics units had to be "integrated" into a normal eighth grade science class. As a grade in science is mandatory, it was necessary to grade students on their achievement in these units--which does not necessarily fit the "Logo philosophy." Time pressure proved to be another constraint, in that a certain amount of rushing was necessary to address the stated objectives.

Nevertheless, within this context a fairly viable Logo environment was developed for this study. To begin with, an 18-station computer laboratory was made available to the students for 45 minutes per day five days per week, for a period of 14 weeks. This meant that no more than two students need share a computer, and most could work at a computer independently when they wished.

The author of this study did most of the teaching and was ably assisted by the students' regular eighth grade science teacher. This meant there was a less than 12 to 1 student-teacher ratio.

Teacher preparation for teaching Logo included formal study of Logo, wide reading in this field, and extensive subject preparation and planning. Actual Logo teaching experience was limited to tutoring individual children along with the observation of experienced Logo teachers. Other teaching experience includes 20 years of teaching science and mathematics to junior and senior high school students. The assisting teacher, though he had limited computer training, taught junior high school science for more than 20 years. Lack of Logo teaching experience did not prove to be a problem, as it was countered by careful preparation and general teaching experience.

While every attempt was made to provide an open environment for students where they could explore and discover "neat phenomena" for themselves, it was felt that a certain degree of structure and guidance was necessary. To this end, a curriculum guideline was developed to provide direction. Within this general structure, students were given the latitude to move in any direction which interested them.

A typical lesson began with a brief introduction of some Logo concepts which were usually demonstrated. Students were then given a short and usually simple project to complete which allowed them to apply the concepts which had been introduced. After a number of these concept introductions and projects, students were asked to develop a more complicated project of their own choosing, which allowed them to apply what they had learned.

While students worked on their respective projects, the teachers went about the room working with individual students. This included answering questions in ways that allowed students to make their own discoveries, making suggestions, giving ideas, discussing problems, and generally encouraging students to extend their ability and curiosity. Students were not given direct answers and solutions to their questions and problems; instead, problem solving was encouraged.

Students were free to work with other students and seek their help when it was needed. Student cooperation did, in fact, occur to a great extent. Quite often, when an individual student came up with a good idea, or made an interesting discovery, he or she would share it with the class. These good ideas, and a few not so good ideas, would quickly spread throughout the room.

As it invariably happens, students would find bugs in their programs. When this occurred, they were encouraged to work their problems out. They did this by trial and error, deductive and inductive reasoning, and very often by simply "stepping" their Logo program instructions out on the floor. They were made to feel that debugging a program was very much a part of writing programs, and that bugs should not be looked upon as "mistakes" to be ashamed of.

Student projects led them into "microworlds" that they were free to explore. Logo games were also used to motivate as well as provide learning opportunities. Through these microworlds and games, they could explore such concepts as the geometry of polygons, variables, vectors and Newtonian motion.

The students worked at their own pace within a structured timeframe. What this meant was that students had to more or less master certain concepts and skills within a certain period of time. But as each child moved in his or her own direction, some accelerated in new directions while others caught up to where they had to be. Some children were able to master problems quickly enough so that they had time to explore their interests in depth, and then could go on to more complex problems. Others were slower and could only handle relatively simple problems and projects. These students also explored and made discoveries, but usually at a simpler level. However, they were all brought to a point where they were ready to investigate new Logo commands and concepts.

As the class reached a given stage of their progress, an evaluative paper-and-pencil test was given. While the inventors of Logo have reservations concerning tests and grades, it was felt that these tests could provide important insights into what students understood and what they did not understand. An attempt was made to present these tests more as projects than as a means of arriving at a student's grade; and after the test was over, the student could work out the solutions to the test at his or her computer. In fact, achievement on tests was not directly used to determine student grades, but were given for the purposes of this study.

The presentation of concepts and projects was designed to be increasingly difficult and complex. At the beginning of the study, students shot through their projects at break-neck speed, but as the complexity of the subject matter increased, the students slowed down considerably. Nevertheless, most seemed to feel that each day they accomplished more; and while some of the students looked to discover more and more, others were satisfied with simple accomplishments. It was hoped that students would feel that they were not part of the usual academic competition, but rather that they were in a sharing situation where they were encouraged to help and be helped by one another.

The Physics Environment

Developing a physics environment for eighth graders can be as challenging as developing a Logo environment. So many physics concepts are counterintuitive, highly abstract, and most easily dealt with by introducing mathematical equations. This, the introduction of mathematical equations, was not feasible as the students had not yet learned algebra, and many had with simple arithmetic.

Furthermore, it was important that the physics concepts being introduced were concepts which most, if not all, the students had not been exposed to before. This, actually, was not a big problem as these students had studied life science in the seventh grade, and did not, in general, have a strong science background.

The problem, then, was to develop an environment where students could be introduced to not highly mathematical, yet abstract concepts of physics. Furthermore, it was felt that the abstract concepts of this unit had to be presented in as concrete a manner as possible so that they could be assimilated by these mostly concrete operational students.

To provide such an environment, it was felt that a "hands-on" atmosphere was needed. Students would be asked to do experiments where they could explore phenomena, make guided discoveries, and apply introduced concepts to a variety of situations. Demonstrations and audiovisual aids were often used to introduce new concepts, as well as to provide examples and applications of introduced concepts.

A typical lesson (not necessarily given in one teaching period) began with a hands-on experiment where students could explore a given situation. Then a concept was introduced which was closely related to their explorations, usually with a concomitant demonstration to illustrate the concept. Students then further explored and extended this concept to a point where they were ready to be introduced to still another concept. In other words, exploration was followed by concept introduction, which was followed by application and further application, which led to new concept introduction and so on.

This method, known as a learning cycle, is described by Karplus, Lawson, et al., in a workshop on Science Teaching and the Development of Reasoning publication (1980, section 9:2). It was developed to make the introduction of abstract ideas as concrete as possible.

The author of this study, again, did most of the teaching, and was again ably assisted by the students' eighth grade science teacher. During periods of laboratory activities, both teachers would assist students with their work. The emphasis was on problem solving and comprehension of concepts. The introduction of new concepts and class demonstrations were done by the author. This was true for both the control and treatment classes.

Collecting, Reporting, and Analyzing the Data

The final section of this chapter summarizes the research procedures for collecting, reporting, and analyzing the data generated in this study. The data collected here represents the scores achieved by 43 eighth grade science students, out of a population of 181, on the Modified Lawson Classroom Test of Formal Reasoning, a physics pre- and post-test, and 23 students who took one, two, or three Logo knowledge evaluation tests.

Collecting the Data

The Modified Lawson Classroom Test of Formal Reasoning was administered over a period of three days to 43 eighth grade students in two science classes. These tests were given at the beginning of the spring semester to establish the developmental reasoning level of each student. Following this, each of the students were given a 45 minute, 30 item physics pre-test to establish their physics knowledge-base level.

Two weeks later, 23 of these students began a 14-week study of Logo. During this period of time, three 45-minute Logo tests were administered at approximately equal intervals to evaluate student progress in their study. Twenty-three students took the first test, 22 took the second, and 21 took the third. Both groups then began a three-week study of physics. Following this, each of the 43 students took a physics post-test which was identical to the pre-test.

To insure that teachers would not be influenced by test results, the reasoning test and the physics pre-test were not scored until the completion of the study. The Logo tests were scored during the teaching of the Logo unit, and results were used to evaluate and correct specific learning problems. All tests were administered by the investigator himself.

Reporting the Data

The Modified Lawson Classroom Test of Formal Reasoning has a 0 to 15 range of scores. Those who score from 0 to 5 are listed as concrete operational, and are the primary focus of this study. Those who scored from 6 to 11 were at a transitional stage of reasoning development; while those who scored between 12 to 15 are considered formal reasoners. Transitional and formal reasoning students will be considered in terms of how they learn physics and/or Logo as compared to concrete operational students.

The physics pre/post-test consists of a 30-item multiple choice test which will be scored in terms of percentage of items answered correctly. Improvement of post-test as compared to pre-test will be recorded in terms of plus or minus percentage point difference between pre- and post-tests.

Logo test scores will be recorded on the basis of percentage correct. The average of test scores will be used as an indication of Logo achievement. Students with a Logo test score average of 50 percent or better based on all three Logo tests will be considered Logo knowledgeable.

Analyzing the Data

The results of this study were related to the stated hypotheses by the following analysis.

Hypothesis 1: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics than similar students who have not been taught to program in Logo.

(a) Analysis of developmental reasoning scores to determine concrete operational reasoners among the control and treatment groups.

(b) Analysis of physics pre/post-test scores with respect to abstractness of questions.

(c) Analysis of Logo test scores to screen for Logo knowledge.

(d) Significance testing of differences between means of percentage point difference of the physics tests of concrete operational students for control and treatment groups using t-test analysis.

(e) Significance testing of differences between means of percentage points difference of the physics tests of concrete operational students for control group and Logo test screened treatment group using t-test analysis.

(f) Significance testing of differences between means of percentage point difference on abstract questions of the physics tests of concrete operational students for control and treatment groups using t-test analysis.

(g) Significance testing of differences between means of percentage point difference on abstract questions of the physics tests of concrete operational students for control group and Logo test screened treatment group using t-test analysis.

Hypothesis 2: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics which are directly related to the Logo concepts learned than similar students who have not been taught to program in Logo.

(a) Analysis of physics pre/post-test scores with respect to Logo-related questions.

(b) Significance testing of differences between means of percentage point difference of Logo-related questions on the physics tests of concrete operational students for control and treatment groups using t-test analysis.

(c) Significance testing of differences between means of percentage points difference of Logo-related questions on the physics tests of concrete operational students for control group and Logo test screened treatment group using t-test analysis.

(d) Significance testing of differences between means of percentage point difference of Logo-related abstract questions on the physics tests of concrete operational students for control and treatment groups using t-test analysis.

(e) Significance testing of differences between means of percentage point difference of Logo-related abstract questions on the physics tests of concrete operational students for control group and Logo test screened treatment group using t-test analysis.

The analysis and interpretation of the statistical results of this study is the subject of the next chapter.

NOTES

[1] A. Lawson, "The development and Validation of a Classroom Test of Formal Reasoning," Journal of Research in Science Teaching 15, No. 1 (1978): 11-24.

CHAPTER IV

ANALYSIS AND INTERPRETATION

This chapter reports, analyzes and interprets the data collected as a result of testing a sample of eighth grade students. The tests administered were the Modified Lawson Classroom Test of Formal Reasoning and the physics pre- and post-test evaluation instrument to all students in our sample, and three tests of Logo achievement to the Logo treatment group. Particular attention was paid to whether or not learning to program in Logo helped concrete operational students learn abstract physics concepts, especially if these concepts are directly related to the Logo learned. Specifically, these research findings were related to the two hypotheses which directed this study. The following two hypotheses will be considered in this chapter in turn.

Hypothesis 1: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics than similar students who have not been taught to program in Logo.

Hypothesis 2: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics which are directly related to the Logo concepts learned than similar students who have not been taught to program in Logo.

Before presenting the results of this study, it is important to note that this was basically a pilot study and exploratory in nature. The study was performed in a public school setting where experimental controls were constrained by student, community, and administrative needs and desires, along with the normal organizational structures which generally exist in public schools. Furthermore, little research has been done which is related to this present study, and even less research, if any, has been done that is directly related. As a result, research instruments, curricula and teaching strategies had to be specifically developed.

Among the purposes of exploratory studies are the generation of topics and questions which should be considered in future investigations; and the development of valid and reliable research instruments. In this respect, the present study succeeds in beginning this important process. However, a great deal more must be done before we can reach any but the most tenuous of conclusions. Nevertheless, this study does add to the growing body of information on the development and use of the computer language Logo as a means of helping children to deal with abstract concepts and problems.

Hypothesis 1

To test Hypothesis 1, it is necessary to first determine which students in our sample are concrete operational. This was done by administering the Modified Lawson Classroom Test of Formal Reasoning to both control and treatment groups alike. The results of this test are listed as logic scores in Table 2 for the control group and Table 3 for the treatment group.

TABLE 2

CONTROL GROUP TEST SCORES FOR LOGIC TEST

Student Number	Logic Score
1.	1
2.	1
3.	6
4.	3
5.	6
6.	3
7.	2
8.	1
9.	3
10.	4
11.	3
12.	0
13.	0
14.	1
15.	0
16.	4
17.	1
18.	0
19.	4
20.	3

TABLE 3

TREATMENT GROUP TEST SCORES FOR LOGIC TEST

Student Number	Logic Score
21.	9
22.	3
23.	2
24.	1
25.	7
26.	2
27.	3
28.	1
29.	2
30.	1
31.	3
32.	1
33.	5
34.	1
35.	9
36.	5
37.	3
38.	6
39.	6
40.	4
41.	8
42.	2
43.	2

Analysis of Developmental Reasoning Scores to Determine Concrete Reasoners Among the Control and Treatment Groups

The mean of the logic scores for all 43 subjects is 3.07 with a standard deviation of 2.40. This mean is somewhat low as compared to the mean score of 4.93 (standard deviation = 3.27) for the entire eighth grade population of 165 students tested at this school in 1981. The 4.93 mean score is more typical for eighth grade students as found by other researchers. This lower score probably reflects the "creaming off" effect on general scheduling, including non-grouped science classes as a result of ability grouping of mathematics sections.

The logical score mean for the control group was found to be 2.30 with a standard deviation of 1.89, while the treatment group had a mean of 3.74 with a standard deviation of 2.63. As the focus of this study is the concrete operational student, the scores of all students with a logic score greater than five were ignored, as were the scores of the two students who did not take the physics pre-test. Recalculation of logic scores for control and treatment groups gives a mean of 1.81 with a standard deviation of 1.47 for the control group, and a mean of 2.41 with a standard deviation of 1.32 for the treatment group. These scores are not significantly different at the $p = .05$ level of confidence.

Analysis of Physics Pre/Post-Test Scores

Tables 4a and 4b indicate the scores achieved on the physics pre-test for the control group students for each of the thirty questions. A "1" indicates a correct response, while a "0" indicates an incorrect response. Tables 5a and 5b do the same for the treatment group,

TABLE 4a

PHYSICS PRE-TEST SCORES: CONTROL CLASS (QUESTIONS 1-15)

Student No.	Question No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
3.	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0
4.	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
5.	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0
6.	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0
7.	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0
8.	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0
9.	1	0	0	0	1	0	1	0	1	1	1	1	0	0	0
10.	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0
11.	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
12.	0	0	0	0	1	0	1	0	1	1	1	0	1	1	0
13.	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0
14.															
15.	1	0	0	0	1	0	1	0	0	1	1	1	1	1	0
16.															
17.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
19.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
20.	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1

TABLE 4b

PHYSICS PRE-TEST SCORES: CONTROL CLASS (QUESTIONS 16-30)

Student No.	Question No.														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.	0	1	1	0	0	1	0	0	0	0	1	0	1	1	0
2.	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0
3.	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0
4.	0	0	1	0	0	1	1	0	0	0	0	1	1	0	0
5.	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0
6.	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
7.	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0
8.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
9.	0	1	0	1	0	1	0	0	0	1	0	1	0	0	1
10.	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0
11.	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
12.	0	1	1	0	0	1	1	0	1	0	1	0	0	0	0
13.	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
14.															
15.	0	0	0	0	1	1	0	0	0	1	1	0	0	1	1
16.															
17.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18.	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1
19.	0	0	0	1	0	1	0	0	0	1	0	1	1	1	0
20.	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0

TABLE 5a

PHYSICS PRE-TEST SCORES: TREATMENT CLASS (QUESTIONS 1-15)

Student No.	Question No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1
2.	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0
3.	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
4.	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0
5.	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0
6.	1	0	0	0	0	0	0	0	0	1	1	1	0	0	1
7.	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
8.	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
9.	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
10.	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
11.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
12.	1	1	1	0	0	0	0	0	1	1	0	1	0	1	0
13.	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0
14.	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
15.	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1
16.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
17.	1	0	0	0	0	0	1	0	1	0	1	1	0	0	0
18.	1	0	0	0	1	0	1	0	0	1	1	1	1	0	1
19.	0	1	0	0	0	0	1	1	0	0	1	1	0	0	0
20.	1	1	0	0	1	0	0	0	0	0	1	1	1	0	0
21.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
22.	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1
23.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

TABLE 5b

PHYSICS PRE-TEST SCORES: TREATMENT CLASS (QUESTIONS 16-30)

Student No.	Question No.														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.	1	0	0	1	1	1	0	1	1	0	0	1	0	0	0
2.	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0
3.	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0
4.	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0
5.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
6.	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0
7.	0	0	1	0	1	0	0	0	0	0	0	1	1	0	0
8.	0	0	0	0	1	1	0	0	0	0	1	1	0	1	0
9.	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0
10.	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0
11.	0	1	1	0	0	1	0	1	0	0	0	1	0	1	0
12.	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1
13.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
15.	0	0	0	0	1	1	1	1	0	0	1	1	0	1	0
16.	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
17.	0	1	1	1	0	1	0	0	0	0	0	1	1	0	0
18.	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0
19.	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0
20.	0	0	0	1	1	1	0	0	0	1	0	0	1	1	0
21.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
22.	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0
23.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

while Tables 6a and 6b, and Tables 7a and 7b report control and treatment scores respectively on the physics post-test.

Physics pre- and post-test scores, percentage points improved, and the percentage points difference of physics test scores are listed in Table 8 and Table 9 for control and treatment groups respectively. These tables list scores for only those students found to be concrete operational and who have taken both the pre- and post-physics tests. Question 28 was not used for calculating the physics post-test scores, as the concept tested by that question was inadvertently not taught. The percentage points difference in the physics test scores were found by subtracting the percentage correct score on the physics pre-test from the percentage points correct on the physics post-test.

Table 10 lists the means and standard deviations of the scores listed in Table 8 and Table 9.

The mean of the physics pre-test scores for both the control and treatment groups are fairly close to what would be expected from randomly choosing answers. Furthermore, there are no significant differences in these scores ($p = .05$). This is a good indication that the concrete operational students are fairly well matched, and have had minimal exposure to the physics concepts which were later taught to them.

Post-test scores for both control and treatment groups made very significant improvement in their test scores ($p = .001$), with the treatment group having a somewhat lower post-test mean score. However, the difference between post-test scores for control and treatment groups is tenuous at best, even at the $p = .1$ level of confidence. Also, while

TABLE 6a

PHYSICS POST-TEST SCORES: CONTROL CLASS (QUESTIONS 1-15)

Student No.	Question No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1	0	0	1	0	1	0	1	0	0	1	0	0	0	1
2.	0	1	0	0	1	1	1	0	0	0	0	1	1	0	1
3.	1	0	0	0	1	1	0	0	1	1	0	0	0	0	0
4.	0	1	0	0	1	1	0	0	1	1	0	1	0	1	0
5.	1	1	1	0	1	0	0	1	0	0	0	1	0	1	1
6.	1	1	1	0	0	0	0	1	1	0	0	1	0	1	0
7.	0	0	1	0	1	1	1	1	1	1	0	0	1	1	1
8.	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1
9.	1	0	0	0	0	0	0	1	1	1	0	1	0	1	0
10.	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0
11.	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
12.	1	1	1	1	1	0	0	1	0	1	1	1	1	0	0
13.	1	1	0	0	1	1	1	1	0	0	0	1	0	1	0
14.	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0
15.	1	1	1	0	1	0	1	1	0	0	0	1	0	1	0
16.	1	0	0	0	0	0	1	0	0	0	0	1	1	0	1
17.	1	0	1	0	0	1	1	1	0	1	0	1	0	0	1
18.	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0
19.	1	1	1	0	0	0	1	0	1	1	0	1	1	1	1
20.	1	1	1	0	1	0	1	0	0	0	1	1	1	1	0

TABLE 6b

PHYSICS POST-TEST SCORES: CONTROL CLASS
(QUESTIONS 16-30)

Student No.	Question No.														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0
2.	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0
3.	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1
4.	1	0	0	0	0	1	0	1	1	1	0	0	0	1	1
5.	1	1	0	1	1	1	0	1	0	1	1	0	0	0	1
6.	0	1	1	0	0	1	1	1	0	1	0	1	0	1	0
7.	0	0	0	1	1	1	0	0	1	0	0	1	0	1	1
8.	0	1	1	0	1	0	0	0	1	0	0	0	1	0	1
9.	1	1	0	0	0	1	0	0	1	1	0	0	0	1	0
10.	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0
11.	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0
12.	0	1	0	1	1	1	0	1	1	1	0	0	0	0	0
13.	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0
14.	0	1	1	0	0	1	0	1	1	0	1	1	0	0	1
15.	0	0	0	1	0	1	0	1	0	1	0	0	0	1	1
16.	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
17.	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
18.	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0
19.	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0
20.	0	0	0	0	0	1	0	0	1	0	0	1	1	0	1

TABLE 7a

PHYSICS POST-TEST SCORES: TREATMENT CLASS
(QUESTIONS 1-15)

Student No.	Question No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1	1	1	0	0	1	0	1	0	1	0	1	0	0	1
2.	1	1	1	0	1	0	0	1	1	1	1	0	0	0	0
3.	0	1	0	0	1	0	1	1	0	0	0	1	1	1	1
4.	1	1	0	0	1	1	1	0	0	0	0	0	0	1	0
5.	1	1	1	0	0	1	1	0	1	0	0	1	1	1	0
6.	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0
7.	1	1	0	0	0	0	1	1	1	0	0	1	0	0	0
8.	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0
9.	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
10.	1	0	0	0	1	0	0	1	0	1	0	0	1	1	0
11.	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1
12.	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0
13.	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0
14.	1	1	0	0	1	0	1	1	0	0	0	0	0	1	0
15.	1	0	1	0	0	0	0	0	1	1	0	1	1	0	0
16.	0	1	0	0	1	0	1	0	0	1	0	1	0	0	0
17.	1	0	0	0	1	1	1	0	1	1	0	1	0	0	0
18.	0	1	1	0	1	0	1	1	1	1	0	1	1	1	1
19.	1	0	0	0	0	1	1	1	1	1	0	1	0	0	0
20.	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0
21.	1	1	0	0	0	1	1	1	1	0	0	1	0	0	0
22.	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0
23.	0	1	0	0	1	0	1	1	0	1	0	0	0	1	0

TABLE 7b

PHYSICS POST-TEST SCORES: TREATMENT CLASS (QUESTIONS 16-30)

Student No.	Question No.														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1
2.	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1
3.	1	0	1	0	0	1	0	1	0	0	1	1	0	1	0
4.	0	1	1	0	0	1	0	0	0	1	0	1	1	0	1
5.	1	0	0	0	0	1	0	1	0	0	1	1	0	1	0
6.	0	1	0	0	1	1	0	1	1	1	0	1	1	1	1
7.	0	1	1	0	0	1	0	0	0	0	0	1	0	0	1
8.	0	1	1	0	0	1	0	0	0	0	1	1	0	1	0
9.	0	0	1	0	1	1	0	0	0	0	0	1	1	1	0
10.	0	0	0	0	0	1	0	0	1	0	0	0	1	1	1
11.	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0
12.	0	0	1	0	0	0	0	1	1	1	0	1	1	0	1
13.	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1
14.	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1
15.	0	0	0	0	0	1	1	0	1	1	0	1	1	1	0
16.	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0
17.	1	1	1	0	0	1	0	0	0	0	0	1	0	0	1
18.	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0
19.	1	1	0	0	1	1	0	0	0	0	0	1	0	0	1
20.	1	0	0	0	1	1	0	1	1	1	0	1	0	0	1
21.	0	0	1	0	0	1	0	0	0	1	0	0	0	1	1
22.	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
23.	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1

TABLE 8

PHYSICS PRE-TEST AND POST-TEST SCORES AND PERCENTAGE POINTS DIFFERENCE FOR CONCRETE OPERATIONAL CONTROL GROUP STUDENTS

Student Number	Physics Pre-Test Percent Correct	Physics Post-Test Percent Correct	Percentage Points Difference
1.	33.3	34.5	1.1
2.	30.0	37.9	7.9
4.	26.7	48.3	21.6
6.	23.3	51.7	28.4
7.	23.3	58.6	35.3
8.	20.0	34.5	14.5
9.	43.3	41.4	-2.0
10.	26.7	34.5	7.8
11.	13.3	24.1	10.8
12.	43.3	58.6	15.3
13.	23.3	44.8	21.5
15.	46.7	48.3	1.6
17.	10.0	37.9	27.9
18.	13.3	31.0	17.7
19.	23.3	62.1	38.7
20.	23.3	44.8	21.5

TABLE 9

PHYSICS PRE-TEST AND POST-TEST SCORES AND PERCENTAGE POINTS DIFFERENCE FOR CONCRETE OPERATIONAL TREATMENT GROUP STUDENTS

Student Number	Physics Pre-Test Percent Correct	Physics Post-Test Percent Correct	Percentage Points Difference
22.	30.0	41.4	11.4
23.	16.7	51.7	35.1
24.	30.0	41.4	11.4
26.	30.0	44.8	14.8
27.	20.0	37.9	17.9
28.	26.7	34.5	7.8
29.	20.0	27.6	7.6
30.	16.7	34.5	17.8
31.	26.7	34.5	7.8
32.	33.3	34.5	1.1
33.	13.3	27.6	14.3
34.	10.0	41.4	31.4
36.	10.0	31.0	21.0
37.	36.7	44.8	8.2
40.	40.0	48.3	8.3
42.	30.0	20.7	-9.3
43.	10.0	31.0	21.0

TABLE 10

MEANS AND STANDARD DEVIATIONS OF PHYSICS PRE- AND POST-TESTS, AND PERCENTAGE POINTS DIFFERENCE OF PRE-TEST SCORES

	Control Group	Treatment Group
Mean of Pre-Test Scores	26.4	23.5
Standard Deviation of Pre-Test Scores	10.8	9.7
Mean of Post-Test Scores	43.3	36.9
Standard Deviation of Post-Test Scores	10.8	8.2
Mean of Percentage Points Difference	16.9	13.4
Standard Deviation of Percentage Points Difference	12.1	10.5

improvement was significant for both groups, neither group's mean score was greater than 50 percent.

The mean of percentage points difference score was slightly higher for the control group than for the treatment group. However, there is no significant difference between these scores at the 95 percent confidence level.

These results relate to the physics tests taken as a whole. The same analyses were then done with respect to only those test items considered strongly abstract in nature.

Analysis of Physics Pre- and Post-Test Scores with Respect to Test Questions Considered Highly Abstract in Nature

The analysis of the physics pre-test and post-test done in Chapter III, and reported in Table 1, indicates that Questions 3-12, 14-21, and 24-30 may be considered abstract as based on the criteria used in this study. Question 28 was not used here for previously-mentioned reasons.

Physics pre- and post-tests, and percentage points difference of the physics test abstract question scores are listed in Table 11 and Table 12 for control and treatment groups respectively.

Table 13 lists the means and standard deviations for scores on the abstract questions of the pre- and post-physics tests, along with the mean and standard deviation of the percentage points difference of the physics test scores.

Again, pre-test scores are little better than what would be obtained from random guessing of answers, and there is no significant difference between control and treatment groups for pre-test, post-test,

TABLE 11

PHYSICS PRE-TEST AND POST-TEST ABSTRACT QUESTION SCORES AND PERCENTAGE POINTS DIFFERENCE OF ABSTRACT QUESTION SCORES FOR CONCRETE OPERATIONAL CONTROL GROUP STUDENTS

Student Number	Physics Pre-Test Percent Correct	Physics Post-Test Percent Correct	Percentage Points Difference
1.	33.3	33.3	0.0
2.	29.2	33.3	4.2
4.	20.8	50.0	29.2
6.	16.7	45.8	29.2
7.	29.2	66.7	37.5
8.	20.8	29.2	8.3
9.	50.0	45.8	-4.2
10.	33.3	37.5	4.2
11.	12.5	29.2	16.7
12.	45.8	54.2	8.3
13.	29.2	41.7	12.5
15.	50.0	45.8	-4.2
17.	8.3	41.7	33.3
18.	16.7	25.0	8.3
19.	20.8	58.3	37.5
20.	25.0	41.7	16.7

TABLE 12

PHYSICS PRE-TEST AND POST-TEST ABSTRACT QUESTION SCORES AND PERCENTAGE POINTS DIFFERENCE OF ABSTRACT QUESTION SCORES FOR CONCRETE OPERATIONAL TREATMENT GROUP STUDENTS

Student Number	Physics Pre-Test Percent	Physics Post-Test Percent	Percentage Points Difference
22.	33.3	37.5	4.2
23.	12.5	50.0	37.5
24.	33.3	41.7	8.3
26.	33.3	41.7	8.3
27.	16.7	37.5	20.8
28.	33.3	33.3	0.0
29.	20.8	33.3	12.5
30.	20.8	33.3	12.5
31.	25.0	25.0	0.0
32.	33.3	29.2	-4.2
33.	12.5	29.2	16.7
34.	8.3	41.7	33.3
36.	12.5	33.3	20.8
37.	37.5	50.0	12.5
40.	33.3	45.8	12.5
42.	37.5	20.8	-16.7
43.	12.5	33.3	20.8

TABLE 13

MEANS AND STANDARD DEVIATIONS OF PHYSICS PRE- AND POST-TESTS, AND PERCENTAGE POINTS DIFFERENCE OF SCORES ON ABSTRACT QUESTIONS

	Control Group	Treatment Group
Mean of Pre-Test Scores	27.6	24.5
Standard Deviation of Pre-Test Scores	12.6	10.4
Mean of Post-Test Scores	42.4	36.3
Standard Deviation of Post-Test Scores	11.3	8.2
Mean of Percentage Points Difference	14.8	11.8
Standard Deviation of Percentage Points Difference	14.4	13.3

or percentage points difference at the p = .05 level of confidence. (See Table 17 for t-test values.)

These results would seem to indicate that concrete operational students exposed to a Logo environment do not seem to learn abstract physics any better than a similar group of students that have not been exposed to a Logo environment.

Analysis of Physics Test Score Differences for Concrete Operational Students Screened for Their Knowledge of Logo

Teaching students to program in a Logo environment does not insure that these students have actually learned Logo. To screen for student knowledge of Logo, a series of Logo tests, described in Chapter III (see Appendix E), were administered to the Logo group. The criteria used to indicate sufficient Logo knowledge was that students had to take all three Logo tests and obtain an average of 50 percent or greater on these tests.

The Logo scores for the concrete operational students used here are listed in Table 14. As seen in Table 14, Students 22, 23, 26, 28, 33, 36, and 40, meet the criteria of being concrete operational, having taken all three Logo tests, and having a Logo average of 50 percent or better. Table 15 lists the percentage points difference in physics scores for these students for all questions (except Number 28), and for abstract questions.

The means and standard deviations in percentage points difference scores for these students were compared with the control group students. These results are listed in Table 16.

TABLE 14

LOGO SCORES FOR CONCRETE OPERATIONAL STUDENTS (TREATMENT GROUP)

Student Number	Logic Score	Logo Test 1	Logo Test 2	Logo Test 3	Logo Average
22.	3	75	80	30	61.7
23.	2	90	65	35	63.3
24.	1	60	50	10	40.0
26.	2	80	80	70	76.7
27.	3	60	65	20	48.3
28.	1	60	75	25	53.3
29.	2	55	50	--	--
30.	1	70	--	--	--
31.	3	60	45	10	38.3
32.	1	50	60	35	48.3
33.	5	65	60	25	50.0
34.	1	40	25	5	23.3
36.	5	80	85	45	70.0
37.	3	60	50	20	43.3
40.	4	65	85	25	58.3
42.	2	70	20	10	33.3
43.	2	40	70	30	46.7

TABLE 15

PERCENTAGE POINTS DIFFERENCE IN PHYSICS SCORES FOR CONCRETE OPERATIONAL STUDENTS WHO HAVE BEEN SCREENED FOR LOGO KNOWLEDGE

Student Number	Percentage Points Difference	Percentage Points Difference for Abstract Questions
22.	11.4	4.2
23.	35.1	37.5
26.	14.8	8.3
28.	7.8	0.0
33.	14.3	16.7
36.	21.0	20.8
40.	8.3	12.5

TABLE 16

MEANS AND STANDARD DEVIATION ON PHYSICS PERCENTAGE POINTS DIFFERENCE SCORES FOR LOGO KNOWLEDGE SCREENED STUDENTS AND CONTROL GROUP STUDENTS

	Control Group	Logo Screened Treatment Group
Mean of Percentage Points Difference Scores	16.9	16.1
Standard Deviation of Percentage Points Difference	12.1	9.5
Mean of Percentage Points Difference of Abstract Scores	14.8	14.3
Standard Deviation of Percentage Points Difference of Abstract Scores	14.4	12.5

Again, the means of percentage points difference scores indicate very little difference for each of these categories, and, in fact, no significant differences in scores were found at the 90 percent level of confidence. It would seem, then, that concrete operational students who have demonstrated a fair knowledge of Logo still do not learn physics any better than a group of similar students who have not learned any Logo.

Table 17 presents the results of a t-test analysis for concrete operational students who have taken the pre- and post-physics tests given in this study.

Summary of T-Test Analysis Results for Hypothesis 1

Analysis of t-test results, in general, supports Hypothesis 1. That is, concrete operational students who have been taught to program in Logo, in a Logo learning environment, are not any better at learning abstract physics concepts than similar concrete operational students who have not been taught to program in Logo. These results indicate that at the $p = .05$ level of confidence, there is no significant difference in improvement on pre-test results for physics concepts considered abstract, and physics concepts in general. Furthermore, even those students who had been screened for their knowledge of Logo do not do significantly better at learning these concepts.

Hypothesis 2

To test Hypothesis 2, many of the statistical tests done to test Hypothesis 1 were repeated. This time, however, only those test items

TABLE 17

T-TEST ANALYSIS OF VARIABLE DIFFERENCES BETWEEN CONTROL AND TREATMENT GROUP CONCRETE STUDENTS

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Logic Score					
Control:	16	1.81	1.5	1.23	2.042
Treatment:	17	2.41	1.3		
Pre-Test					
Control:	16	26.4	10.8	1.51	2.042
Treatment:	17	23.5	9.7		
Post-Test					
Control:	16	43.3	10.8	1.92	2.042
Treatment:	17	36.9	8.2		
Control					
Pre-Test:	16	26.4	10.8	4.41	2.042
Post-Test:	16	43.3	10.8		
Treatment					
Pre-Test:	17	23.5	9.7	4.36	2.042
Post-Test:	17	36.9	8.2		
Points Difference					
Control:	16	16.9	12.1	.88	2.042
Treatment:	17	13.4	10.5		
Abstract Pre-Test					
Control:	16	27.6	12.6	.77	2.042
Treatment:	17	24.5	10.4		
Abstract Post-Test					
Control:	16	42.4	11.3	1.80	2.042
Treatment:	17	36.3	8.2		

TABLE 17--Continued

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Abstract Points Difference					
Control:	16	14.8	14.4	.64	2.042
Treatment:	17	11.8	13.3		
Points Difference					
Control:	16	16.9	12.1	.15	2.082
Treatment: (Logo Screened)	7	16.1	9.5		
Abstract Points Difference					
Control:	16	14.8	14.4	.09	2.082
Treatment: (Logo Screened)	7	14.3	12.5		

considered to be strongly related to Logo were scored for both the pre- and post-tests.

Analysis of Physics Pre- and Post-Test Scores with Respect to Test Questions Strongly Related to Logo Concepts Taught

The analysis of the physics pre/post-test done in Chapter III, and reported in Table 1, indicates that Questions 2, 3, 4, 8, 9, 19, 20, 21, 22, and 23 are strongly related to the Logo concepts taught to the treatment group. The pre-test, post-test, and the percentage points difference scores for these questions are presented in Table 18 and Table 19 for control and treatment groups respectively. All test scores are reported in terms of percentage of questions correct. The means and standard deviations for these scores with respect to pre-test, post-tests, and percentage points difference are presented in Table 20, along with t-test values for control and treatment students on these questions.

To reject Hypothesis 2, it would be necessary to show that there was a significant difference in improvement of physics test scores for Logo-related questions. An examination of the scores and means listed in Tables 18, 19, and 20 indicate that while there is only a 1.2 point difference in pre-test score means between groups, there is an 11.3 point difference between means on post-test scores and a 12.2 point difference in the means of percentage points difference scores.

The results of the t-test analysis for these variables presented in Table 20 indicate that for the Logo-related items on this test, there was significant improvement on the physics test for both control

TABLE 18

PRE-TEST, POST-TEST, AND PERCENTAGE POINTS DIFFERENCE SCORES FOR CONCRETE OPERATIONAL CONTROL GROUP STUDENTS ON LOGO-RELATED QUESTIONS

Student Number	Logo Related Pre-Test Scores	Logo Related Post-Test Scores	Logo Related Percentage Points Difference Scores
1.	10.0	40.0	30.0
2.	20.0	30.0	10.0
4.	30.0	40.0	10.0
6.	20.0	70.0	50.0
7.	10.0	60.0	50.0
8.	10.0	20.0	10.0
9.	30.0	30.0	0.0
10.	30.0	20.0	-10.0
11.	10.0	30.0	20.0
12.	30.0	80.0	50.0
13.	30.0	50.0	20.0
15.	20.0	60.0	40.0
17.	20.0	30.0	10.0
18.	0.0	30.0	30.0
19.	20.0	50.0	30.0
20.	30.0	30.0	0.0

TABLE 19

PRE-TEST, POST-TEST, AND PERCENTAGE POINTS DIFFERENCE SCORES FOR CONCRETE OPERATIONAL TREATMENT GROUP STUDENTS ON LOGO-RELATED QUESTIONS

Student Number	Logo Related Pre-Test Scores	Logo Related Post-Test Scores	Logo Related Percentage Points Difference Scores
22.	30.0	50.0	20.0
23.	20.0	40.0	20.0
24.	30.0	20.0	-10.0
26.	0.0	30.0	30.0
27.	20.0	40.0	20.0
28.	30.0	20.0	-10.0
29.	20.0	30.0	10.0
30.	30.0	20.0	-10.0
31.	20.0	50.0	30.0
32.	30.0	30.0	0.0
33.	0.0	10.0	10.0
34.	20.0	50.0	30.0
36.	10.0	20.0	10.0
37.	30.0	20.0	-10.0
40.	40.0	60.0	20.0
42.	20.0	0.0	-20.0
43.	10.0	30.0	20.0

TABLE 20

T-TEST ANALYSIS OF VARIABLE DIFFERENCES BETWEEN CONTROL AND TREATMENT GROUP CONCRETE STUDENTS FOR LOGO-RELATED TEST ITEMS

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Pre-Test Logo Related					
Control:	16	20.0	9.7	.32	2.042
Treatment:	17	21.2	11.1		
Post-Test Logo Related					
Control:	16	41.9	18.0	1.91	2.042
Treatment:	17	30.6	16.0		
Points Difference Logo Related					
Control:	16	21.9	19.1	2.02	2.042
Treatment:	17	9.4	16.4		
Control Logo Related					
Pre-Test:	16	20.0	9.7	4.29	2.042
Post-Test:	16	41.9	18.0		
Treatment Logo Related					
Pre-Test:	17	21.2	11.1	1.99	2.042
Post-Test:	17	30.6	16.0		

and treatment groups. This is especially true for the control group. However, there were no other significant differences in all other scores at the $p = .05$ level.

Analysis of Physics Pre- and Post-Test Scores with Respect to Test Questions Considered Both Abstract and Strongly Related to Logo Concepts Taught

A further t-test analysis was done for these variables, but this time for physics test items which met the criteria of being both abstract and strongly Logo related. The analysis of test questions done in Chapter III and listed in Table 1 indicates that Questions 3, 4, 8, 9, 19, 20, and 21 meet these criteria.

Table 21 and Table 22 list the pre-test, post-test, and percentage points difference scores for abstract Logo related questions for control and treatment groups respectively.

Table 23 presents the means and standard deviations and t-test analysis for these scores.

Examination of Table 23 shows the means of scores for Logo related and Logo related abstract questions to be higher for the control group than the treatment group with respect to the physics post-test and the percentage points difference in scores. The t-test results seem rather inconsistent and somewhat inconclusive. No significant differences at the $p = .05$ level were found for abstract, logo related pre-test scores. Furthermore, at this level of confidence, the difference between post-test scores and percentage points difference scores for control and treatment groups were not significantly different. Also, for these questions, the pre- and post-test scores for the control group showed a

TABLE 21

PRE-TEST, POST-TEST, AND PERCENTAGE POINTS DIFFERENCE SCORES FOR CONCRETE OPERATIONAL CONTROL GROUP STUDENTS ON LOGO RELATED ABSTRACT QUESTIONS

Student Number	Abstract Logo Related Pre-Test Scores	Abstract Logo Related Post-Test Scores	Abstract Logo Related Percentage Points Difference Scores
1.	14.3	42.9	28.6
2.	28.6	14.3	-14.3
4.	14.3	28.6	14.3
6.	14.3	57.1	42.9
7.	14.3	85.7	71.4
8.	14.3	14.3	0.0
9.	42.9	42.9	0.0
10.	42.9	28.6	-14.3
11.	14.3	42.9	28.6
12.	28.6	85.7	57.1
13.	42.9	42.9	0.0
15.	28.6	57.1	28.6
17.	28.6	42.9	14.3
18.	0.0	14.3	14.3
19.	14.3	42.9	28.6
20.	28.6	28.6	0.0

TABLE 22

PRE-TEST, POST-TEST, AND PERCENTAGE POINTS DIFFERENCE SCORES FOR CONCRETE OPERATIONAL TREATMENT GROUP STUDENTS ON LOGO RELATED ABSTRACT QUESTIONS

Student Number	Abstract Logo Related Pre-Test Scores	Abstract Logo Related Post-Test Scores	Abstract Logo Related Percentage Points Difference Scores
22.	42.9	42.9	0.0
23.	0.0	28.6	28.6
24.	28.6	14.3	-14.3
26.	0.0	28.6	28.6
27.	14.3	42.9	28.6
28.	42.9	14.3	-28.6
29.	28.6	42.9	14.3
30.	42.9	28.6	-14.3
31.	14.3	42.9	28.6
32.	28.6	14.3	-14.3
33.	0.0	0.0	0.0
34.	14.3	57.1	42.9
36.	14.3	14.3	0.0
37.	42.9	28.6	-14.3
40.	42.9	57.1	14.3
42.	28.6	0.0	-28.6
43.	14.3	28.6	14.3

TABLE 23

T-TEST ANALYSIS OF VARIABLE DIFFERENCES BETWEEN CONTROL AND TREATMENT GROUP CONCRETE STUDENTS FOR LOGO RELATED AND ABSTRACT LOGO RELATED TEST ITEMS

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Pre-Test Abstract Logo Related					
Control:	16	23.2	12.7	.06	2.042
Treatment:	17	24.1	16.3		
Post-Test Abstract Logo Related					
Control:	16	42.0	21.8	1.48	2.042
Treatment:	17	28.6	17.5		
Points Difference Abstract Logo Related					
Control:	16	18.8	24.3	1.70	2.042
Treatment:	17	5.0	22.0		
Control Abstract Logo Related					
Pre-Test:	16	23.2	12.7	2.98	2.042
Post-Test:	16	42.0	21.8		
Treatment Abstract Logo Related					
Pre-Test:	17	24.1	16.3	.88	2.042
Post-Test:	17	28.6	17.5		

significant improvement, while the improvement was not significant at p = .05 for the treatment group.

To determine if tested knowledge of Logo affected physics test results, the t-test was again done for the students listed in Table 14 who met the criteria of being concrete operational, have taken all three Logo tests, and have obtained a Logo grade average of 50 percent or better.

Analysis of Physics Pre- and Post-Test Scores with Respect to Test Questions Considered Strongly Related to Logo, and Questions Considered Both Abstract and Related to Logo for Concrete Operational Students Who Have Been Screened for Their Knowledge of Logo

Table 24 lists the scores for percentage points difference on Logo Related and Abstract Logo Related test questions for concrete operational students screened for their knowledge of Logo, and Table 25 lists means, standard deviations for these scores. Also included in Table 25 are the t-values for Logo screened students with respect to control student scores on Logo related and abstract Logo related questions.

The results of the t-test analyses for Logo screened students on Logo related test items does not show any significant difference in percentage points difference physics pre-test and post-test scores at the p = .05 level of confidence for Logo related and abstract Logo related test items. This would seem to indicate that for Logo screened students, Hypothesis 2 cannot be rejected.

TABLE 24

PERCENTAGE POINTS DIFFERENCE SCORES ON LOGO RELATED AND ABSTRACT LOGO RELATED QUESTIONS FOR CONCRETE OPERATIONAL TREATMENT GROUP STUDENTS WHO HAVE BEEN SCREENED FOR KNOWLEDGE OF LOGO

Student Number	Logo Related Percentage Points Difference Scores	Abstract Logo Related Percentage Points Difference Scores
22.	20.0	0.0
23.	20.0	28.6
26.	30.0	28.6
28.	-10.0	-28.6
33.	10.0	0.0
36.	10.0	0.0
40.	20.0	14.3

TABLE 25

T-TEST ANALYSIS OF VARIABLE DIFFERENCES BETWEEN CONTROL AND LOGO SCREENED TREATMENT GROUP CONCRETE STUDENTS FOR LOGO RELATED AND ABSTRACT LOGO RELATED TEST ITEMS

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Points Difference Logo Related					
Control:	16	21.9	19.1	.96	2.080
Treatment: (Logo Screened)	7	14.3	12.7		
Points Difference Abstract Logo Related					
Control:	16	18.8	24.3	1.20	2.080
Treatment: (Logo Screened)	7	6.1	19.9		

Summary of T-Test Analysis Results for Hypothesis 2

Analysis of t-test results, in general, supports Hypothesis 2. That is, concrete operational students who have been taught to program in Logo, in a Logo learning environment, are not any better at learning abstract physics concepts than similar concrete operational students who have not been taught to program in Logo, even when the abstract concepts involved are directly related to concepts taught as part of the Logo curriculum.

In fact, if we had used the $p = .1$ level of confidence, a significant difference in scores on abstract Logo related items would exist between control and treatment groups which favors the control group. However, the significance of this difference disappears when only those students in the treatment group who have been screened for their knowledge of Logo are used. It may well be that any of the tenuous differences found in scores for Logo related and abstract Logo related questions are due more to the diminished reliability of the respectively ten and seven item test as compared to the reliability of the complete test.

Further Investigations

There were only a few students in both classes who had developmental reasoning scores greater than 5, and none were greater than 12. This indicates that only a few students were in a transitional stage between concrete and formal reasoning and none were formal reasoners. The scarcity of non-concrete reasoners in this sample of students makes statistical studies involving them difficult. Nevertheless, analysis of these students' test results may give us some further insights into student learning of abstract concepts.

There were 6 students in the treatment class whose developmental reasoning scores were higher than 5. Of these, Student Number 35 had to be eliminated from the sample due to insufficient class attendance. Logic scores, and percentage points difference scores on the physics test for the rest of the students are presented in Table 26. Scores for abstract questions, Logo related questions, abstract Logo related questions are listed as well. A t-test analysis of the scores with respect to the concrete operational students of the control group, along with the means and standard deviations of the scores, are listed in Table 27.

The means of these scores, except for the percentage points difference for Logo related test items, indicate somewhat higher scores for the transitional level treatment students as compared to the concrete control group. This is especially true when abstract questions are considered. However, there is no statistically significant difference in these scores. Considering the size of the sample, there would have to be a fairly large difference in scores for the difference to be statistically significant. Nevertheless, when one considers the reversal in score trends as when concrete control students were compared to concrete treatment students, one sees an indication that students who scored higher on the reasoning test tend to do better at learning abstract physics. Unfortunately, there was not a sufficiently large spread in reasoning level scores to do a meaningful estimate of

TABLE 26

LOGIC AND PERCENTAGE POINTS DIFFERENCE SCORES FOR PHYSICS TEST, INCLUDING: ABSTRACT QUESTIONS, LOGO RELATED QUESTIONS, AND ABSTRACT LOGO RELATED QUESTIONS

Student Number	Logic Scores	Percentage Points Difference	Abstract Percentage Points Difference	Logo Related Percentage Points Difference	Abstract Logo Related Points Difference
21.	9	22.1	20.8	10.0	0.0
25.	7	14.8	29.2	30.0	14.3
38.	6	14.3	8.3	30.0	28.6
39.	6	8.3	20.8	0.0	28.6
41.	8	31.4	33.3	20.0	28.6

TABLE 27

T-TEST ANALYSIS OF TRANSITIONAL TREATMENT GROUP STUDENT SCORES AS COMPARED TO CONCRETE OPERATIONAL CONTROL GROUP STUDENTS FOR PERCENTAGE POINTS IMPROVEMENT ON PHYSICS TEST, INCLUDING: ABSTRACT QUESTIONS, LOGO RELATED QUESTIONS AND LOGO RELATED ABSTRACT QUESTIONS

Variable	Number of Students	Mean	Standard Deviation	T-Value	T-Probability (p = .05)
Percentage Points Difference					
Control:	16	16.9	12.1	.91	2.093
Treatment: (Logic > 5)	5	22.4	11.1		
Abstract Percentage Points Difference					
Control:	16	14.8	14.4	1.10	2.093
Treatment: (Logic > 5)	5	22.5	9.6		
Points Difference Logo Related					
Control:	16	21.9	19.1	.42	2.093
Treatment: (Logic > 5)	5	18.0	13.0		
Points Difference Abstract Logo Related					
Control:	16	18.8	24.3	.11	2.093
Treatment: (Logic > 5)	5	20.0	12.8		

correlation between reasoning level and physics test score differences.

CHAPTER V

SUMMARY, IMPLICATIONS OF RESEARCH FINDINGS, RECOMMENDATIONS FOR FURTHER RESEARCH, AND CONCLUSION

Chapter V summarizes the findings of the research done in this present study, and discusses the practical and theoretical implications of teaching Logo as an aid to helping concrete operational students learn abstract physics concepts, and abstract concepts in general. In addition, important modifications and extensions of the present study were generated for future research.

Summary

Briefly stated, this is an exploratory study which examines the effects of learning the computer language Logo on students tested to be, in a Piagetian sense, at a concrete operational stage of their development. The study sought to determine if a sample of such students were taught to program in Logo, and, in general, were educated in a Logo learning environment, would they then be able to learn abstract concepts better than a similar sample of students who were not taught Logo.

Piagetian theory indicates that concrete operational students would have great difficulty understanding and applying abstract concepts. As much of the science content widely found in science curricula today is clearly abstract in nature, it is no surprise that these students are having difficulty learning science. To see whether or not learning Logo helped these students to learn science was the primary goal of this study.

To do this study, a sample of students who were studying eighth-grade science, most of whom were concrete operational reasoners, were divided into a control group and a treatment group. Each group was pre-tested as to their knowledge of abstract physics concepts which were to be taught as part of a self-contained physics unit designed for these students.

The treatment group then received 14 weeks of instruction in Logo Turtle graphics, as part of a specially-designed Logo learning environment. During this period of time, the control group continued to be taught science as part of their normal science program. Following this period of time, both groups were taught a three-week physics unit. This unit was designed to provide an exposure to a variety of abstract concepts, some of which were strongly related in the Logo that had been taught to the treatment group, and the rest either unrelated or weakly related to the Logo.

Both groups were then post-tested as to their knowledge of the physics taught. A statistical analysis of the results on the physics pre- and post-tests was done to see if the treatment group made significantly greater improvement in test scores than the control group. A further analysis was done with respect to individual test items to see if the treatment group made significantly greater improvement on test items which were judged strongly related to the Logo that had been taught, than the control group.

The sample used for this study consisted of 43 students taken from a population of eighth-grade students from a small town, Vermont junior high school. These students had been randomly programmed by computer into heterogeneous science classes. The two science classes chosen were picked on the basis of their being taught by the same science teacher, and that one of the classes met at a time when it was possible for them to use the school's eighteen-station computer laboratory. These students were all tested to determine their developmental reasoning level and their pre-knowledge of the physics concepts they were to be taught.

No significant differences were found in either the developmental reasoning level scores or physics pre-test scores between these groups, which indicated that the groups were suitably matched. Furthermore, physics pre-test results indicated that these students had little or no pre-knowledge of the physics to be taught them, as the means of their scores were about what they would be if the students randomly picked their answers. It was found, however, that both of these groups had developmental reasoning level scores which were considerably lower than scores made by the entire eighth-grade population of this school when it had been tested during a previous year. Furthermore, these scores were considerably lower than the mean scores of eighth-grade students reported by other schools around the nation. It was concluded that these lower scores were due to a "creaming off" effect caused by ability tracking students for their mathematics courses. While science students were not ability tracked, per se, tracking in mathematics apparently affected how students would be grouped in other subjects, including science.

This creaming off of developmentally higher-level students did not, it is felt, detrimentally effect the study, since both groups were apparently affected in the same way. This is clear from the lack of significant difference in developmental reasoning scores between groups, and the judgment of the science teacher, familiar with each group's work, who felt these groups had about equal ability.

Of the 43 student sample used in this study, 20 students made up the control group and 23 students made up the treatment group. Of the 20 students that made up the control group, 18 were tested to be concrete operational, and two of these missed taking the physics pre-test. This left 16 students in the control group. Of the 23 students who made up the treatment group, 17 were tested as concrete operational and were left in the treatment group.

The instrument used to determine developmental reasoning level was a modified version of the Lawson Classroom Test of Formal Reasoning. This test was developed so as to keep as many of the positive aspects of the Piagetian clinical methods as possible, but still allow one test to be administered to an entire group of students. This test was shown to have face, convergent, and factorial validity, and was found highly reliable as well. The modification made to this test by the author of the present study consisted of using videotaped demonstrations in place of live demonstrations. The modified version of this test was found to be valid in a previous study done by the researcher, and had the advantage of being more consistent in its presentation.

The second instrument used in this study was developed by the author since there had been no previous research on learning abstract physics in this context. The instrument was designed to directly test the objectives of the physics unit taught. The questions had to be mostly abstract in nature, yet still be presented on an eighth-grade level, both verbally and mathematically. In addition, some of the questions had to be shown strongly related to the concepts taught as part of the Logo unit, while others had to be unrelated.

An analysis of each question was done to insure curricular validity. In addition, the test was judged by two experts in the field, who agreed that the test basically measures what it was trying to measure and is, therefore, valid to that extent. Furthermore, the test was found to be reasonably reliable, having a Spearman-Brown corrected KR-20 split half correlation of 0.6.

The other instruments used in this study consist of three Logo tests developed on an ad hoc basis to evaluate student progress in learning Logo. As these tests were specifically designed to evaluate student progress, and were based on Logo concepts studied, they should be valid indicators of student progress.

The data collected through the use of these instruments during this study were guided by two hypotheses:

Hypothesis 1: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics than similar students who have not been taught to program in Logo.

Hypothesis 2: Concrete operational students who have learned to program in Logo will not make significantly greater progress towards learning selected abstract concepts in physics which are directly related to the Logo concepts learned, than similar students who have not been taught to program in Logo.

The first hypothesis was concerned with the question of whether or not concrete operational students who were taught to program in Logo, in what is considered a Logo learning environment, would learn abstract physics concepts better than similar students who were not taught Logo, but attended their normally-scheduled science class instead. To test this hypothesis, a sample of concrete operational eight-grade students was divided into a control and a treatment group and were pre-tested in physics. The treatment group was then taught to program in Logo during a fourteen-week period of time in what was considered to be an appropriate Logo learning environment. Student progress in Logo was monitored along the way by use of a series of Logo evaluation tests. These tests were used in addition to the evaluation of student projects and class work.

After this period of time, both groups were taught a self-contained three-week physics unit designed to be highly abstract in terms of concepts, but on grade level with respect to the mathematics and verbal skills needed. Following the teaching of this unit, both groups were post-tested as to their knowledge of the physics taught them.

An analysis of pre- and post-test scores was done to determine if the Logo-trained students made significantly greater improvement in their test scores than the control group. By using a t-test analysis, it was found that improvement in pre-test scores did not differ significantly (p = .05) for the test taken as a whole, or for only those questions considered to be abstract. These results were also true for students who were screened for their knowledge of Logo as based on their taking all three Logo tests, and achieving a 50 percent or better average for the three tests.

It is evident from these results that Hypothesis 1 cannot be rejected, as there is no evidence that Logo-trained concrete operational students learned selected abstract physics concepts any better than students who were not trained in Logo.

The second hypothesis was concerned with whether or not learning Logo helped students learn abstract physics concepts which were strongly related to the Logo learned. To test this hypothesis, only those test items judged to be strongly related to the Logo taught were used.

A t-test analysis of pre-test and post-test scores was again performed, but this time only for Logo-related test items. The results of this analysis indicated that there was no significant difference ($p = .05$) in improvement of test scores for control and treatment groups with respect to Logo-related test items, even for students who were screened for their knowledge of Logo.

The results of this analysis indicate that Hypothesis 2 cannot be rejected, as there is no evidence that concrete operational students who are trained in Logo do any better at learning abstract physics concepts than students who were not trained in Logo, even when the abstract concepts to be learned are related to the Logo.

A further investigation indicated that when students who are transitional in their developmental level are compared to concrete operational students, they tend to do better at learning abstract physics concepts. However, the number of students who were at the transitional stage of their development was too small to show that their scores were significantly different than control group scores.

Implication of the Research Findings

There is no doubt that many, if not most, children when introduced to Logo for the first time find the computer language fascinating. This is especially true for the Turtle graphics aspect of the language. In this study, the eighth graders who became part of the Logo treatment group did not volunteer to take part in the study. Furthermore, the group as a whole was somewhat below the average in ability, and were not particularly well behaved. In fact, several of the children were constantly in trouble, and one was twice suspended from school while the study was in progress. To add to these difficulties, the class was scheduled as the last class of the day, which did not make teaching these "itchy" eighth graders any easier.

Nevertheless, the students were pleased to become part of this study, and looked forward to working with the computer enthusiastically. In fact, even the most difficult of these students were extremely excited about learning to program, and their misbehavior faded as their attention was riveted to the screen. Indeed, the computer environment they were becoming part of seemed to be a most appropriate setting for Piagetian learning--learning without being taught.

It is easy to see how the teacher of Logo would be impressed with what the children could do and learn. It is easy to understand the glowing testimonials based on qualitative observations. Students were surely learning, and the learning seemed natural and unforced. But the lingering questions of just what was being learned, how well was it being learned, and what effect would this learning have on other, perhaps more traditional, learning could not be swept aside by glowing testimonials.

It seems clear that the many advocates of Logo believe that the Logo environment is a mathematics-rich environment where children learned to think mathematically as a French child learns to speak French. In this environment, they would learn how to think logically and solve problems. Were this the case, surely it would be a pedagogical breakthrough of some sort.

That Logo can be used to teach mathematics or physics certainly cannot be denied. DiSessa's Turtle Geometry[1] presents some higher mathematics concepts in a new and fascinating way, and some recent books using Logo to teach physics give us a rather novel approach to understanding this subject. But still we must ask if these approaches are any more useful than more traditional approaches for teaching these subjects. And, furthermore, we should ask if the Logo approach to teaching and learning these abstract concepts are more effective than the traditional methods, with the student that has traditionally found learning abstractions difficult--the concrete operational thinker.

Papert, one of the developers of Logo, and his associates tell us that traditional methods may be best for teaching traditional subjects, but that these traditional subjects are antiquated. He points out that the many hours spent learning long division, for example, are unnecessary in this day of the hand-held calculator. Mathematics is so much deeper than the mechanical routines slavishly practiced by fifth graders everywhere. These routines, he says, will not teach children to understand mathematics, but learning Logo will.

It is hard to deny the logic of Papert's arguments; much of what he says rings true. Yet, this study seems to indicate that the concrete operational student, who is most in need of help in learning to think abstractly, has not been helped by learning Logo.

As pointed out, the Logo treatment class got off to an enthusiastic start. The beginning concepts were quite easy to learn, and the beginning projects were fairly easy to achieve. Students who had a history of doing nothing in class, or worse, were hard at work on their projects. Students were encouraged to share ideas, and could be seen helping one another as they discovered new and interesting techniques. However, as the Logo concepts needed in order to continue to make progress grew increasingly sophisticated, the rate of learning slowed drastically.

This slow down was not universal; those students who, as it turns out, had the highest developmental reasoning scores continued to make good progress, while those with the lowest scores made little progress.

The first problems arose with the developing of procedures and superprocedures. An indication that things were not going to go smoothly was seen in the methods used to choose names for procedures. The slower students seemed to have difficulty understanding that procedures should be "named" in such a way as to help them put together superprocedures. Instead, names were chosen in a fairly random or illogical way. Very often procedures were given proper names, such as Mary or Sue. One student went through all the names of his girlfriends before completing his first project.

Another problem developed with the use of variables within procedures. Slower students, though they often used variables within their procedures, never seemed to understand the powerful concept of the variable. Still another source of problems concerned the orderly control of variables in discovering the properties of regular polygons. While students were shown how to start a table which tested the use of angles or side lengths in the drawing of polygons, they failed to see the developing pattern, often choosing to try angles or lengths which did not fit into a logical trial sequence. These are just a few examples of the many problems these students had in grasping some of the more complex aspects of what they were doing. In fact, it would seem that the very students who might be expected to have difficulty learning the abstract concepts of physics were having difficulty learning the abstract concepts of Logo. This was in spite of the fact that they could use as much trial-and-error and exploration as they pleased.

The slowest of the students did not seem to learn from their trial-and-error techniques, and their exploration often ended in frustration. This was often the case, even though they had two teachers and a number of helpful classmates to guide them along; or, when all else failed, give them the solutions to their problems. In one case, an eighth-grade girl grew furious with her computer, insisting that what she did was correct, but the computer refused to do what it was supposed to. It were as though the computer had a mind of its own and was vengefully wronging this young lady. No amount of explaining that these machines did what we instructed them to do--no more, no less--seemed to help.

This lack of understanding of important Logo concepts becomes evident when one examines the results of the three Logo tests taken by the students during the fourteen weeks that they were studying Logo. For many of the students, these tests indicated that they failed to understand many of the most fundamental concepts of Logo.

The tests, which were presented as projects to be done during a timed period rather than a means of grade evaluation-grades, which were required by school officials, were determined for the most part by completion of projects which consisted of number of straight-forward Logo tasks and problems. Students, for example, had to follow the directions given in a short Logo procedure in order to graph a shape such as a rectangle, or write a simple Logo procedure to perform a task, or modify a given procedure so as to incorporate a variable, or find a "bug" in a procedure and correct it. (See Appendix B for a listing of the Logo procedures used in this study.) Though credit was given liberally, Logo test grades for concrete operational students tended to be rather low. (See Table 18 for a listing of Logo grades.)

In spite of the bleak picture described, the class appeared to be going well. Students worked at their computers alone or in small groups. They were constantly asking and answering questions, or playing Logo games and working puzzles. Students were helping each other with projects and discovering this or that. In fact, it was only towards the end of the fourteen-week period that some of the students truly began to lose patience. However, a number of the slowest students stopped making progress early in the project. They occupied their time producing involved pictures without benefit of procedures or superprocedures, or variables, or anything else which demonstrated a degree of sophistication. The rest of the time was spent playing various dynamic Logo games, without apparently making any cognitive breakthroughs.

Had these activities led to a clear indication that students were better prepared to organize their thoughts, solve problems logically, and learn abstract concepts any better than they did before learning Logo, the value of Logo would be clear. But, although the Logo computer language undoubtedly has many intrinsic values, such as being a good first exposure to structured programming techniques or having many practical applications, its value as a language for learning how to understand abstract concepts, at least in the case of concrete operational students, has in no way been proven by the results of this study.

The implication of this study's findings for the teaching of Logo is that Logo does not help concrete operational students learn abstract physics concepts, even if these concepts are related to the Logo taught. And, furthermore, much of Logo is, in fact, abstract itself and not learned very well by the concrete operational student. While it may be that Logo is worth teaching for a variety of reasons based on its own intrinsic value as a computer language, using it as an indirect method for helping students learn science is of questionable worth.

Recommendations for Further Research

The present study was exploratory in nature, and some of its results tenuous. The instruments and research processes used represent an initial attempt to determine the effect of teaching Logo on learning abstract concepts; however, the tenuous nature of some of the results indicate a need for replicating and extending this investigation.

To begin with, a large, more varied sample of students would help insure the statistical validity of the study. However, if the sample becomes too large to be effectively handled by one teacher, it would be necessary to develop a study design which would allow for possible differences in teaching methods and skills. Furthermore, the time needed to teach the Logo should be increased as it was found that many important concepts could be barely touched upon in the time allotted for doing the study. Many of the slower students would have benefitted from having more time to let the concepts "sink in," while the more able students could have delved deeper into the subject material.

Also, the number and variety of questions asked on the physics test needs to be modified, so that there are many more Logo-related physics questions asked. This could be accomplished by doubling the number of questions asked while making certain that at least half the questions are Logo related, with the remaining questions unrelated. This should improve the reliability of the test, especially with respect to Logo-related questions.

This present study investigated the effect of Logo on eighth-grade science students who were tested to be concrete operational. Extending this study to include many more students whose developmental reasoning level goes beyond this stage could be useful. We could, for example, see if a strong correlation between developmental level and learning Logo exists. Perhaps, if there is a high correlation between developmental level and the ability to learn Logo, higher-level students who learned Logo would be better learners of abstract physics concepts than similar students who have not learned Logo. We could then replicate this investigation for students at a higher stage of reasoning development to see if this is, in fact, the case.

To be able to generalize any of the results of this study, it would be necessary to expand the study beyond this one school. We would have to study a fair-sized number of schools at a variety of locations. However, considering the time needed to teach the Logo effectively, the cost of equipment, the number of students and teachers that would have to be involved, it would not be a practical undertaking to have schools teach Logo just for research purposes. However, during the period of time from when this study was first conceived to the present day, Logo has proliferated around the country. Furthermore, many schools now have computers in sufficient numbers to develop ideal Logo learning environments.

Considering these circumstances, there is certainly no shortage of students who are presently being taught Logo. And certainly we could find equal numbers of students who have not been taught Logo. Then, perhaps, instead of performing a controlled teaching experiment as was done here, we could match students with and without Logo training, and do a statistical comparison of the science grades, for example, of students who have studied Logo and the students who have not studied Logo. There would, undoubtedly, be serious design and logistical problems to undertaking such a statistical study, and it would not take developmental level into account; but it could give us an indication as to Logo's ability to help students to learn abstract concepts.

Conclusion

The purpose of this study was to determine if a method could be found to help non-abstract reasoning students learn the abstract concepts of science. It was hoped that this study would show that learning the computer language Logo would help concrete operational students to learn the abstract concepts of science. Certainly the developers of Logo, and the many advocates of its study, expressed the belief that it can. However, none of the admittedly few, objective studies reported here has found clear evidence, if any evidence, that this is the case.

Neither does this present study support the hypothesis that Logo can help students think abstractly and learn abstract concepts. Certainly it may be argued that this experiment was flawed, and undoubtedly conditions were less than ideal. Certainly it may be argued that the Logo was not taught as it should have been taught, and perhaps it was not. Yet, considering the difficulties involved in setting up an ideal experiment in a "real world" situation, the researcher went to great lengths to approach that ideal.

One would have hoped that even if statistical significance could not be established, there would at least have been an indication that Logo helped a little. There was no such indication. And considering the reported proliferation of the study of Logo, one has to wonder what is not being taught when Logo is.

Logo is an aesthetically pleasing computer language. It is a powerful tool, and can be used in a practically unlimited variety of ways. Certainly, there are many good reasons for students to learn at least some Logo; but is it the "learning" language that some think it is? There would seem to be more evidence, at this time, that it is not rather than is.

Considering the evidence that does exist, it would seem unwise to cut into the time needed to teach concrete operational students traditional science in order to teach them Logo. Perhaps our efforts to teach such students effectively would be better directed in developing science curricula which more properly fit the developmental level of the student. The computer and computer languages, such as Logo, certainly have a role in shaping the future education of our students; and they may well be shown to be an effective means of teaching students to think and learn abstractly. However, given a finite amount of time and funds, schools should consider the results of this and other studies of Logo before making a large commitment to its teaching.

NOTES

[1] H. Abelson and A. diSessa, Turtle Geometry (Cambridge, Massachusetts: The MIT Press, 1981).

APPENDIX A

LAWSON CLASSROOM TEST OF FORMAL REASONING STUDENT ANSWER SHEET

NAME: ______________________ DATE: __________

SCIENCE TEACHER: ______________________ AGE: __________

1. Has the weight of clay ball #1 changed as compared to the weight of clay ball #2?

   Answer:

   Reason:

2. How will the level of the water in the container change when the heavy-weight is placed in it, as compared to when the light-weight is placed in it?

   Answer:

   Reason:

3. How high would a given amount of water, that rises 6 units in the wide container, rise if it were poured into the narrow container?

Answer:

Reason:

4. How high would 11 units of water in the narrow container be in the wide container?

Answer:

Reason:

5. Where on the balance beam should a 5-unit weight be hung to balance a 10-unit weight hung 7 units of length from the balance point?

   Answer:

   Reason:

6. Where on the balance beam should a 10-unit weight be hung to balance a 15-unit weight which is hung 4 units of length from the balance point?

   Answer:

   Reason:

7. Which pendulum should be used in an experiment to find out if changing the length of the string affects the time it takes a pendulum to swing back and forth?

   Answer:

   Reason:

8. Which pendulum should be used in an experiment to find out if the weight of the pendulum affects the time it takes the pendulum to swing back and forth?

   Answer:

   Reason:

9. Should we use the heavy-weight ball or the light-weight ball to find out whether or not a ball placed at a higher position on the ramp will cause the target ball to travel farther after it is hit?

Answer:

Reason:

10. Does this experiment prove that ball #1 will move a target ball farther than ball #2?

Answer:

Reason:

11. How many ways of flipping the switches would you have to flip to be sure to find the one way to light the bulb? (There is only one arrangement of the four switches that will light the bulb.)

    Answer:

    Reason:

12. How many different ways can these four blocks be arranged side-by-side along a straight line?

    Answer:

    Reason:

13. What are the chances of choosing a red square on the first pick?

Answer:

Reason:

14. What are the chances of choosing a red object on the first pick?

Answer:

Reason:

15. What are the chances of choosing a red diamond on the first pick?

Answer:

Reason:

APPENDIX B

LOGO OBJECTIVES AND LESSON PROCEDURES

LOGO GOALS

The student, by learning to program in Logo, will:

1. Learn powerful ideas from physics or mathematics or linguistics which are embedded into the Logo language in a natural fashion.
2. Explore methods of thinking and solving problems by self-analysis of one's thinking process.
3. Gain knowledge previously accessible only through formal processes in a concrete manner with the help of the computer.
4. Develop a logical way of solving abstract problems by being provided with concrete down-to-earth models of thinking.
5. Understand that solving problems may involve making errors and working those errors out or "debugging."
6. Develop powerful strategies for "debugging" problems.
7. Gain confidence in his or her problem solving ability, and thus be willing to tackle difficult problems, while enjoying the process.

LESSON NUMBER 1

The student will be able:

1. To start up and load the Logo program.
2. To use the following commands:

PRINT	(PR)	HIDETURTLE	(HT)
FORWARD	(FD)	SHOWTURTLE	(ST)
RIGHT	(RT)	CLEARSCREEN	(CS)
BACK	(BK)	PENERASE	(PE)
		PENUP	(PU)
		PENDOWN	(PD)

Questions and Activities:

1. Move turtle around screen using: FD, BK, RT, and LT with different input numbers.
2. Move turtle through provided mazes.
3. Clear screen and draw various shapes. Example: Squares, rectangles, triangles, etc.
4. LOAD "MAZE8 and "MAZE9. Move turtle through each maze in turn.
5. Experiment with small and large inputs (angles, distances).
6. Use HT, ST and CS commands to see what happens. Use PU and PD and PE commands in addition to FD, RT, LT and BK to draw three shapes at three different parts of the screen with no lines joining shapes. (PD cancels PE command.)
7. Use PRINT command with +,-,*,/ to do arithmetical calculations. Example: PR 3 + 2; PR 5 - 1; PR 6 * 4; PR 8 / 2

LESSON NUMBER 2

The student will be able:

3. To use these commands to draw simple geometric figures.
4. To understand how angles are used in constructing these figures.
5. To understand how side length and angle size determines shape of simple figures.

Questions and Activities:

1. Draw and square using FD 50 RT 90.
2. What are the angles of the square's corners?
3. Draw different sized squares.
4. Draw a rectangle.
5. Draw a square within a square (with no connecting line).
6. Draw a square which is tilting to the right or left.
7. Use squares to produce a design or picture.
8. Draw your initials.
9. Draw a triangle on paper and measure the angles of the triangle. Then use this information to draw a triangle on the screen.
10. Draw a triangle with three equal angles.
11. Draw triangles with different shapes.

LESSON NUMBER 3

The student will be able:

6. To define a Logo procedure using TO and END.

7. To correct mistakes while defining procedures using:

   <- delete character to left of cursor.
   -> moves cursor to right without deleting characters.
   [A] moves cursor to beginning of line.
   [B] moves cursor to left without deleting.
   FULLSCREEN or [L] to give full graphic screen.
   TEXTSCREEN or [T] to give full text screen.
   SPLITSCREEN or [S] to give mixed screen.

8. To use the REPEAT command to draw simple geometric figures (e.g., REPEAT 4 [FD 50 RT 90]).

9. To use [G] to stop a Logo execution.

Questions and Activities:

1. Write a procedure for drawing a square, rectangle, and equilateral triangle.

2. Use the REPEAT command to draw these shapes.

3. Change your procedures using the above commands.

4. Use the control G command to stop the computer from completing your instructions.

LESSON NUMBER 4

The student will be able:

10. To go into EDIT mode and edit a Logo procedure using:

EDIT	"NAME.
[C]	exits editor with text processed.
[G]	exits editor with text unprocessed.
->	at end of line to move to next line.
[A]	moves cursor to beginning of line without deleting.
[B]	moves cursor back without deleting and at beginning of line to move to end of previous line.
<-	at beginning of line to combine line with previous line.
[D]	at end of line to combine line with next line.
[N]	to move down to Next line.
[O]	to Open new line at cursor position.
[P]	to move cursor up to Previous line.
[V]	to scroll forward one screenful.
[ESC]	to scroll back one screenful.
[L]	to scroll cursor line to center of screen.

11. To define more than one procedure at a time.

12. To save a procedure to disk using SAVE "NAME.

13. To catalog disk using CATALOG command.

14. To load saved procedures using LOAD "NAME.

Questions and Activities:

1. Go into EDIT mode and define a procedure for drawing a geometric figure.

2. Use control C to leave EDIT mode and save procedure to disk.

3. Write several more procedures and save them. (Use ERALL to clear workspace before beginning.)

4. Use defined procedures, such as SQUARE and TRIANGLE to draw a house, and save using the name HOUSE.

5. Use editing commands to change a procedure.
6. Use procedures to edit the procedure named "SLOPPY which can be loaded from your disk and has deliberately misspelled words in it.
7. CATALOG procedures on disk.
8. Turn off computer, then re-boot and load saved procedures.

LESSON NUMBER 5

The student will be able:

15. To print hard copy using .PRINTER #
16. To manage workspace using:

    PO "NAME: (prints out definition of NAME)

    PO [NAME OTHERNAME

    POALL: (prints names and procedures)

    ERASE (ER) "NAME: (erases file called "NAME)

Questions and Activities:

1. Catalog procedures, load one, and make a "hard copy" print.
2. Print out all definitions in workspace.
3. Erase some procedures from the workspace.

LESSON NUMBER 6

The student will be able:

17. To use commands learned so far to draw a more complicated picture using defined procedures.

Questions and Activities:

1. Draw a scene with houses, mountains, trees, etc., or something else which interests you. Define and name parts of the procedure and use in a "superprocedure."

LESSON NUMBER 7

The student will be able:

18. To use the following screen commands:

HOME	to clear screen and move turtle to center position.
CLEAN	to clear graphic screen without moving turtle.

19. To set pen colors using:

    SETPC # (0-black, 1-white, 2-green, 3-violet, 4-orange, 5-blue)

20. To set background using:

    SETBG #

21. To reverse pen colors using:

    PENREVERSE (PX).

Questions and Activities:

1. Use color commands (if color monitor is available) to change colors in a procedure or to add color to a procedure.

LESSON NUMBER 8

The student will be able:

22. To understand what is meant by a variable.

23. To use Logo variables and inputs in Logo procedures, e.g.,

```
TO SQUARE :S
REPEAT 4 [FD :S RT 90]
END

SQUARE 100
```

24. To perform arithmetical operations on variables (e.g., using 2 * S in SQUARE :S procedure).

Questions and Activities:

1. Write a procedure for a square with a variable side. Use arithmetical operators on variable.

2. Starting from HOME position, draw a series of squares by varying the size of the square so that each new square is larger than the next. Save this procedure as "GROWSQUARE. (See Figure 8.)

3. Do the same for a triangle.

4. Write a procedure for a rectangle using variables for length and width. (For example: TO RECTANGLE :LENGTH :WIDTH)

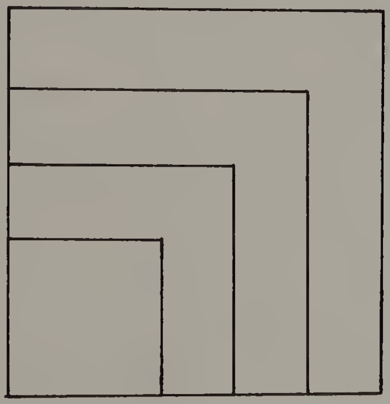


Figure 8

LESSON NUMBER 9

The student will be able:

25. To understand what is meant by recursion.

26. To use recursion in procedures.

27. To use recursion and variables to draw designs.

Questions and Activities:

1. Examine procedures which take an angle as a variable and then calls on itself.

```
Procedure Defined                     Procedure Used

Example 1:

TO SPINSQUARES :ANGLE                 SPINSQUARE 45
SQUARE 50
RT :ANGLE
SPINSQUARES :ANGLE
END (use control G to stop)

Example 2:

TO STARS :ANGLE                       STARS 30
SQUARE 50
RIGHT :ANGLE
SPINSQUARES :ANGLE
END
```

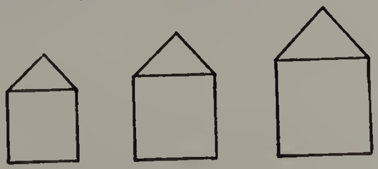
2. Write procedures for your own spinning designs.

3. Use your square procedure to draw a square.

4. Modify procedures so that it draws squares twice as large.

5. Write a procedure which draws a series of houses, one next to the other, but slightly larger.

Example:



(Hint: Use recursion and control G to stop)

LESSON NUMBER 10

The student will be able:

28. To understand the infinite nature of recursive procedures.

29. To use the following predicates with the following conditional expressions:

    >, <, =.

30. To control recursion with conditional expressions.

    Example: `IF :X > :Y [STOP]`

Questions and Activities:

1. Call up GROWSQUARES program. Modify procedure so that program stops if side size is greater than 100.

   Example: `IF :SIZE > 100 [STOP]`

2. Modify SPINSQUARE program to include variable sides and angles. Save as SPINSQUARE1.

3. Modify SPINSQUARE1 to include a conditional stop command.

LESSON NUMBER 11

The student will be able:

31. To define a regular sided shape.
32. To write a procedure which draws regular sided shapes.
33. To understand that only certain angles will produce regular shapes.

Questions and Activities:

1. Write a procedure which moves the turtle forward 50 and then turns right 150 a number of times.
2. Modify the procedure using the REPEAT command.
3. Try this procedure with a number of different angles.
4. Determine the angle needed and the number of times repeated to draw a square.
5. Which angles produce regular shapes? What do the other angles produce?
6. Use procedure to draw multiple sided regular shapes starting with three and going to many sides. (Use hide turtle to help see what you are drawing.)
7. What type of figure do you get as the sides become many?

LESSON NUMBER 12

The student will be able:

34. To apply knowledge of polygons to construct circles.

35. To understand angular relationships with circles and other polygons.

36. To understand nature of infinity and approximations of infinity.

37. To use HEADING to control poly program.

Questions and Activities:

1. Examine the recursive procedure called POLY which includes size and angle variables. Call procedure POLY. (Use control G to stop.)

```
TO POLY :SIZE :ANGLE
FD :SIZE RT :ANGLE
POLY :SIZE :ANGLE]
```

2. Input various sides and angles to draw geometric shapes. These shapes may look like stars or polygons which are closed figures such as a square.

3. Keep track of shapes made using the following chart:

SIZE	ANGLE	TYPE OF SHAPE	NUMBER OF SIDES	DOES IT WRAP AROUND SCREEN
30	30	Polygon	12	No
60	30	Polygon	12	Yes
30	60	Polygon	6	No
30	80	Star	9	No

4. Do chart again, but control variables by changing only one variable at a time, while keeping other variables constant. (Example: Keep size constant, but vary angle.)

5. Keeping size the same, find the angles needed to draw the following shapes: square (4 sides), triangle (3 sides), hexagon (6 sides), octagon (8 sides), nonagon (9 sides), pentagon (5 sides), heptagon (7 sides).

6. Keeping size constant, find the angles to draw stars with 5, 8, 9 points, etc.

7. Now keep angles constant while changing sides.

8. Use different combinations of size and angle; include very large or very small inputs to see what happens.

9. Answer the following questions:

   How many sides for each of these angles: 30, 60, 90, 120, 180?

   What is the rule for connecting the number of sides with angles?

   How about these: 80, 150, 160, 200?

   Can you find a rule for these angles?

   (Hint: The rule involves the number 360 -- Why?)

10. Draw a circle using POLY. How are the angles needed related to 360?

LESSON NUMBER 13

The student will be able:

38. To use the MAKE command in a procedure. For example:

```
MAKE "APPLE 50
PRINT :APPLE
50
```

39. To understand that a conditional stop command must be inserted in the logically correct place in a procedure to work properly.

Questions and Activities:

1. HEADING is a Logo command that tells which way the turtle is pointing at any time. After a HOME command, the turtle has a heading of zero. HOME the turtle, then modify the POLY procedure to stop POLY when the heading is zero. Call this POLY1. (Use IF HEADING = 0 [STOP])
If this does not stop execution of procedure, try placing the stop statement at a different position in the procedure. Why should it work in one position, but not at another?

2. If heading does not begin at zero, but at some other heading which we will call START. The computer must be told that START is the starting heading. This can be done by using the Logo command MAKE to make START the starting heading.
(For example: MAKE "START HEADING)
When MAKE is used, the first input is always a name and needs a quotation mark.

3. Write a POLY procedure which uses the MAKE "START HEADING. Call it POLY2. Clear screen and turn the turtle so that it is no longer at zero; then use your POLY2 procedure.

4. Use:

```
TO POLYSPI :SIZE :ANGLE
FD :SIZE
RT :ANGLE
POLYSPI (:SIZE + 1) :ANGLE
END
```

What happens? Why?

5. Modify the procedure to make the shape grow smaller and smaller.

6. Here are some more examples of how STOP commands are used:

```
IF :SIZE > 100 [STOP]
IF :SIZE < 1 [STOP]
```

7. Write some procedures using these or similar commands.

LESSON NUMBER 14

The student will be able:

40. To construct circles using the radius of circle.
41. To construct arcs of various sizes.
42. To include procedures for arcs and circles in designs.

Questions and Activities:

1. The distance from the center of a circle to the circle is called the radius of a circle. Can you write a procedure to draw circles around particular points with a given radius?

   a) To do this, begin with a procedure for drawing circles, such as:

   ```
   TO CIRCLE
   REPEAT 360 [FD 1 RT 1]
   END
   ```

   b) Now write this procedure using a variable for the forward step. Call this CIRCLE2.

   c) Print out a number of circles of different radii. Using a ruler and string, measure the circumference of the circle and compare its length to the length of the radius. What number do you get when you divide the radius into the circumference? This number times the radius or half this number times the diameter will always give us the circumference of a circle. This number is so important we give the number a special name. Actually, it is half the number which we give the name, and that name is the Greek letter pi. The value of pi is approximately 3.14.

   d) To draw a circle with a particular radius, we can use our CIRCLE2 procedure and let:
   size = radius X pi/180 = 0.0174.

   e) Write a procedure called CIRCLE which takes an input RADIUS and uses CIRCLE2 with an input of RADIUS * 0.0174.

2. An arc (a continuous part of a circle) may be drawn using a procedure which uses the step-turn part of the circle program, but only turns as many one degree steps as there are degrees in the arc. For example:

```
TO RIGHTARC :RADIUS :DEGREES
RIGHTARC1 :RADIUS * 0.0174 :DEGREES
END

TO RIGHTARC1 :SIZE :DEGREES
REPEAT :DEGREES [FD :SIZE RT :1]
END
```

3. Write a procedure to arc left.

4. Use arc and circle procedures to make designs or draw pictures.

LESSON NUMBER 15

The student will be able:

43. To understand what a "frame of reference" is.

44. To define Cartesian frame of reference.

45. To move the turtle by specifying x,y Cartesian coordinates using the SETPOS command, e.g., SETPOS [30 40].

46. To move the turtle horizontally by using the SETX command.

47. To move the turtle vertically by using the SETY command.

48. To set the direction of the turtle using the SETHEADING, (SETH) command. Rotates turtle clockwise with zero directed straight up, e.g., SETH 180.

49. To understand what a random number is and use RANDOM # in a procedure.

Questions and Activities:

1. Move turtle to various parts of the screen using SETX and SETY commands. Negative values must have a parentheses around them. (For example: SETX (-10))

2. Clear screen, then draw an object at some X,Y point. Use SETH to aim turtle at object. Move turtle in that direction to see if you hit the object.

3. Give the computer the following instructions:

```
TO GOODBYE
CLEARTEXT
PRINT [WELCOME TO LOGO]
ERALL
END
```

then

```
GOODBYE
```

4. Define the following procedures:

```
TO STARTDATA
MAKE "SHOTNUMBER 0
MAKE "XTARGET (90 - 10 * RANDOM 19)
MAKE "YTARGET (90 - 10 * RANDOM 6)
MAKE "XSTART (90 - 10 * RANDOM 19)
MAKE "YSTART (-10 * RANDOM 3)
MAKE "HSTART (10 * RANDOM 36)
END

TO STARTGAME
CS
SETBG 6
HT
DRAWTARGET :XTARGET :YTARGET
STARTTURTLE :XSTART :YSTART :HSTART

TO DRAWTARGET :XTARGET :YTARGET
PU
SETX :XTARGET
SETY :YTARGET
PD
CIRCLER 10
END

TO STARTTURTLE :XSTART :YSTART :HSTART
PU
SETX :XSTART
SETY :YSTART
SETHEADING :HSTART
END

TO START
STARTDATA
STARTGAME
END

TO SHOOT
MAKE "SHOTNUMBER :SHOTNUMBER + 1
PRINT [HOW FAR?]
MAKE "SHOT READNUMBER
PD FD :SHOT
TEST DISTANCE :XTARGET :YTARGET < 10
IFTRUE HIT
IFFALSE MISS
END
```

```
TO HIT
PRINT [CONGRATULATIONS! YOU HIT THE TARGET!
PRINT (SENTENCE [IT TOOK YOU ONLY]
:SHOTNUMBER [SHOTS])
END

TO MISS
PRINT SENTENCE [MISSED! SHOT NUMBER]
:SHOTNUMBER
WAIT 200
STARTTURTLE :XSTART :YSTART :HSTART
END

TO DISTANCE :X1 :Y1
OUTPUT SQRT (( XCOR - :X1) * (XCOR - :X1)
+ (YCOR - :Y1) * (YCOR - :Y1)
END

TO READNUMBER
OUTPUT FIRST READLIST
END
```

6. Play shoot game.

7. Change game--make target bigger or smaller, new messages, etc.

8. Then add:

```
TO EXPLODE :SIZE
HT
REPEAT 18[FD :SIZE BACK :SIZE RT 20]
END
```

(Use IFTRUE HIT EXPLODE 20 in "HIT procedure)

LESSON NUMBER 16

The student will be able:

50. To define what a vector is.

51. To use Logo commands to construct vectors.

52. To add and subtract vectors.

53. To resolve vectors into components.

Questions and Activities:

1. Coordinate systems are important; we want to describe the turtle (or some other object's) "absolute" position or motion with respect to a frame of reference. If, on the other hand, we are only interested in the absolute direction of the turtle (HEADING), so that its position is "relative," we can describe this "displacement" using "vectors."

   A displacement is a movement through some distance in a certain direction. The direction is "absolute," but we may not be interested in its starting position.

   A vector can be thought of as an arrow of definite length and direction, but starting from some "arbitrary" starting position, pointing from the beginning to the end of a displacement.

2. The following procedure may be used to describe a vector:

```
TO VECTOR :DIRECTION :LENGTH
SETHEADING :DIRECTION
FORWARD :LENGTH
END
```

3. Use vectors to draw a square, rectangle, or other geometric figure.

4. Vectors may be added by drawing each vector to be added to the arrow head of the preceding vector. The order in which these vectors are added are not important. The sum of the vectors, called the "resultant," will have a value equal to the length of the arrow which connects the tail of the starting vector with the head of the last vector added. The direction of this

resultant vector is pointing from the tail of the first vector to the head of the last vector added (this is the HEADING of the vector).

If we start our vector addition from center screen, a HOME command will connect the final vector head with the initial vector's tail. The resultant may be found by measuring the length of the vector and its heading directly from the screen, but be sure your units are the same as the units used on the Logo drawing. (A HIDETURTLE command will make it easier to see what you are doing.)

5. Vectors are subtracted by reversing the direction of the vector you are going to subtract by 180 degrees, and then adding.

   If V1 = 40 100 and V2 = 70 100, first add
   V1 and V2 and then subtract V1 from V2.

6. Vectors may be described by heading and direction. Add the following vectors by using the VECTOR procedure (start from HOME) for each vector in turn. Then give the HOME command and measure the resultant length and direction from the screen. Try adding the vectors in a different order and see if you get the same result.

   a) V1 = 45 30, V2 = 90 20, V3 = -90 50, V4 = 290 20

   b) V2 = 0 50, V2 = 180 50, V3 = 180 50, V4 = 270 50

7. Use vectors as part of a procedure?

8. If the vectors represent forces acting on an object, which way would the object move?

9. Using the principles of geometry, it is possible to define a procedure to find the resultant of a vector addition. Use the following procedure to find the resultants of the previously given vectors (X1 and Y1 represent the starting position of the addition--they are 0 0 if started from HOME):

```
TO RESULTANT :X1 :Y1

MAKE "R SQRT ((XCOR - :X1) * (XCOR - :X1) +
(YCOR - :Y1) * (YCOR - Y1))

MAKE "D ARCTAN (YCOR - :Y1) / (XCOR - X1)

MAKE "E (90 - :D)

MAKE "F SQRT (:E * :E)

IF :R = 0 [MAKE "F "UNDEFINED]

(PRINT [THE MAGNITUDE OF THE RESULTANT IS] :R

[WITH A HEADING OF] :F "DEGREES)

END
```

10. Show that there are many ways to add vectors so that they produce equal resultants. Vectors which make up a vector resultant are components of that vector.

LESSON NUMBER 17

The student will be able:

54. To understand force as a vector quantity.

55. To understand motion in terms of vector quantities.

56. To understand the dynamics of motion using the dynaturtle program.

57. To understand the dynamics of circular motion.

Questions and Activities:

1. Forces are sometimes defined as a "push" or a "pull." They may vary in strength (magnitude) and direction. Since forces have both magnitude and direction, they may be treated as vectors.

2. If more than one force acts on an object at the same time, they will balance if their resultant is zero. This condition is known as "equilibrium." Add or subtract a number of made-up vectors to produce equilibrium. If we are working with three or more vectors, for example, must the magnitude of one of the vectors equal the sum of the magnitudes of the other two vectors? Illustrate your answer.

3. If an "unbalanced" vector or resultant of vectors acts on an object, the object will change its motion. Call up the Dynaturtle procedure to see how this happens.

4. To move the dynaturtle, you must apply a force or "kick" it. This kick will be in the direction that the turtle is pointing, and the magnitude of the kick may be varied. Use this procedure to move the turtle around the screen. Describe how the turtle moves in response to kicks in various directions with various magnitudes.

5. Does the turtle stop moving when you no longer kick it? What does this tell you about the motion? Can you apply this to objects moving in the "real" world?

6. Apply reverse kicks to the turtle. What happens? What does this tell us about the forces acting on the turtle?

7. Try to get the turtle to move along a particular path. Call up the procedure which produces a "racetrack" and move the turtle around the track. Keep in mind how you must kick the turtle to get it to move around the track.

8. What happens to the dynaturtle when the direction of the kick is 90 degrees to the direction of the turtle's motion? Does it speed up or slow down? Describe what happens.

9. Make a "generalization" about the forces needed to move the turtle along a circular path.

APPENDIX C

SELECTIVE ABSTRACT PHYSICS CONCEPTS: OBJECTIVES AND PROCEDURES

LESSON NUMBER 1

The student will:

1. Know the definition of a force.
2. Know the definition of a vector.
3. Know that forces have vector properties.
4. Understand how to add vectors.

Lesson procedure:

1. Students will be asked to define a force. Examples of forces will be demonstrated with the help of the class.
2. The concept of force having magnitude and direction will be elicited from the students.
3. The concept of the vector will then be introduced, and force will be defined in terms of its vector properties.
4. Scales used to measure forces will be introduced. These will then be used to show that forces do not add as ordinary numbers do.
5. The vector properties of forces and velocities will then be elicited from class.
6. Graphical representation of vectors will be introduced.
7. Force table experiment will be done.
8. Graphical methods for adding vectors will be introduced.
9. Graphical analysis for force table experiment results will be made.

LESSON NUMBER 2

The student will:

5. Know that an unbalanced force will cause objects to speed up, slow down, or change direction.
6. Know that friction is an "invisible" force which can act on a moving or standing object.
7. Understand the relationship between unbalanced forces and motion.

Lesson procedure:

1. The concept of equilibrium will be introduced and explained in terms of balanced forces.
2. The concepts of static and dynamic equilibrium will be introduced. Air track demonstration will be done to reinforce the concept.
3. The concept of friction will be introduced and discussed with respect to dynamic equilibrium.
4. The concept of unbalanced forces causing motion will be introduced.
5. Accelerometer will be used as an indicator of different types of motion.

LESSON NUMBER 3

The student will:

8. Know that motion is a change in position over an interval of time, the rate of which is called speed.
9. Know that velocity is an object's speed in a given direction.
10. Understand and apply the formula for velocity as it relates to distance and time.
11. Understand what is meant by instantaneous velocity.
12. Understand the meaning of accelerated motion.
13. Understand how unbalanced forces produce accelerated motion.

Lesson procedure:

1. Analysis of ticker tape experiment tape will be used to introduce the concept of average and instantaneous velocity.
2. Further analysis of tape will be used to discuss constant velocity and accelerated motion.
3. Definition of accelerated motion in terms of changing velocity will be elicited from class after analysis of ticker tape.
4. Pendulum will be demonstrated and discussed with respect to force and acceleration.

LESSON NUMBER 4

The student will:

14. Know what is meant by a frame of reference.
15. Understand why position is given with respect to a frame of reference.
16. Understand relative motion.

Lesson procedure:

1. The need for a frame of reference to describe motion will be elicited from the class.
2. The concept of position as a set of coordinates with respect to a frame of reference will be discussed with the class.
3. The concept of relative motion will be introduced to the class.

LESSON NUMBER 5

The student will:

17. Understand the concept of inertial motion.
18. Understand the effects of force on moving objects.
19. Understand the effect of gravity on an object's motion.

Lesson procedure:

1. The first part of the film "Frame of Reference" will be shown to the class and discussed.
2. The law of inertia will be introduced with respect to concepts illustrated in the film.
3. The effect of unbalanced forces on moving objects will be discussed.
4. The effect of a force acting perpendicular to an object's motion will be demonstrated with respect to projectile motion. Independence of horizontal motion to gravitationally accelerated vertical motion will be demonstrated.
5. The effect of gravity on a projectile's motion will be discussed with respect to concepts illustrated in the film.

LESSON NUMBER 6

The student will:

20. Understand how applying a force to an object may lead to curved or circular motion.

21. Understand the centripetal nature of the force causing an object to move in a circle with constant speed.

Lesson procedure:

1. Examples of centrifugal forces will be elicited from the class.

2. Relationship between centrifugal and centripetal forces will be explained.

3. Accelerometer will be used to illustrate the centripetal direction of the force acting on object moving in a circle.

4. Demonstration of centripetal force, using overhead swinging rubber stopper, will be made and discussed.

5. Last part of "Frames of Reference" film will be shown.

LESSON NUMBER 7

The student will:

22. Know that there are forces such as the grativational or electromagnetic force that does not seem to push or pull by direct contact.

23. Know that these forces may act through the exchange of "invisibly" small particles, called respectively gravitons and photons.

24. Understand that these "unseen" forces influence the space surrounding them.

25. Understand the "field" nature of this space in terms of these forces.

Lesson procedure:

1. The centripetal force demonstration will be used to show how weight or gravitational force can provide the centripetal force needed for circular motion.

2. The relationship between the Earth's gravitational force on the moon and the moon's circular orbit will be discussed.

3. The concept of unseen forces acting through great distances will be discussed with respect to the gravitational attraction between heavenly bodies.

4. The concept of the gravitational field will be introduced.

5. Magnetic forces will be introduced and demonstrated.

6. Similarities and differences between the way gravitational and magnetic forces act will be elicited from the class.

7. Experiments will be performed to illustrate the nature of the magnetic field.

8. The concept of force fields being due to the possible exchange of invisibly small particles will be introduced and discussed.

9. Students will toss medicine ball back and forth while seated on moveable carts to illustrate phenomena.

LESSON NUMBER 8

The student will:

26. Understand some of the properties of field in space, such as the inverse proportional nature of the force emanating from a point.

27. Apply these properties to explain observed phenomena.

Lesson procedure:

1. Introduce concept of inverse relationship.
2. Describe the "inverse square" geometry of space formed by straight lines emanating from a point.
3. Show geometric model of inverse square spread.
4. Describe inverse square properties using "butter gun" analogy.
5. Introduce and demonstrate electrostatic force effects.
6. Elicit force field aspects of electrostatic effects.
7. Explain how the inverse square nature of forces due to point electrostatic charges predicts the lack of charge effects within a charged hollow conductor.
8. Demonstrate this phenomenon.
9. Generalize this effect to the gravitational field within a hollow earth.
10. Elicit predictions from the class.
11. Sum up nature of force as a possible part of a grand unification of "force interactions."
12. The Nova videotape "What Einstein Didn't Know" will be shown and discussed.

APPENDIX D

PRE/POST-TEST OF SELECTIVE ABSTRACT PHYSICS CONCEPTS

NAME: ______________________________

PHYSICS EVALUATION

1. Which of the following statements are examples of force being applied?

   (a) A girl tries to lift a heavy weight, but can't budge it.

   (b) A boy spends five minutes thinking about solving a math problem.

   (c) A girl pedals her bicycle.

   Answer:

   (1) A and B

   (2) B and C

   (3) A and C

   (4) C only

2. Which two words best belong in the blanks?

   To describe a force, we must know its __________ and __________.

   Answer:

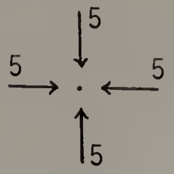
   (1) speed, power

   (2) type, direction

   (3) magnitude, direction

   (4) cause, start

3. Four forces act on a point as shown in Figure 3.



(Figure 3)

The resultant of the four forces is:

(1) 0

(2) 5

(3) 14

(4) 20

4. Two forces of 10 and 20 pounds act on a point at some angle other than 0° or 180° between them. Which one of the following forces, when applied to this point at some angle, might be able to balance these two forces?

(1) 10 pounds

(2) 28 pounds

(3) 30 pounds

(4) 35 pounds

5. A man pushes a book along a table from point A to point B with a force of 5 pounds. The force of friction acting on the book is also 5 pounds. Which statement best describes the book's motion?

(1) It comes to a sudden stop.

(2) It moves along with constant speed.

(3) It speeds up.

(4) It slows down.

6. The man in problem five suddenly stops pushing the book. Which statement best describes the book's motion?

   (1) It stops immediately.

   (2) It slows down.

   (3) It keeps going.

   (4) It speeds up.

7. The man now pushes the book with 10 pounds of force, while the force of friction remains at 5 pounds. Which statement best describes the book's motion?

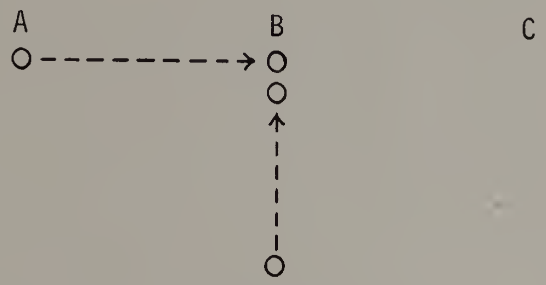
   (1) It stops immediately.

   (2) It moves with constant speed.

   (3) It slows down.

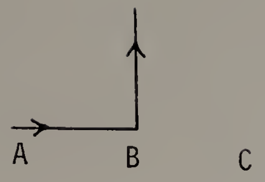
   (4) It speeds up.

8. A marble rolls along a straight line from point A to point B, as shown in Figure 8. Which picture best describes how the marble moves after it was hit directly on center by a similar marble at point B?

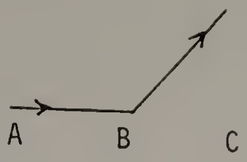


(Figure 8)

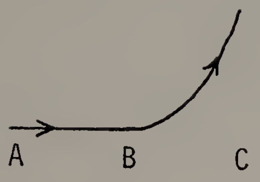
(1)



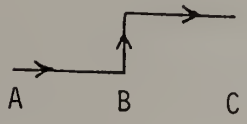
(2)



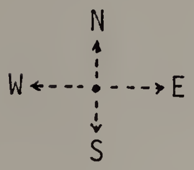
(3)

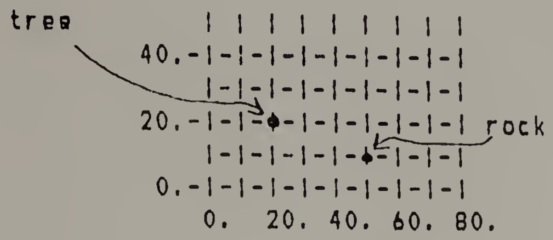


(4)



9. To find a pirate's treasure on the map in Figure 9, you must start digging at a point 10 feet north of the tree and 20 feet east of the tree. Describe the location of this treasure using the rock as a starting point instead of the tree?





(Figure 9)

(1) 10 feet north and 20 feet east

(2) 10 feet west and 20 feet north

(3) 10 feet south

(4) 20 feet north and 10 feet east

10. A train moves north along a straight track at 50 m.p.h. A bug walks south along the floor of the train at a speed of 2 m.p.h. How fast is the bug moving with respect to the train tracks?

    (1) 2 m.p.h.

    (2) 48 m.p.h.

    (3) 50 m.p.h.

    (4) 52 m.p.h.

11. How fast is the bug in Question 10 moving with respect to one of the train's seats?

    (1) 2 m.p.h.

    (2) 48 m.p.h.

    (3) 50 m.p.h.

    (4) 52 m.p.h.

12. How fast is the bug moving with respect to a boy on the train who is walking 2 m.p.h. south?

    (1) 0 m.p.h.

    (2) 50 m.p.h.

    (3) 48 m.p.h.

    (4) 54 m.p.h.

13. A bicycle rider travels 20 miles down a stretch of road. How fast is the rider moving if it takes 45 minutes to travel that far?

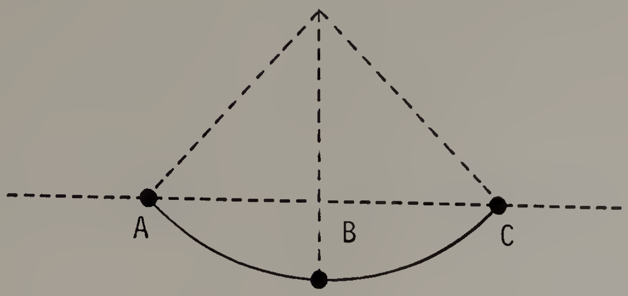
    (1) 10 m.p.h.

    (2) 20 m.p.h.

    (3) 26.66 m.p.h.

    (4) 32 m.p.h.

14. A pendulum is swinging from point A through point B at the bottom of its swing to point C and back again to point A, as shown in Figure 14. At the exact instant the pendulum is passing point B, it:



(Figure 14)

(1) is not moving.

(2) is speeding up.

(3) is moving at maximum speed.

(4) is slowing down.

15. As the pendulum in Problem 14 moves through point B, the only forces acting on the pendulum (ignore friction or air resistance) are the upward pull of the string and the downward pull of gravity. The resultant of these forces:

(1) acts downward.

(2) is zero.

(3) acts upward.

(4) acts toward point C.

16. At the exact instant that the pendulum in problem 14 reaches point C, the pendulum is:

    (1) moving with constant speed.

    (2) moving with non-constant speed.

    (3) slowing down.

    (4) not moving.

17. A coin is thrown directly up into the air. While the coin is moving up, the only force(s) acting on the coin (ignoring air resistance):

    (1) is the pull of gravity.

    (2) is the upward projecting force.

    (3) are the upward projecting force and the pull of gravity.

    (4) is the internal force of the coin.

18. The resultant of the forces acting on the coin in problem 17:

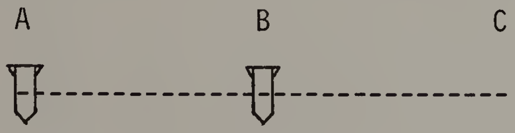
    (1) acts sideways.

    (2) is zero.

    (3) acts upward.

    (4) acts downward.

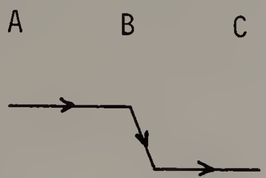
19. A rocket is moving along sideways in deep space with its engine off from point A to point B, as shown in Figure 19.



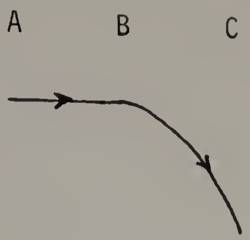
(Figure 19)

It is not near any planets and there are no other forces acting on it. If the engine is fired for an instant (an instant being as brief a period of time as you can imagine) at point B, which of the following paths will it take?

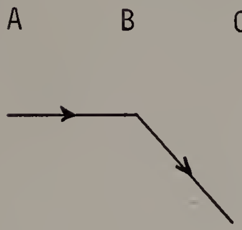
(1)



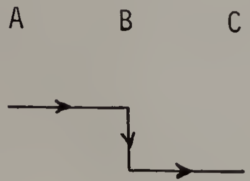
(2)



(3)

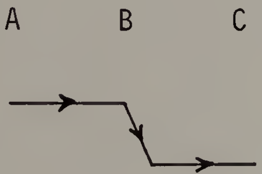


(4)

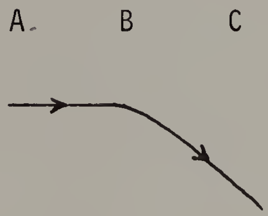


20. If the engine of the rocket in problem 19 is fired for 10 seconds at point B, which of the following paths will it take?

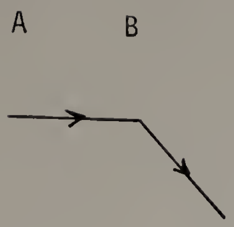
(1)



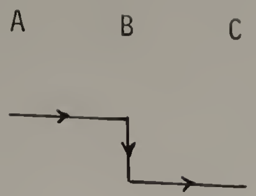
(2)



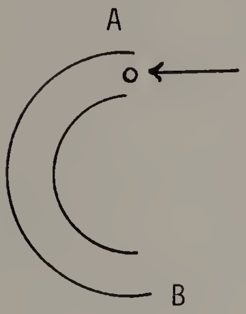
(3)



(4)

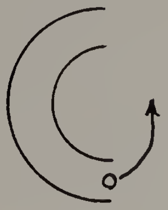


21. A fast rolling ball enters a curved guide on a table top at point A and leaves at the other end, point B, as shown in Figure 21. Which of the following paths will it take?

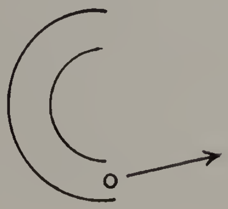


(Figure 21)

(1)

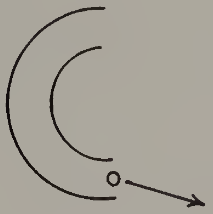


(2)



(3)

(4)



22. A car travels 10 miles north, then 3 miles east, then 2 miles north, and then another 2 miles east. How far has the car been displaced from its starting point?

(1) 0 miles

(2) 10 miles

(3) 13 miles

(4) 17 miles

23. A car travels 20 miles east, then 10 miles north, then 5 miles west, then 10 miles north, then 15 miles west, and then another 20 miles north. How far has the car been displaced from its starting point?

(1) 0 miles

(2) 25 miles

(3) 50 miles

(4) 70 miles

24. A racing car travels around a circular track at a constant speed of 120 m.p.h. The force needed to keep the car moving in a circle is:

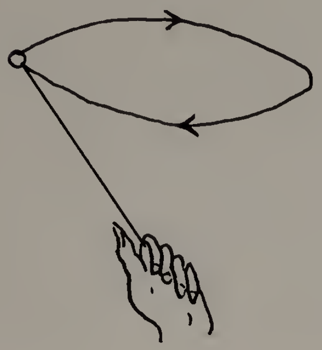
(1) constant in magnitude but changing in direction.

(2) constant in both magnitude and direction.

(3) changing in magnitude but constant in direction.

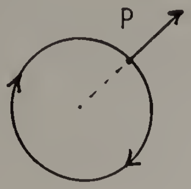
(4) changing in both magnitude and direction.

25. A rock attached to a hand-held string is twirled overhead so that it moves as shown in Figure 25. Which path will be taken by the rock if the string is released at point P? (paths viewed from above)

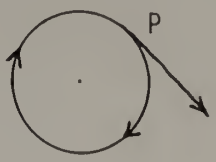


(Figure 25)

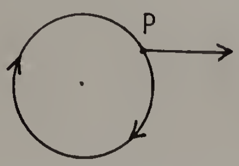
(1)



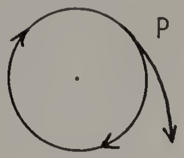
(2)



(3)



(4)



26. The distance separating the earth and a rocket heading for the moon is twice as great at it had been. The earth's gravitational force on the rocket during this time:

(1) remains the same.

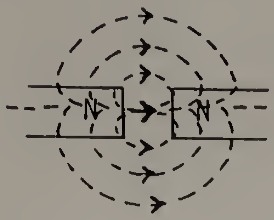
(2) doubles.

(3) becomes half as great.

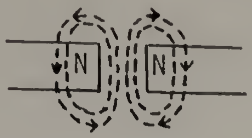
(4) becomes one-forth as great.

27. Two bar magnets with their north poles facing each other are separated by a short distance. Which diagram best represents the magnetic lines of force around the magnets?

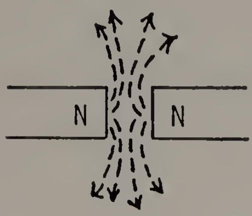
(1)



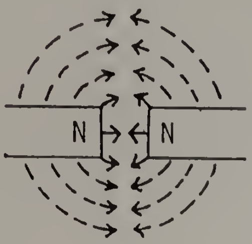
(2)



(3)



(4)



28. As the electric charge on the surface of a hollow metal ball increases, the electric field inside the ball:

(1) increases.

(2) decreases.

(3) remains the same

29. A heavy cannon ball and a marble are dropped from the same height at the same time. Which one of the following statements is true?

(1) The cannon ball will land much before the marble.

(2) The marble will land much before the cannon ball.

(3) The cannon ball will land a short while before the marble.

(4) They will both land at about the same time.

30. The subatomic particle which takes part in the electromagnetic interaction is the:

(1) meson.

(2) graviton.

(3) neutron.

(4) photon.

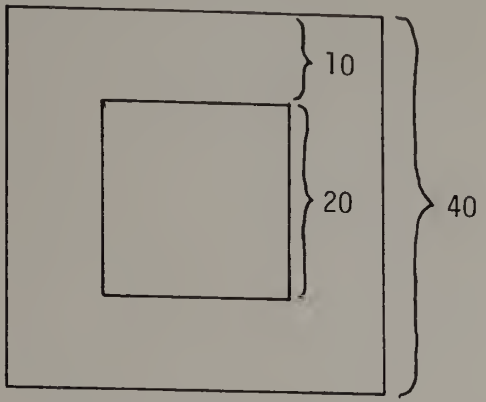
APPENDIX E

LOGO TESTS

NAME: ____________________

1. Write a program, in the space provided on your paper, which will draw the figure (call it SQUARES) shown:

```
TO SQUARES
```



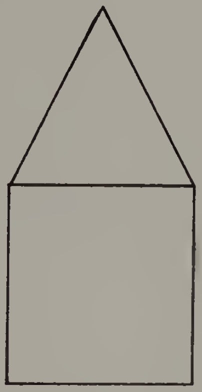
(Not Drawn To Scale)

2. The program given below was meant to draw the "House" as shown, but was incorrectly written. In the space provided, write a corrected program.

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

TO TRIANGLE
REPEAT 3[RT 120 FD 120]
END

TO HOUSE
SQUARE
FD 50
RT 30
TRIANGLE
END
```



(Not Drawn To Scale)

NAME: ____

3. The graph paper provided represents the screen of your computer, with each small grid line representing five turtle steps. Using a protractor and straight edge, and starting at the HOME position, follow the instructions below to draw the "town" that would be drawn by the computer. (Use a pencil with an eraser.)

```
TO TOWN
CS
PU
RT 180 FD 65
RT 90 FD 100
RT 90
PD
HOUSE
MOVE
HOUSE
MOVE
HOUSE
END
```

```
TO MOVE
PU
RT 90]
FD 25 LT 90 FD 30 LT 90
PD
```

```
TO BOX
REPEAT 4[FD 10 LT 90]
END
```

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

```
TO HOUSE
SQUARE
FD 50 RT 30
TRIANGLE
PU
RT 60 FD 10
RT 90 FD 5
PD
BOX
PU
FD 10 LT 90
FD 20
PD
BOX
PU
RT 90 FD 10
PD
DOOR
END
```

```
TO DOOR
REPEAT 2[FD 25 RT 90 FD 10

END
```

```
TO TRIANGLE
REPEAT 3[FD 50 RT 120]
END
```

NAME: ________________________________

1a. The following program draws a shape:

```
TO SHAPE
REPEAT 2 [FD 30 RT 90 FD 50 RT 90]
END
```

Draw this shape to scale in the space provided below. (Each grid mark is five turtle steps.)

```
_____________________________________________________________
¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
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¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__^__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
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¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦__¦
```

1b. Rewrite the above procedure so that variables may be used to change the size of the shape. (Use the space provided below.)

NAME: ____________________

2a. The following program will draw triangles which grow in size. The command GROWTRIANGLES 10 is given. How many triangles will be drawn before the procedure stops?

```
TO GROWTRIANGLES :SIDE
IF :SIDE > 95 [STOP]
REPEAT 3 [FD :SIDE RT 120]
GROWTRIANGLES :SIDE + 20
END
```

Number of triangles: __________

2b. Rewrite this procedure so that the triangles grow smaller by 20 each time instead of bigger (call it SHRINKTRIANGLES), and will draw four triangles before stopping after the command SHRINKTRIANGLES 100 is given.

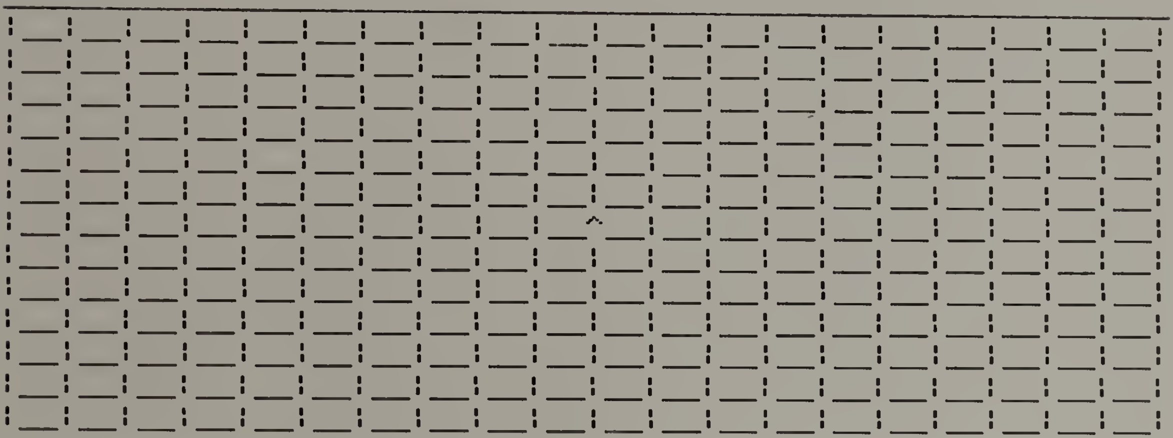
NAME: ______________________________

3. The following procedure is supposed to stop after three squares are drawn when the command GROWSQUARES 20 is given, but it does not work. In the space next to it, rewrite it so that it works.

```
TO GROWSQUARES :SIDE
REPEAT 4 [FD :SIDE RT 90]
GROWSQUARES :SIDE + 20
IF :SIDE > 60 [STOP]
END
```

4. The following procedure draws a shape. Sketch this shape in the space provided. (Each grid mark is ten turtle steps.)

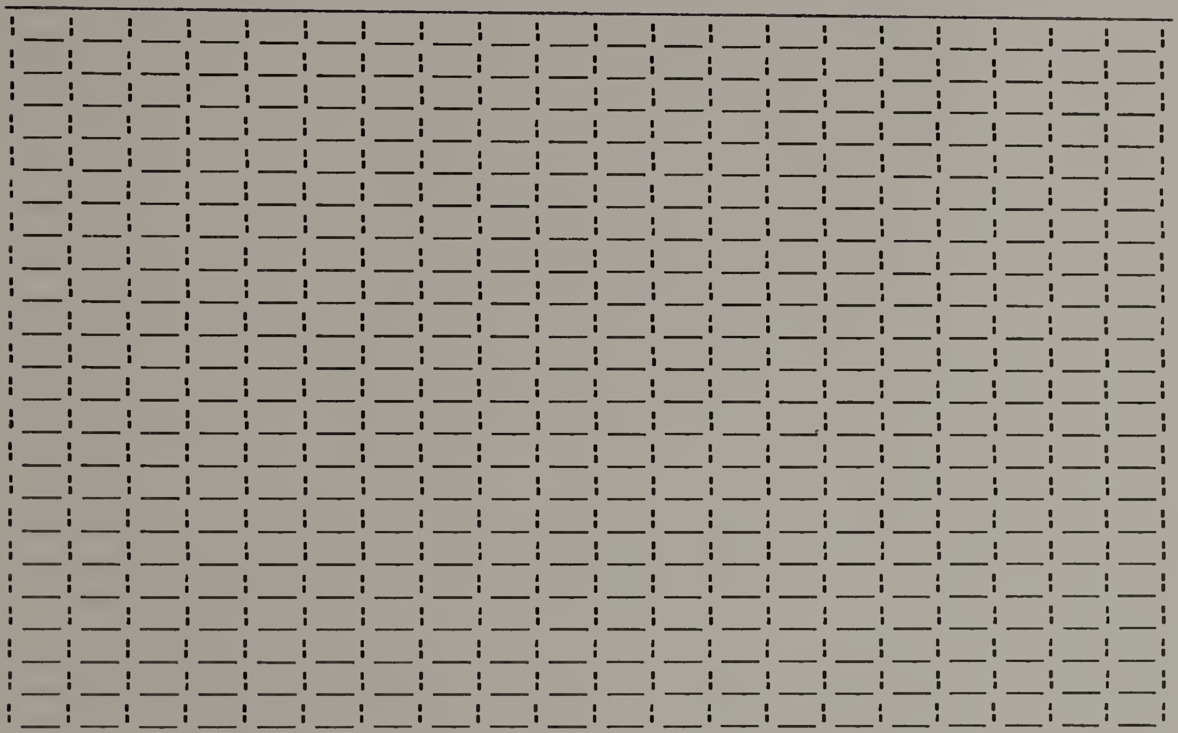
```
TO SHAPE2
FD 50 RT 90
SHAPE2
END
```



NAME: ______________________________

1. Using the coordinate system provided below (each grid line represents five turtle-steps), draw the shape that would result if you called the following procedure:

```
TO SHAPE
PU
SETPOS [ 25 -50]
PD
SETPOS [-25 -50 ]
SETPOS [-25 0 ]
SETPOS [ 0 25 ]
SETPOS [ 25 0 ]
SETPOS [ 25 -50 ]
SETPOS [-25 0 ]
SETPOS [ 25 0 ]
SETPOS [-25 -50]
END
```



NAME: ________________________________

2a. Using the following procedure, write the command needed to draw a six-sided polygon with each side being 50 turtle-steps long.

```
TO POLY :LENGTH :ANGLE
FD :LENGTH RT :ANGLE
POLY :LENGTH :ANGLE
END
```

Command: ________________________________

2b. What type of geometrical shape will be drawn as a result of using the following procedure?

```
TO SHAPE
FD 1 RT 1
IF HEADING = 0 [STOP]
SHAPE
END
```

Answer: ____________________

Sketch the shape in the space below.

3. Using the following procedure:

```
TO VECTOR :ANGLE :LENGTH
SETH :ANGLE
FD :LENGTH
END
```

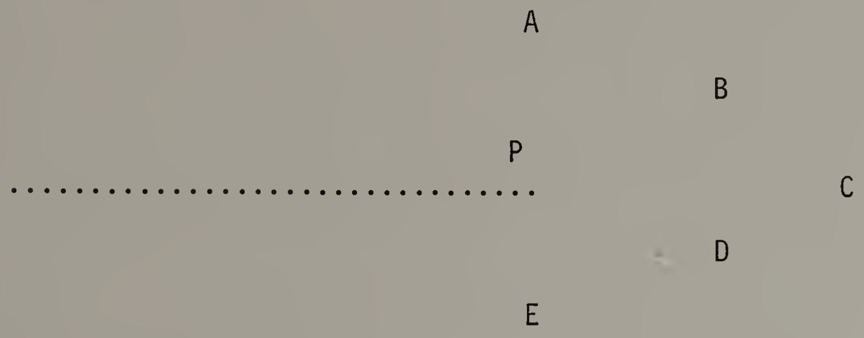
Write the commands needed to draw a rectangle with a 100 turtle-step length and a 50 turtle-step width.

NAME: ______________________________

4. Using the following POLYSPI procedure and command POLYSPI 5 90, do a rough sketch of the resulting figure in the space below.

```
TO POLYSPI :SIZE :ANGLE
IF :SIZE > 150 [STOP]
FD :SIZE RT :ANGLE
POLYSPI (:SIZE + 5) :ANGLE
END
```

5. The dynaturtle is moving along the dotted line towards point C, as shown. It is given a "kick" as it passes point P in the direction that the turtle is pointing. To which of the points, A, B, C, D or E, will the turtle most likely move towards after this kick?



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