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UTILIZATION OF COMPUTER SIMULATED EXPERIMENTS (CSE) FOR DIAGNOSTIC PURPOSES.

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1971
UTILIZATION OF COMPUTER SIMULATED EXPERIMENTS (CSE) FOR DIAGNOSTIC PURPOSES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
The Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Barbara Swanson Thomson, B.S., M.A.

*****

The Ohio State University
1970

Approved by
[Signature]
Advisor
School of Education
PLEASE NOTE:

Several pages have indistinct print. Best available copy. Filmed as received.

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FORWARD: THE PURPOSE OF THE STUDY

The purpose of this study is to explore empirically the use of computer simulated experiments (CSE) as a tool to diagnose elements of propositional thinking in the cognitive functioning of sixth and seventh graders. The rationale for this study is based on the work of Piaget and its application into its educational context by Stendler and others. Often instructional packages utilizing lessons requiring propositional thinking are presented to pupils without diagnosing whether they can function successfully within a framework requiring propositional thinking. Although cognitive functioning proceeds toward formal operations it is important for teachers to identify how effectively each student functions within the area of propositional thinking in order to provide them with suitable instructional materials. The relationship of academic achievement, intelligence, age, sex, reading, grade level, and Piagetian tasks to propositional thinking will also be explored.

The subsequent chapters deal with the design of the study; examination of relevant literature and research; procedures, presentation and analysis of data gathered in the study; and finally, the conclusions based on these data.
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CHAPTER I

PROBLEM

Introduction

The purpose of this study was (a) to develop an instrument to diagnose sixth and seventh graders' levels of propositional or abstract thinking using computer simulated experiments, and (b) to determine the direct or indirect relationships of the following factors to propositional thinking, i.e. academic achievements, intelligence, sex, age, reading, grade level, and Piagetian tasks.

The rationale for the study emerged from a consideration of the following six factors:

1. the role of cognitive processes in learning
2. cognitive functioning proceeds toward propositional, abstract modes of thinking as children grow older
3. the typical upper elementary, junior high school curriculum largely assumes abstract thinking capabilities in all pupils
4. scientific experimentation requires elements of propositional thinking
5. there is a need for tools to diagnose pupils'
level of cognitive functioning

6. Computer simulated experiments have the potential capabilities for diagnosing cognitive functioning

Cognition and Learning

It is important to build a case for the importance of studying cognition and learning and it is relatively simple to support the need for this particular type investigation for the following reasons:

1. The purpose of the school is to help children learn in the most effective way. (1, p. 1)

2. Learning encompasses the cognitive, affective, and psychomotor domains. (2)

3. However, cognitive processes are crucial in learning.

4. Cognitive processes are those intellectual processes by which knowledge is acquired. (3, p. 5)

5. As children learn, the cognitive aspect is functioning continuously and educators need to know as much as possible about these processes in order to identify lessons, instructional materials, and procedures so optimum learning can be obtained from each individual student.

6. In order to help children learn in the most effective way, it is essential that teachers have diagnostic techniques related to cognition
available as well as prescriptive materials, and evaluative measures.

7. Thus, it is crucial to the educative process that diagnostic tools be developed to aid the teacher in his goal.

Although considerable research needs to be undertaken in all three of the domains, (i.e. cognitive, psychomotor, and affective), this study focused only on the cognitive domain and within the boundaries of diagnosing levels of cognitive functioning. (2)

Developmental Cognitive Theory

Many educators in a variety of fields have focused on cognition. For more than 40 years Piaget, a Swiss psychologist, has conducted extensive research in the area of cognitive functioning and has developed a theory of developmental levels. (4) His theory of developmental levels explains how these processes begin in infancy and change as the child matures. He believes that learning is a continual restructuring of mental activity, not merely a process of adding previous knowledge. (5, p. 36) Piaget contends that children pass through various levels during their mental development and that the development of intelligence begins in infancy and continues through stages from birth to maturity. (3, pp. 7-13)
Stendler writes:

The first stage Piaget calls the sensorimotor, birth to 18 months. The second stage, preoperational, extends from 18 months to about 7 years. During this period the child does not use logical operations in his thinking. Between 7 and 11 years the child reaches the stage of concrete operations, using logical operations while the content of his thinking is concrete rather than abstract. At about 12 years of age, thinking becomes more abstract and formal which Piaget describes as propositional thinking. The pupil can stage propositions in terms of variables and can systematically combine the propositions so as to test the combinations. (3, pp. 7-13)

Thus, at the age of 11 or 12 the children can move into the abstract or formal operational stage. However, although the capacity for abstract or formal thought occurs near the end of the elementary school experience, Piaget argues that each stage arises only when its predecessor has been properly attained, and that if an early stage is incomplete, later stages will be defective. (5, p. 39) This is extremely important for the elementary and junior high teacher as they may be structuring science lessons which are inappropriate for those children who have not reached the formal operational level. Also, children who can function at this level will do so at varying levels of sophistication. The teacher needs to be able to identify how well they are functioning in the area of propositional thinking and also
be able to diagnose strengths and weaknesses for each student in order to attain the goal of working in the most effective way with each student.

Students have the potential of reaching and functioning within the formal level beginning at approximately 11 or 12 years of age. Since the youngest students in the junior high school are 11 or 12 years old, educators sometimes teach under the assumption that these students are functioning within the propositional or formal level of thinking.

Karplus illustrates this condition when he says:

"... you will probably all agree that there is a transition between children's preoperational thinking at kindergarten age and some of their thinking in terms of propositions when the pupils leave the elementary school at twelve years or so. It seems to be that in general this transition in children's thinking is not recognized by present educational practice in the United States. As an unfortunate consequence of this fact many students never understand the intent of instruction and become dissatisfied with school by the time they are fourteen or sixteen. (6, p. 113)"

Unless educators have techniques for identification of levels of propositional thinking, they cannot appropriately identify at which level the pupil is working in this area.

Siegel supports this notion when he says:

"Teachers with whom I have been in contact have not seemed to be much aware that there is such a change taking place and I would say that most instruction above the kindergarten takes place on what one
might call the formal level. 
(7, p. 467)

Cognitive Level of Upper Elementary, 
Junior High School Science Curricula

In looking at science materials used at the upper 
elementary and junior high school levels one can infer that, if teachers are using these instructional materials as sug­gested by the authors, they are being used as if all stu­dents had successfully reached the formal operational level. Speaking for the Macmillan Science Series, Stendler says:

Beginning in Book 5 and increasingly 
in Book 6 content encourages the pupil 
to do propositional thinking. (3, p. 17)

An examination of upper elementary and junior high science publications indicates that pupils are expected to hypothes­ize and deal experimentally with variables which are, according to the literature, elements of propositional thinking. (3, p. 12)

Although the capacity for abstract thought comes earlier in the sciences than in some areas (8, p. 263), one must remember that even if the potential exists in every pupil for the attainment of this level, the teacher cannot be assured that every student has reached this potential. According to Lovell (9), and other researchers, many average to bright junior high school children have not reached the stage of formal thinking. (9, p. 367) Smith suggests that
even many adults have never made the transition from the concrete to the formal level of thinking. (10, p. 8) To Karplus this is not only a problem teachers face in the area of science but also in mathematics. Research by Karplus and Peterson entitled, "Intellectual Development Beyond Elementary School II, Ratio" indicated

. . . that successful proportional reasoning is not achieved until the last years of high school, even though the subjects of ratio and proportion make their appearance in most math programs in the sixth grade and in junior high school. It seems, therefore, that there is a serious gap between secondary school mathematics curricula and the children's reasoning ability. (11, p. 70)

Teachers of children at the upper elementary and junior high levels need techniques for identifying the levels at which pupils are operating and, once they have attained the formal operational level, how skillfully the students are functioning within this formal operational level of thinking. They also need to have indicators identified that may be predictors of success for the student in this area of propositional thinking, e.g., reading, academic achievement, age, etc. Only with this type of information can teachers effectively determine appropriate instructional materials for each student.
Experimentation in Science

Using Scientific Methodology

Requires Propositional Thinking

As previously stated, beginning at approximately 11 or 12 years of age there are gradual changes that occur in modes of thinking. Thinking becomes less tied to the concrete and becomes more abstract and formal. (3, p. 13) Piaget states that propositional thinking occurs when the pupil can state propositions in terms of variables he has identified and can then systematically combine the propositions so as to test all possible combinations. (3, p. 12) Scientific methodology utilizing data collection and hypothesis development is prevalent in the curriculum at the upper elementary and junior high levels; therefore, the students are being asked to work within the propositional level. Kuslan and Stone state:

Once the student has images evolved and has verbalized concepts, the child has a new capacity for solving problems both by trial and error and by testing hypotheses. This logical operation is no longer concrete, because its raw materials are the images of objects which have been observed or handled . . . they are beginning to think in a formal, propositional way. They can reason from hypotheses and assumptions, and not merely from objects which are directly at hand. (5, pp. 38-39)

Thus, in order to conduct experimentation in science using scientific methodology, students should be able to
think and function within the realms of propositional thinking. The literature was carefully surveyed and it was found that elements of propositional thinking require the following criteria:

1. Reasoning from assumptions (5, p. 39)
   An assumption is a statement accepted or supposed true without proof or demonstration. (12, p. 80)
   It is usually interrelated with the hypothesis. When the student begins to think in a formal way, he can reason from hypotheses and assumptions. (5, p. 39)

2. Stating hypotheses (3, p. 12)
   A hypothesis can be defined as an assertion subject to verification or a premise from which a conclusion is drawn. An assumption is used as the basis for action. (12, p. 649)

3. Concrete objects missing as manipulative devices and/or referents (5, p. 38)
   The student can reason from hypotheses and assumptions and not merely from objects which are directly at hand. (5, p. 39)

4. Reasoning from hypotheses (5, p. 39)
   The student must not only be able to state the hypothesis but should be able to operate on it mentally, not by trial and error. This is related to identifying variables.
5. Stating propositions in terms of variables (2, p. 12)
After the pupil becomes cognizant of the variables he will be testing, he develops questions which are called propositions but each of these questions must be restated as a hypothesis for testing. (2, p. 12)

6. Combining propositions in order to test possible combinations (3, p. 12)
When the student is working with multiple variables, he combines the questions into a hypothesis utilizing several independent variables for the purpose of investigating the dependent variables.

7. Synthesizing in order to arrive at conclusions (13, p. 370)
After the student has identified his hypothesis and collected his data, the next step is the evaluation and the interpretation of results. (10, p. 2) This is done by looking at the data and the hypothesis. The AAAS program identifies this part of experimenting--interpreting in order to answer a question. (14, p. 173)

Stendler says:
Beginning at about 12 years, there are further changes that occur in modes of
thinking. Thinking is less tied to the concrete and becomes more abstract and formal. Piaget describes it as propositional thinking. The pupil can state propositions in terms of the variables he has identified and can then systematically combine the propositions so as to test all possible combinations. (15, pp. 26-27) Beginning in Book 5 and increasingly in Book 6, content encourages the pupil to do propositional thinking. For example, in the introductory unit to Book 5, the reader is introduced to the specifics of scientific method. (15, pp. 29-30)

In the first unit as suggested by Stendler, the elements of the method they propose are: (a) Statement of hypothesis, (b) Description of plan you used to test the hypothesis, (c) What you found out, and (d) Your conclusion—whether the experiment seemed to prove or disprove your hypothesis. (15, p. 6)

If the students are unable to perform these tasks, they are theoretically still at the concrete level and perhaps, need additional experiences at this level before entering a curriculum requiring propositional thinking.

The instrument developed for the purpose of this study is titled the PAL Scale (Propositional or Abstract Level Scale). It was designed in parts to test the seven elements in the preceding list. The scale is divided into three sections with components in each section (See Appendix V). The hypothesis section (I) evaluates the pupil's capability in #1 reasoning from assumptions, #2 stating
hypotheses, #5 stating propositions in terms of variables, and #6 combining propositions in order to test possible combinations. The data section (II) is an evaluation of #3 concrete objects are missing as manipulative devices. The student can reason from hypotheses and not merely from objects directly at hand, and #4 reasoning from the hypotheses. This aspect is also related to identifying variables. The synthesizing or interpretation section (III) requires #7 Synthesizing in order to arrive at conclusions and considers both the use of the data and the hypotheses for the interpretations. In the Smith (10, p. 2) model, the formal operational pupils evaluated and interpreted their results and accepted or rejected their hypotheses. Thus, utilizing all seven elements of propositional identified in the literature, a score using the PAL Scale can be derived on the basis of each student's individual investigation.

**Tools to Diagnose**

**Need for Propositional Thinking Acquisition**

In the previous section it was indicated that once a student has reached the formal level of thinking, he has a new capacity for solving problems. Although a student may be on the threshold or even functioning within the formal level, there are still a variety of functioning levels within the larger category of formal thinking. The student may
operate very effectively with a simple problem but be totally incapable of handling a more complex one. There seems to be transition stages which are gradual not only between levels but within them too. Thus, a child may operate inconsistently within the same field at different times. (5, p. 39)

In the past the researcher has often used Piagetian tasks in order to identify the level at which the student was currently functioning. This technique indicated if the student had reached the formal level or whether he was still functioning at the concrete level. This evaluation did not tell the educator where in the gradual transitory process the student was functioning but merely that the student had or had not reached a new level of cognitive functioning. Since this is a gradual process and some students are working at a more complex level than others within the category of propositional thinking, it is imperative for teachers to have more refined evaluative measures in order to select suitable instructional materials that will assist the progress of each student and provide information on that progress. The combination of computer simulated experiments and the PAL Scale is an attempt to provide a package for the teacher to use as a diagnostic tool to evaluate the cognitive functioning of students in the area of propositional thinking.
Capabilities of the Computer and CSE for Diagnosis of Propositional Thinking

The use of the computer as an instructional tool is gaining momentum in the educational arena. The most frequent use is for the solving of mathematical problems since answers are obtained quickly and accurately through the use of a computer. With the increased numbers of computers available in educational institutions, teachers are seeking meaningful ways to effectively utilize this equipment. A number of forms of computer assisted instruction (CAI) have been criticized on the basis that it is so expensive it costs less to hire a live teacher who can do the same type of teaching. (16) If CAI is more costly than a live teacher and is no more effective, the cost cannot be justified. However, if utilization of a computer allows educators to do something with students that is not easily done with out a computer, its use for those purposes is definitely justified. One such technique is the Computer-Simulated Experiment (CSE). It is unique because the student using logical thinking, plans an experiment, gathers data, and analyzes the results. Although an experiment can be set up in a laboratory, it is often difficult to discover how the student gathered data, if all the data was analyzed, if all data was real data, if the student reported all the data, etc. Computer-Simulated Experiments (CSE) are ideal in this aspect because all the
data is reproduced on a print-out sheet. If a student alters an idea, the instructor can identify the alterations through analysis of the print-out sheets. This makes Computer-Simulated Experiments (CSE) unique and provides an ideal vehicle for diagnostic work since each student develops an hypothesis, manipulates variables, collects data, and draws conclusions on the basis of the open-ended simulated experiment. Using background information sheets (See Appendix I), the student develops hypotheses. The variables are identified and listed as instructions at the computer terminal. (See instruction sheets in Appendix II) With a computer simulated experiment (CSE), the pupil collects data which is recorded on a print-out sheet. (See Appendix III) Utilizing the print-out sheets, the student analyzes the data and draws conclusions. The PAL Scale can then be applied to determine quantitatively the strengths and weaknesses of each student by using his total CSE investigation. The teacher can prescribe appropriate instructional experiences that will serve to expand and strengthen the student's cognitive processes. Additional computer simulated experiments could be used periodically to evaluate the progress of each pupil.

**Importance of the Study**

It was the purpose of this study (a) to develop a diagnostic instrument based on Piagetian cognitive theory that would assess the cognitive functioning of sixth and
seventh graders using computer simulated experiments (CSE); (b) to determine the direct or indirect relationships of the following factors to propositional thinking, i.e. academic achievement, intelligence, sex, age, reading, grade level, and Piagetian tasks. In the proceeding paragraphs the rationale upon which the study was built has been presented in six parts:

1. The role of cognition is an important aspect of the purpose of the school.
2. Cognitive functioning proceeds toward formal operations (propositional or abstract thinking).
3. Upper elementary and junior high curriculum is largely based on propositional or abstract thinking for all students.
4. Experimentation in science using scientific methodology at the upper elementary and junior high school levels requires elements of propositional thinking.
5. Need to diagnose if students have reached the formal operational stage and identify the intellectual tools they have to function at this level.
6. The capabilities of the computer and computer simulated experiments (CSE) to diagnose propositional thinking is realistic.

Therefore on the basis of the six arguments discussed
above a study exploring the use of computer simulated experiments (CSE) to diagnose elements in the cognitive functioning of sixth and seventh grade pupils using propositional thinking is clearly justified.

The Problem

This study was designed to accomplish two purposes: (a) to develop an instrument designed to identify levels of cognitive functioning, based on Piagetian propositional thinking, of sixth and seventh graders using computer simulated experiments (CSE) and (b) to determine the direct and indirect relationship of the following factors to propositional thinking, i.e. intelligence, academic achievement, sex, age, reading, grade level, and Piagetian tasks.

Hypotheses

Theoretical Hypotheses

The research or theoretical hypotheses to be tested in this study are that:

1. Piagetian tests have a direct effect upon the PAL scores.
2. Academic achievement has a direct effect upon PAL scores.
3. Academic achievement has a direct effect on the Piagetian scores.
4. Grade has a direct effect on Piagetian scores.
5. Grade has an indirect effect on PAL scores.
6. Reading has a direct effect on Piagetian scores.
7. Reading has an indirect effect on PAL scores.
8. IQ or intelligence has a direct effect on reading, grade, and academic achievement.
9. IQ or intelligence has an indirect effect on Piagetian scores and PAL scores.
10. Sex has a direct effect on IQ.
11. Sex has an indirect effect on reading, grade level, academic achievement, Piagetian tests, and PAL scores.
12. Age has a direct effect on IQ.
13. Age has an indirect effect on reading, grade level, academic achievements, Piagetian tests, and PAL scores.

Figure 1 illustrates the direct and indirect paths among the variables.

The null hypotheses which will be tested in this study are:

1. Piagetian tests have no direct or indirect effect on the PAL scores.
2. Academic achievement has no direct or indirect effect on the PAL scores.
3. Academic achievement has no direct or indirect effect on the Piagetian scores.
Model I

Figure 1
4. Grade has no direct or indirect effect on Piagetian scores.
5. Grade has no direct or indirect effect on PAL scores.
6. Reading has no direct or indirect effect on Piagetian scores.
7. Reading has no direct or indirect effect on PAL scores.
8. IQ has no direct or indirect effect on reading, grade, or academic achievement.
9. IQ has no direct or indirect effect on Piagetian tests and PAL scores.
10. Sex has no direct or indirect effect on IQ.
11. Sex has no direct or indirect effect on reading, grade level, academic achievement, Piagetian tests, and PAL scores.
12. Age has no direct or indirect effect on IQ.
13. Age has no direct or indirect effect on reading, grade level, academic achievement, Piagetian tests and PAL scores.

The level of significance that will be used to determine a statistically significant relationship is .05.

Sample

Thirty-two sixth graders and thirty seventh graders were selected by the schools' principals to be participants
in this study. The sample selected was representative of the school population and totaled 62 pupils. Both sexes were included in the sample and a range of ages and abilities were represented. This particular grade level range was identified for this study since, according to Piagetian theory, these pupils were supposedly at a transitional stage from the concrete level to the level of propositional thinking. At these grade levels some students should be still functioning at the concrete level of thinking, some should be at a transition stage, while others should be functioning within the abstract level of thinking. These grades were selected to insure a representation of a range of levels from concrete to abstract.

**Instrumentation**

In order to quantify some of the variables related to student ability, a number of different instruments were utilized in this study. Reading scores were identified through the use of the *Gray Oral Reading Paragraphs*. (17) This test was administered by the writer individually to each pupil. The level of cognitive functioning was identified by using the *Piagetian Task Administration Instrument*. (See Appendix) The final score indicated whether the student was at the concrete level or abstract level of thinking. The use of this instrument once again necessitated individual test administration by the writer for each student in the
study. Concrete objects were used to illustrate each task as the test was being administered. The Otis Quick Scoring Mental Ability Test, Form FM (18) was used as a group test to obtain individual IQ scores. The PAL Scale was developed and validated specifically for this investigation in an attempt to obtain a more refined score than provided by the Piagetian Task test. The PAL Scale scores indicate a range of scores within the category of propositional thinking. This scale was used to obtain a score for each investigation by using it in conjunction with each computer simulated experiment. Each student conducted three experiments and the three resulting PAL scores were arranged to obtain one score. A total of 186 experiments were analyzed and scores using the PAL Scale.

Through the use of these four instruments: (i.e., Gray Oral Reading Paragraphs, Piagetian Task Administration Instrument, Otis Quick Scoring Mental Ability Test, and the PAL Scale), scores were obtained for each pupil.

Assumptions of the Study

1. The Piagetian task test is appropriate to utilize in this study since it identifies whether students have satisfactorily attained the concrete level as defined by Piaget. (5, p. 38) According to the theory developed by Piaget, pupils are able to think in a formal propositional way only after they have reached the upper stage of the
concrete level. (5, p. 39) The Piagetian Task Analysis instrument was selected for use since the analysis of the data obtained from interviews of several hundred children impressively verified Piaget's findings. (19, p. 6)

2. The Otis Quick Scoring Mental Ability Test was used to obtain an intelligence score. This test is recognized by experts to be a satisfactory measure of intelligence. (18)

3. The Gray Oral Reading Paragraphs provides a reading score suitable for comparison purposes. (17)

4. The investigator conducted all the classes, administered all the tests, and answered any questions. Although this is apt to produce a halo effect, all the pupils were exposed to this effect and it is not considered a bias.

Limitations and Delimitations of the Study

1. The sample size was \( N = 62 \), 32 sixth graders and 30 seventh graders. The \( N = 30 \) is the minimum number that should be used when sampling a population as the sampling distributions are approximately normal if \( N = 30 \). When \( N \neq 30 \) the approximation is not good and becomes worse with decreasing \( N \), so that appropriate modifications must be made. (20, p. 188)

2. The school utilized for this study does not
contain a representative sample of all types of children for all kinds of sociological backgrounds. However, it is more representative than most urban or suburban schools since it contains children from a small town, rural, and suburban settings.

3. The study was limited to sixth and seventh graders enrolled at Dublin Elementary and Junior High School.

4. The students in the study were taught by the investigator rather than the classroom teacher but both grades are departmentalized and the children are accustomed to having a variety of teachers. The writer being a new teacher to the students probably created additional motivation but all students were exposed to this variable.

5. The sample of pupils from the two grades were selected by the school administrators in a random fashion and not by the investigator.

6. In this study the PAL Scale yields diagnostic information and does not provide prescriptive information.

7. This study will not evaluate the effectiveness of the science teachers or the science curriculum.

**Definition of Terms**

1. **Accommodation** - The way a child's own patterns of response change with new knowledge. (5, p. 36)

2. **Assimilation** - How a child incorporates what he sees into his own frame of reference. (5, p. 36)
3. **Cognitive Processes** - Those intellectual processes by which knowledge is acquired. (3, p. 5)

4. **Concrete Operations** - A period in which the child develops certain important representations of the physical world such as the quantitative concepts of matter, weight, volume, and number and a growing ability to utilize two types of logic: class inclusion and serial ordering. (21, p. 13)

5. **Equilibration** - A balancing dynamic relationship between assimilation and accommodation. (5, p. 36)

6. **Propositional Thinking** - The ability to perform formal operational behaviors. The pupil can state propositions in terms of variables he has identified and can then systematically combine the propositions so as to test possible combinations. (3, p. 12) Concrete objects are not used in this type of operation. Children at the concrete level rely on direct manipulation. Children at the propositional level work with images of objects not with the objects themselves. (5, p. 38) Piaget calls the fourth stage the level of formal or hypothetic-deductive operations. (22, p. 324) Stendler refers to this abstract level as propositional thinking. (3, p. 12) Broadbent refers to this level as the formally operational level. (21, p. 8)

**Outline of Chapters**

In chapter one the study design has been reported. The
design includes hypotheses, terms, sample, instrumentation, limitations, and definition of terms. In chapter two related literature and research is reviewed in the area of computer assisted instruction, in the use of computers in the field of education, in the area of simulation, and in the cognitive theory of Piaget. In chapter three the procedures of the study are reported. The procedures include a description of the overall study, the pilot project, the data collection phase, the statistical model used, and the explanation for the validity and reliability aspect of the instrument development. In chapter four the data is reported, analyzed, and discussed in terms of the research hypotheses. In chapter five the study summary, conclusions based on the hypotheses, and recommendations for further research are presented. The appendixes contain the PAL Scale, Piagetian Task Administration Instrument, Terminal Use Instruction, Computer Simulated Experiment (CSE) Background Information Sheets, and Dr. Showalter's article.
Bibliography


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CHAPTER II

REVIEW OF LITERATURE AND RESEARCH

Computer Simulated Experiments (CSE) are unique open ended inquiry oriented investigations that are designed and conducted by students with the assistance of a program and a computer terminal. (1) Although these programs (CSE) are a recent innovation of 1969 and 1970, computer terminal usage is not unusual in the schools these days. A variety of different techniques have been designed to enable the use of the computer in classroom and individual instruction. Using shared time the cost is reduced considerably which makes this possible. A variety of research and literature has been published around what has been termed Computer Assisted Instruction (CAI). Since Computer Assisted Instruction was the forerunner of CSE, a review of this area has been conducted.

Like CAI, simulation is not an unusual instructional tool for the schools of the sixties but a simulated experiment is unique since the aspects of simulation suggest that it is synonymous with a concrete or real situation. Although the definition of simulation is met by the CSE experience, it is different from other simulated instructional
experiences.

The third aspect of the literature that needs to be carefully reviewed is in the area of Piaget's work. Though Piaget established the theoretical and testable constructs in the area of the cognitive development of children, it has been the responsibility of the educators to operationalize this theory for use in the identification of children's levels of functioning and evaluation of classroom practices and/or instructional materials. An extensive review of this category has been undertaken to identify the work that has been done in this important area prior to this study.

Computers in the Educative Process

Introduction

When administrators and educators convene for the purpose of looking at promising innovations for the decade ahead, the one topic that continually reoccurs is that of computers and Computer Assisted Instruction. (2,3) The multitude of uses for the computer in education can be categorized:

1. Administrative Information Storage
2. Library Usage, Retrieval
3. Computer Assisted Instruction (4)

The role of the computer can be best examined in terms of preplanning, use, and function. (4) If anyone of these
aspects is neglected, the full potential of this aid is not realized. The computer can most satisfactorily be used in the area of:

1. administration and services, including decision making, processing, communicating and summarizing
2. direct and indirect services to faculty members
3. instruction (5)

The message that repeatedly is given is that man must become aware of present day technology since it provides for handling masses of materials. (6) It is an important trend in all areas of study and the public will continue to see more money put into the computer area for educational purposes.

Administration and Services to Faculty Members

University personnel have initiated the use of computers in various administrative areas. One of these is facilities. Facility requirements for a large university can be developed using a computer. (7) Architects can be aided in the design problems, site analysis, and management. (8) Construction deadlines, minimizing time and cost of construction projects can be aided through computer techniques. (9) Once the educational facilities are planned, initiated and completed, space allocations can be effectively made by placing this data in the computer for analysis. (10) Not only is the effective planning of
buildings essential but accurate information on what facilities are available and the number of students necessary for appropriate use can also be determined. (11) All of these facility type administrative decisions can be intelligently decided for the benefit of all, the faculty and the students if computers are carefully used.

Another administrative and faculty service area is that of storage and retrieval. Administrative records, procedures, and materials all fall into this category. (12) A management information system such as PERT can help administrators plan activities efficiently. (13) Or, a program can help to make a priority decision when several approaches are possible. (14)

A major task that a number of educational institutions have assigned to a computer is that processing, storing and analyzing information found in school files, e.g., pupil-personnel records, school reports, etc. (15) Various information control plans have been devised to handle this. (16) Even a state certification system can be computerized. (17) Probably the most helpful; however, is the storage of grades since a computer can compile and report cumulative scores thus relieving the faculty of a tedious task. (18)

A study of the Illinois schools showed that the schools, which included 43% of the total public school enrollment, used data processing for school censuses, accounting, attendance, grades, and scheduling. (19)
Flexibility of a curriculum can be more easily achieved if scheduling can be set up on a computer program. (20) Different schools employ different methods to meet this challenge. (21) Even bus schedules have become part of the service that can be performed by the use of computers. (22) The real problem, however, is that the success of many of the systems is in the hands of the school principals. Each of the principals must accept and understand the basic principles if it is to succeed. (23) This is a crucial "if".

It seems appropriate to move ahead and indicate that "if" principals do support computer assistance, the faculty can be aided in another way. A number of programs have been tried as an inservice aid for teachers. Oklahoma tried a summer institute to train teachers for their new statewide computer science system. (24) Providence College trained vocational teachers in the use of CAI. (25) These teachers wrote and stored their own vocational education programs. (26,27) The Stanford Project on CAI in Initial Reading trained their teachers on an inservice CAE basis. (28) Biology teachers were trained in CAL (Computer-Assisted Learning) and their questionnaires showed favorable evaluation of the system. (29) Teachers who would be teaching data processing have had inservice work to gear them to do an effective job. (30) Even a postdoctoral program to upgrade Ph.D.'s has been initiated on an inservice basis at Alberta University. (31)
In this section of Administrative and Faculty Services it has been easy to demonstrate the variety of uses the computer can fulfill. However, administrators are always concerned with the economics of a situation. The services that a computer can perform are marvelous but unless the money is obtainable, that service cannot be purchased. How much are institutions spending for computerization? At the college level a survey was conducted to obtain estimates that are helpful guidelines. (32) A study between computers and conventional costs have been made. Costs may be reduced by using newer and less expensive computers, by purchasing less expensive input-output units, and by using time-sharing and less expensive transmission facilities. (34) School districts need to evaluate and decide if they can pay for this type of service and instruction. Perhaps one way to help make this decision is to utilize the cost-effectiveness route. (35) By using it in this way, it would also be available for other aspects of the program and the community could realize its many values. There is even a model for establishing this kind of analysis. (36) This type of model helps in making curricular decisions since effectiveness should be the prime goal.

Change is occurring more rapidly in the schools. The hardware is often installed before educators are sufficiently oriented to ways of using these mechanical aids. This section has dealt with the ways computers can assist teachers
and administrators. There will eventually be other directions but for now there are an important beginning.

Libraries and Retrieval System

An excellent use of the computer for both educators and students is that of storage and retrieval of printed resources. Categorizing (37), using a Dewey Decimal classification (38), subject heading authority (39), on-line retrievals (40), and a variety of other automated retrieval systems are available for adoption by local systems. (41,42, 43) If an educator is interested in a particular discipline, there are even organizations where computer retrieval has been set up for specific areas of specialization. In math the PRIMES Project satisfied this need by computer usage. (45) The Head Start Program in Iowa has a system. (46) In Vocational Education this is also a possibility. (47) The ERIC facilities have recently established a program entitled "Query" for retrieval of materials within the ERIC system. (48) More will be forthcoming in the future and they will probably become more specialized as well as more general. In the State of New York the possibility of a film library network with central computerized handling has been proposed and studied. (49) If adopted, it would function similar to the chain motels' reservation systems. All of these programs are to make the work of the educator more efficient and effective.
A current curricular trend that tends to appear in reviews of the educational scene is that of CAI. Although it has been a frequent educational topic of discussion, most of the articles are descriptive in nature. They tend to dwell on how to do it or how it was done in a particular school. In some cases the advantages and disadvantages as identified by the various authors are also listed. A number of authors have compiled bibliographies that are useful to those interested in locating existing programs that are suitable for various situations. Other countries also use CAI but only scant information is available. At this time the United States seems to be the pioneer in the use of CAI and uses it more frequently than any of the other countries. The prediction for the future seems to be that this usage will increase steadily as effective instructional materials are identified and devised.

The variety of courses is quite amazing and the age levels span from the elementary grades upward. One program for upper elementary children teaches creative problem solving, while another translates Braille. One program assists speech teachers by identifying air flow patterns and another is used in speech training. At the present time many departments and school faculties are still exploring ways to use CAI and making preliminary
decisions concerning potential uses in their institutional settings. Conferences are being held such as the one in chemistry at Stanford (59) and the one at the University of California in physics. (60) Meetings and proceedings of this nature point out the movement toward greater usage of computer assisted instruction as groups meet and discuss how they can use the computer to improve instruction. Many areas have passed the conference stage and have initiated ongoing CAI in the schools. Some fields of study have identified multiple ways of using this hardware and others are moving rapidly to implement this in their areas.

**Engineering**

Engineering Economics, a college course, is one of the courses being offered via CAI. (61) Computer drafting and design is another type of course offered to engineering students. (62) The Commission on Engineering Education has held conferences to explore the impact computers are having on engineering design. (63) This commission is influential not only at the college level but supports the new Engineering Concepts Curriculum Project's high school course which incorporates CAI as an essential teaching tool. (64) The field of engineering has made inroads into the use of CAI.

**Adult Education**

This nation faces the difficult problem of having
adults who need to be trained or retrained for various occupational reasons. It is interesting to note that educators interested in this field have moved forward to find ways of using this kind of equipment. A list of available programs has been compiled by the ERIC Clearinghouse on Adult Education. (65) This document contains only 39 entries but at a time when CAI is still new, this is a significant number. Encouragement has been given by articles providing information on how to prepare and use CAI in adult basic programs. (65) These publications assist those wanting to identify ways to use technological advances in the field of adult education.

Guidance and Counseling

Perhaps the widest initial use of CAE has been in the arena of guidance and counseling which surprises many educators who think of computers as teaching machines and not in its widest context. Counseling adults in planning and modifying their life styles can be done using a computer program. (66) Current human counseling systems cannot provide adequate data when assisting a person in making decisions. Oklahoma State University is presently studying the use of a computer in decision making counseling situations. (67) One counseling situation is even conducted using an Automated Interview. (68) In Los Angeles a program is being tested that evaluates the student’s data file and
points out evaluative statements for use by the counselor. (69) An evaluation of the effectiveness of computer counseling as compared with two counselors was conducted by Friesen indicated that students would use this tool, it was possible to develop it, and it is a useful aid for the counselor. (70) A test instrument using a sentence completion style has been designed whereby the computer interviews the student after he has completed the test. (71) The advantages of the computer in counseling work is obvious. It frees the counselor from functions dependent upon information gathering, data analysis, and reporting which leaves the counselor free to work with students on emotional and psychological problems. (72) A computer program in conjunction with counseling can assure a student an excellent change of obtaining his choice of courses. (73) In the past, time has often been spent to plan a program with the result that the student was closed out of the course. This type of utilization will be beneficial to the student and the counselor.

Careers and vocational guidance are areas in which the counselor spends much time with the student. Using appropriate models, computers can assist students in vocational and career problems. (74) If this is started at the beginning of high school, it seems to be a more effective tool for vocational guidance. (75) There are a variety of different formats that can be used and those already
successfully in use should be analyzed. (76) One type of vocational assistance is the match which brings together employers and would be employees. (77) The computer can assist the student in the decision-making process. (78) This type of tool is still in the model or initial stage of development. It is relatively easy to collect data on students and a program has been developed to analyze this data and describe distinguishing characteristics of students. (79) Using these techniques a program can be used as a screening device to identify the most promising candidates for an educational program. (80) Success in school and grade point averages can be predicted which assists counselors in admission roles. (81,82)

The information explosion has taxed the role of the guidance counselor. The computer used effectively can handle a large portion of the counselor's load more efficiently than without this tool. Even if it is simply used as an information source, this load with college catalogs, etc., has been a burden for the counselor. The long range forecast shows the counselors and computers working in a partnership in order to better serve the students. (83,84)

**Subject Matter Related Programs**

There are many different discipline oriented areas in the curriculum which are suitable for computer assisted instruction. Curricular decisions based on computer programs
are being used more frequently and with greater diversity than ever before. A model is available that helps in the sequencing of subject matter for a course. (85) This type of help can provide a conceptual framework for a curriculum.

One area which is a logical place for computers is that of computer instruction. An increasing number of students are interested in knowing more about computers. The Commission on Engineering Education has a manual containing 31 experiments that deal with logic, library systems, and circuitry. (86) Data processing technology programs have been developed in pilot projects which serve as models for interested educators. (87,88) Some of the business educational programs are expanding to include computer work along with bookkeeping and accounting in certain areas as pilot projects. (89) These pupils upon completion of high school will be trained to do the type of work currently requested by employers.

Reading

Using the computer as a tool for individualization of instruction seems to be the goal of those who have developed materials for the teaching of reading. At San Bernardino Valley College reading CAI program is used to assure sequence, continuity, progress, evaluation, testing, and individualization. (90) At Stanford University a CAI program is being tested in the teaching of reading. (91) First
grade students received a major portion of their instruction on a CAI tutorial system. Four major areas are used, i.e., decoding skills, comprehension, games, and review. Student progress can be generated each week by this particular program. (92)

The Stanford-Brentwood program works with disadvantaged children. The purpose of using CAI for these pupils is that it does not require verbalization skills in which many pupils of this type are deficient. (93) This type of program can isolate certain skills and work exclusively with these. Also, at Stanford, Rodgers is working on beginning reading programs based on psycholinguistic tenets as a part of the Stanford Curriculum in Beginning CAI Reading. (94) The use of computers for reading instruction seems to be located in beginning reading for primary students or remedial reading for college students. The International Reading Association Conference explored the problems poor college readers experience and attempted to identify materials which would be useful for the upgrading of their skills. (95) Most of the literature in the area of CAI reading is still at the "Is this a possibility?" stage. The most comprehensive publication is by Spache as he looks at the present application of CAI to reading, reviews them, and goes on to discuss realistically future applications for this field which is really an expansion of the current programs. (96) The materials in elementary school reading programs are becoming
more and more sophisticated with the advent of computer assisted instruction.

**Linguistics**

The structural approach to linguistics can be taught as a CAI program. The analysis of a sentence and a more complete understanding of language are the goals of computational linguistics. (97) Subroutines and drill are also part of the linguistic problems. (98) These approaches are natural ones to use for CAI programs as they easily lend themselves to CAI treatment.

**Foreign Language Instruction**

Similar to the procedures used by the linguists are the ones adopted by the CAI leaders in foreign languages. Adams has developed CAI modules based on language exercises. This provides practice which frees him for aural-oral practice in the classroom. (99) Frequently used words have been identified by Scherer in German and students can be drilled on the most frequently used words. These words were identified from German short stories and the computer was used to identify frequency. (100) CAI can be used for syntactic analysis which will aid in translation. (101) Instructions on how to use the computer for language research is explained in an article by Martins. (102) One way it can be used is for lexicon development. This was done by two authors in a
Polynesian language. (103) These innovative uses will provide useful materials for the foreign language field. Another technique was developed to identify systematically contrasts between English and Ukranian. (104) The output of materials from projects such as these is just beginning. The student of languages will surely benefit from this research and CAI programs which will be the outcome of these projects. Instructions on how CAI can be developed is currently available. (105) It should be experimentally used by departments as they develop materials to supplement and reinforce present courses.

Math

Mathematics departments at the college level started out by using the computer in a class situation on how to program to solve problems. It was moved into the arena of teaching math by CAI and students used programmed materials to learn their math. (106) Research that has been conducted at the college level indicates that no difference existed between CAI students and those in a conventionally taught math course. The students in the math sections evaluated at Michigan State University were in a remedial math program. (107) Although many believe CAI to be math oriented, those in the area of math have not moved any faster than other areas to install CAI in their curriculums.
English

The English teachers seem very much aware of CAI and have explored potential uses as have other disciplines. One emphasis in this field is the need for preservice exposure to CAI as it will become increasingly important in the schools of the future. (108) English programs for the seventies will stress attention to the individual and CAI will make this concern a reality. (109) The current direction for the English field seems to be toward usage in transformational grammar. (110) Programs for syntactic analysis are already available (111), while new programs such as sentence coordination are still in the research stage. (112) All the articles tend to reflect that this area is a natural one in which to use CAI.

Research

In order to discover more about the individual learner and the areas of study we deem important in the curriculum, research is constantly being conducted. Since the advent of computers, much of the research can become more specific and exacting as techniques for analysis are not possible using computers that seemed impossible with only human labor. For example, in Pittsburgh a computer assisted laboratory is available for social research. (113)

Much of the literature describes the potential use of
computers for classroom instruction and assistance. These "call to action" papers are vital first steps that usually precede new instructional techniques. However, there seems to be more of them than usual and the need is now to progress toward implementation of the computer for educational purposes. This, as has been demonstrated, is being done by various educators throughout the United States. Very little is being done in other countries. (114)

Now that there are some applications of computer usages in ongoing programs, the next aspect that must be explored is the effectiveness in using this new hardware. Research is an essential component before considering the large monetary outlay which accompanies computer usage. The research involving computer usage is quite limited but it is available and there needs to be a close look taken in respect to this type of research in order to develop design models around which more research can be conducted.

At the Wisconsin R and D Center a model was developed by the use of computer techniques to better understand the attainment of concepts. The model at the present time is not considered fruitful due to problems which limit the functioning of the cognitive process model. (115)

At the University of Pittsburgh in the IPI program (Individually Prescribed Instruction) it was discovered that the achievement results for the experimental first grade class were double the normally expected growth. (116)
California University explored the various properties of an automated teaching system and concluded that just as much learning could be produced at less cost by using a card file as by computer usage. (117)

At the International Reading Association it was reported that computer assisted instruction (CAI) and talking typewriters can teach beginning reading, but there is no proof that they can teach reading any better than regular classroom teaching or tutoring. (118) In a well controlled study by Ruddell, programmed learning and basal texts were even in the results they achieved with students. (118)

At the University of Illinois a course in teaching the use of the library was taught for one group in the conventional way while the other group had computer assisted instruction. The experimental and control groups did not differ significantly in the amount of knowledge gained as a result of their different treatments. (119)

An arithmetic CAI program to teach counting and numbered reading was developed and used with low arithmetic ability subjects from a vocational training project. These subjects had positive attitudes about the experience. (120)

The preceding investigations are really very limited in total scope and no generalizations can be drawn from them relative to computers and computer assisted instruction. However, these are initial attempts to evaluate this important area and do serve as models for those who wish to
pursue research in this area.

Summary

Computers are not new machines but the sixties has seen an explosion in the use of computers for business and industry. Education has recently discovered the advantages of the computers and have initiated conferences to consider uses, have designed programs, and experimented with it in various innovative ways. It is being used by statistics specialists to generate statistical tables and random numbers (121,122), while it is also being used to teach math and reading skills to first graders. The extensive uses of this machine have not yet been identified but educators are in increasing numbers exploring creative ways of using the computer for more effective education. As a way of individualizing the curriculum, the role of the student will change as will the role of the teacher. (123) CAI can free the instructor to act as a guide and work with small groups. It can also, hopefully, facilitate learning. (124) The teacher as a tutor and consultant will have to assume this new role or the total concept of CAI will be in jeopardy. Thus the total picture of computers in education is a very complex one. Most of the work done in this area has been to assist with administrative and paper work details. More recently counseling and subject matter related programs were initiated but those have been primarily designed for
purposes of drill or to find a correct answer to a problem. The Showalter (1) design seems to be unique as it is open ended and offers the student an unlimited number of investigation possibilities. (See Appendix VI) It also offers students individualized instruction utilizing some modes of experimentation not feasible for classroom exploration such as oceanography. Showalter states:

CSE . . . enables learners to make a relatively large number of real decisions when the technique is used in a genuine inquiry approach. Thus, CSE opens a new arena for CAI. The CSE technique may well be the first directed to upper elementary and high school students and to include all sciences on an open inquiry basis. (1, p. 47)

With this as a model, more of this type of program should be forthcoming. The delays in developing creative programs have been caused by lack of experience on the part of educators to write programs, excessive time required to write CAI programs, and lack of compatibility of computer languages and equipment. (125) As the importance of computers increases, these problems will eventually be solved. Time seems to be the key to this problem. As one professor said:

Once the kids get their hands on a thing like that, they're no longer in awe of it. And they learn how enormously they can increase their powers. Tens of thousands of kids, perhaps hundreds of thousands, will get their hands on the thing in one generation. I'll be awfully curious to see what they'll do with it. (126, p. 663)
Simulation

Introduction

Imitate or feign are frequently the words used in a dictionary to define the term simulation. (126, p. 1207) However, it currently applies to a variety of technical activities in which models of real situations are created for the purpose of testing or teaching. (127, p. 2) Simulations today is most frequently used in three different ways:

1. to evaluate or analyze an existing system (operations analysis)

2. to develop and evaluate a model or plan for a new system (prediction, experimentation)

3. to provide a learning environment that represents a life situation (training, transfer) (127, p. 2)

Simulation can be found in a wide variety of arenas but the most important one to educators is that it presents the students with a real-life situation where he uses his abilities to discover decision-making skills. (128)

It has been defined in a wide variety of ways by various authors. Cruickshank (128, p. 191) refers to it as the creation of realistic experiences to be played out by participants in order to provide them with life-like problem-solving experiences related to their present or future work. Beck and Monroe (127, p. 2) say that a simulated experience is a naturally occurring activity in children in all
cultures and left to themselves, children spontaneously simulate aspects of their present or future life experience. It is possible to think of simulation in a limited way or in its broad context but one needs to look at a variety of definitions before realizing the true scope of this term.

Beck and Monroe have collected the following definitions:

1. A simulation of a system or an organism is the operation of a model which is a representation of the system or organism. The model is amenable to manipulations which would be impossible, too expensive, or impractical to perform on the entity it portrays. The operation of the model can be studied and, from it, properties concerning the behavior of the actual system or subsystem can be inferred.

2. Simulation means the reenactment of a situation, or a set of circumstances, or an observable problem for which the designer has to make decisions or take other action.

3. Simulation is an analogy, and the human capacity for analogy is unlimited.

4. Simulation is the symbolic or physical representation and exercising of some aspects of a system.

5. Simulation is the

   a. general application of analogy in experimental method, regulated and modified by the changing requirements of experimental inquiry throughout the evaluation of object systems.

   b. differential representation of objects and events in any portion of a referent system and its environment by actual and analogous counterparts as they are operationally defined and exercised in an experimental test setting. (127, p. 9)

It is easy to see that simulation designs can be very
simple or extremely complex depending upon the proposed ob-
jective. The reason for this diversity in the definition of
simulation can best be explained by the diverse kinds of or-
ganizations and institutions which have found ways to uti-
itize simulation in their operations. Simulation is not a
term of the sixties. It is as old as the war games in
Ancient Greece and many people still think of simulation
only in terms of games. (129) Historically, their thinking
is accurate but today the term simulation is a broad spec­
trum of simulated experiences some of which are games.

The game aspect of simulation is currently quite popu­
lar since social processes can be simulated. (130) Games
have been used by the military, industry, and social sci­
entists. Advantages claimed for this type of simulation are
motivation, improved problem-solving ability, emphasis on
communication, and an interdisciplinary approach. (131) Ad­
vocates are enthusiastic about the gaming aspects of simu-
lation but some suggest that experiences which society de­
mands that the individual avoid in real life can also be
simulated and simulation may distort reality. (132) Nat­
urally, games which are designed with care will not cause
these problems. The number of games has increased so rap­
idly that lists are compiled of commercially produced games
to aid in locating appropriate games. (131) Instructions
for using simulation games successfully have been identified
to aid those using the gaming techniques:
1. The teacher of the game should be as short as possible in order to convey the purpose and the operation of the game.

2. The introduction of the game should be as short as possible in order to convey the purpose and the operation of the game.

3. Questions on game operation should be quickly answered as the game progresses.

4. Strategy should be identified through discovery and inquiry. (133)

Once an individual becomes interested in simulation, it becomes very clear that it is a very broad field that encompasses the game chess, which is often cited as a simulation game, to the synthetic simulation of administrative operations. (121, p. 3) A list covering all aspects of simulation that are currently operational is:

1. Environmental Simulation
2. Simulation not involving people
3. Analysis of occupations
4. Simulation for training
5. Real Size Simulation
6. Techniques of Miniaturization
7. Simulation with emphasis on people involved (134)

Various simulations can be placed into one of the preceding categories regardless of the area of specialization in which it was developed. Thus, simulation, as a topic, is very broad and is much more than the area of games although this is a large and important aspect.

Simulation in the Non-School Context

What is currently being conducted in the arena of simulation is quite extensive both in and out of educational
circles. Perhaps industry has been able to pioneer in this field because of their monetary resources to innovate in areas such as this. The military has also moved forward with a realization that simulation is an important tool. The government, the military, business, management groups, and even the American Board of Orthopedic Surgery which has a simulation in situational response are all working in the simulation area in various ways. (135)

Probably one of the most interesting groups to use simulation is the aviation industry. This group is conducting research to simulate complex behavior. (136) Pilots need to be competent and this industry believes simulation is an asset. The United States Air Force simulates training costs and necessary resources that are needed for effective training. (137) This type of simulation develops models from which decisions can be made. Naturally pilots are also actually trained using simulation laboratories. (138) Within this one field, simulation is used in a variety of different ways.

The United States government besides being interested from a military standpoint is also working in a number of other simulation areas. One of these areas deals with culture training. Since many citizens are employed overseas, new techniques for training this type of personnel have been developed. Simulation of foreign societies has been used for several years to help the trainee to acquire the
"flavor" of the other culture. (139) The Navy has also been working on cross-cultural simulation for their employees. (140) Many Americans go abroad so it is not difficult to understand the importance of simulation in this area. One such program contrasts American assumptions and values with the host country. (141) Another agency that prepares employees for foreign assistance work is trying simulation only on an experimental basis. (142) Temper 66 was a computer simulated exercise experimentally tried with students at an army industrial college. Its use was discontinued due to lack of verifiability but they hope to develop more useful simulation systems. (143) Peace Corps trainees experience simulation by using a simulated model that places them in a surrounding which resembles the country in which they will be working. (144) The majority of the simulation systems discussed here are relatively new but the developers are optimistic about their future as a training tool.

Employment is a problem in this country but simulation may eventually help not only the United States but others too. Project Aurora is a simulation experience in manpower planning and development of an imaginary country called Aurora. (145) This kind of simulation allows the players to try out their ideas, regardless of how unusual they might be, without involving real people but still obtaining realistic information. In another project skill training was simulated in order to train subprofessionals for civil
service positions in health, welfare, police, housing, and inspection work in New York. (146) Both of these projects involve simulation but one is a game to acquire answers for directions and the other is for skill acquisition.

The best known management simulation is the Harvard Business School Management Simulation Game which is a simulation that helps to develop business skills. (147) An evaluation of management games which was conducted by Strother failed to show that games of this type were beneficial for business or management students. (148) However, many businessmen feel that they are useful and more are being developed and utilized in management training. The current emphasis seems to be that creative innovative training techniques are important. (149)

The field of economics is frequently in the news with their uses of simulation. Legal and economics research methods utilizing simulation tools can be used by lawyers and economists to solve rural problems that are interdisciplinary. (150) This approach is very realistic as real people need not be involved on an experimental basis for projects that may not be satisfactory. This allows the theorists to "try out" ideas in a simulated situation.

There are many miscellaneous fields where simulation is being used. Some are quite fascinating. One interesting use of simulation is in collective negotiations. Research has been conducted to ascertain the feasibility of using
game theory for simulated collective bargaining. (151) An-
other facet of simulation is a community action game that
was developed to be used as a training aid and to gain in-
sights about human behavior in crisis periods. (152) An
unusual use of simulation is in the retirement simulation
program which was developed to explore four retirement pro-
blems, i.e., financial, housing, health, and social po-
sition. (153) This type of game which was developed by the
National Council on the Aging will give practice in arriving
at satisfactory decisions that fit the players needs and re-
sources. (153)

It is enlightening to know that simulation has such far
reaching potential and many different fields are identifying
creative ways it can be used. In looking at the various
ways it has been utilized, simulation provides a new dimen-
sion to these programs and does not merely replace an exist-
ing technique but enlarges the capacity of an agency or
business to function effectively.

Library Simulation

The stereotype picture of shelves of dusty books tended
by an elderly woman is not typical of the libraries of to-
day which are frequently being labeled resource centers. The
computer and simulation have moved into this realm and will
become more permanent as time progresses. Presently, an
evaluation of library practices can be made and measured
against the objectives of the library. A new library system can then be planned and tested by flow chart simulation. (154) This kind of systems analysis via computer simulation will create better, more useful libraries. In California a simulated plan has been developed to demonstrate the effectiveness of a mechanized center for information services. (155,156) This simulation can study the entire California State Library network and solutions can be identified that will permit a more efficient operation. (155) Purdue is also investigating simulation for library systems analysis and have ongoing research to expand this area. (157) Research is being conducted at Ohio State University to explore the feasibility of an index simulator. (158) Even simulations of retrieval systems are being developed to determine the feasibility of various systems. (159) The effects of using various retrieval systems can be identified and the most efficient type for a particular setting can be initiated. (160) A simulation has also been developed by which the effectiveness of the performance of large file systems can be explored. (161) Thus, the library leaders have identified unique ways they can use simulation to provide better and more efficient library services. Although the above sounds like a very impersonal approach, the human aspect can even be part of the simulation. For example, a user behavior simulated model has been developed and different models can be compared with users to identify the best models for the
library patron. (162) Librarians are interested in providing excellent service at the lowest cost and their usage of simulations demonstrates their concerns.

Counseling Simulation

Counseling services have continued during the last decade to expand and with the introduction of computer simulated services, this area can be even more helpful. Simulation for the counseling field is being developed for the vocational area for the actual training of counselors.

In one study with instruction simulated video tape it was found that the learning transfers to actual counseling situations and facilitates the development of crucial skills. (163)

Resnikoff developed a simulated client experience for the trainees who were to react to an emotional simulation sequence. (164) The model uses a simulation film and video play-back with the assumption that the way a person feels in an anxiety situation is a measure of his counseling effectiveness. (164)

Many counselors spend a major portion of their time in vocational or career counseling. A career simulation game for adolescents has been developed and students were assessed after the simulation and compared to a control group. No differences were found and this game is still being researched. (165) A type of vocational aid is an occupational
simulation kit which provides realistic experience in the fields of appliance repair, law enforcement, and electronics. (166) Another set of career kits are for the areas of accounting, X-ray technology, medical technicians, sales and banking. (167) Vocational awareness skills can be developed by using a model for operational gaming which is a decision making simulation. (168) Even after jobs are decided upon, there are many persons who eventually need vocational rehabilitation. Short-term personal counseling using simulated treatments at Michigan State University indicated that these clients made more significant progress than the control group who experienced no simulation. (169)

It is very clear that the work of simulation in the counseling area is still in the pilot project category but they are making definite progress and are exploring a variety of possible uses for simulation.

Administration and Simulation

The largest group of simulation users in the educational field seems to be the administrative group. A wide range of uses from training administrators to helping them simulate institutional designs have been and are being tried. As administrators have used simulations successfully, their faculties have seen possible uses for simulation in the area of instruction. Simulation for the administrative field is still experimental in many cases but is quite widely used
in a variety of ways.

Administrators operate in many different areas each day and their decisions cost money and/or affect the lives of the faculty community and pupil population. Because of this they are constantly searching for ways to increase their effectiveness. The amount of literature suggests that they believe simulation is a crucial tool for them to use.

Administrators during their preservice education are being exposed to a number of simulation techniques. Management games can be used. (170) Simulation training exercises have been developed to use in 10 week seminars. (171) Practice in administrative decision making and problem solving can be simulated. (172) Simulation roles can also be part of their training. (173) Some institution use "in-baskets" which require application of knowledge and provide practice. (174) Simulations that provide interaction between a human actor and a simulated environment is another technique being used. (175) Games teach useful skills they need and some feedback instruments have been developed to use when incorporating game theory into a curriculum for administrators. (176) Situational problems that force decisions are used for simulated experiences. (177) Elementary principals can have their training extended to include simulation since many move from the ranks of the teachers into an administrative position with no prior training. (178) Supervisors, who also are selected after years of teaching experience,
need continuing training too and simulation is an important tool. (179) The feeling seems to be that simulation is one instructional technique that should be used with supervisors to bring about instructional change. (180) Administrators have used simulation to promote faculty participation in a college government which provided them with administrative decision making duties. (181) Thus, just the inservice and preservice aspects of administrative training demonstrate many uses for simulation.

Practicing administrators use simulation in a multitude of ways too. It can help them to make decisions concerning operations of a large urban system. (182) By providing certain parameters, the decision maker can determine through simulation optimum policy decisions. (183) Projected college enrollments can be simulated and future potential decisions can be discussed. (184) Simulation can then be utilized to solve the problems which occur with an increasing enrollment. (185) Simulating a variety of class schedules and selecting the best one can solve some of the administrators' annual headaches. (186) Even continuous progress plans can run more smoothly if a simulation has been part of the planning. (187) Exploring a continuous progress school by simulation raises important questions that can be solved prior to the implementation of such a program. (188) Computer simulation can also find ways to use simulation techniques as well as other media in a school. (189) Perhaps one of
the most crucial decisions is that of money. Simulation models can be used to establish costs for programs in college departments (190) and a number of cost simulation models are currently ready for use in other colleges. (191) What are the cost implications of alternative plans can be investigated too. (192) The costs of Title I programs can be evaluated using a cost effectiveness model (193,194) and general allocation of resources for a university can be predicted using computer simulation. (195) IBM has developed a computer simulator program to evaluate feasibility for a computer terminal facility. (196) In this case a computer simulated program evaluates whether or not computer terminals would be a satisfactory addition in terms of cost and workload.

Decisions regarding families and construction have been made using simulation of instructional programs. (197) Design change can be suggested (198) and flexible facilities that will adapt to changing conditions can be identified. (199) Total university planning is possible with simulation. (200) With the model titled C.A.M.P.U.S. it is possible to simulate planning, programming, and budgeting. (201) Simulation of community colleges can produce better planning and identify effective methods. (202) Simulation techniques can assist the architects, teachers, contractors and administrators to communicate effectively about proposed construction; consequently, better facilities can be constructed if
simulation planning models are part of the planning. (203) The St. Louis Junior College was constructed using a master schedule and simulated projection which saved the developers three million dollars. (204)

Administrators need all the assistance they can locate to do an excellent job. Their tasks are so diversified that no one person can know everything in this field but tools such as simulation can help administrators make better decisions and function more effectively.

Teacher Education and Simulation

Inservice Education

Simulation has been identified as a change agent for developing teacher's individual potential. (205) Simulation techniques have been used for inservice instruction in a number of different ways such as games (206), reading achievement awareness (207), problem solving and (208), content areas such as social studies. (209) Simulation as a component in workshops for teachers has been shown to be an effective tool. (210) Subject sequencing can be accomplished by using a simulated model; therefore, a presentation schedule can be identified by the teacher. (211)

Training teachers to become better teachers is possible with simulation but they also need to be trained to utilize simulation in their curriculum. A workshop for high school business teachers provided the latter type of training as
they received the knowledge needed for designing and operating simulated business officers in their classrooms. (212)

Simulation can be in the form of sensitivity training. This can be accomplished by providing feedback and insights into procedures and instructional decisions through the use of simulation. The National Education Association proposes that this be used particularly with teachers of disadvantaged pupils. (213)

Social studies is a quite active in identifying inservice simulation techniques. Robinson (214) reviewed game simulation that was used as part of an inservice institute that attempted to provide instruction to translate the role of the Negro into operational models for civics classes. Dayton University worked with the topic "The Negro in the Americas" in conducting an inservice institute using simulation. (215) Simulation was also used with teachers from 21 states to gain an understanding of contemporary international relations. (216) All of these programs were designed for the teachers and they made the translation of their work into their classrooms. In one program the teachers actually developed a simulation game in economics for primary pupils and it was introduced into the schools. (217)

Individual training for inservice teachers has been a problem but with the introduction of simulation the concept of inservice education can be expanded. Teacher training can be implemented through simulation of direct experiences
with children. (218) Educators need to look closely at individualizing some of the inservice work and this is a very promising trend.

**Preservice Education**

Educators need not wait to use simulation techniques until teachers are practicing in the field and there are already many instances where it has been used at the preservice level. Since the teacher role is changing and moving toward greater involvement in dealing with motivational and social processes, simulation seems like an ideal vehicle to provide practice for those complex situations. (219)

A pilot program has been designed at the University of Tennessee to include micro teaching and simulation while the students work in self-instructional, self-pacing components. The writers of this program view simulation as an aspect of theory into practice. (220)

Allen (221) suggests that professional decision making on the part of teachers includes mastery of content, behavior skills, and humanistic skills that can be individually achieved through a variety of instructional modes, one of which is simulation while inservice is, in turn, viewed as an extension of these preservice competencies.

Shulman (222) worked with a teacher's inbasket which was a simulation of problems crossing a teacher's desk in a simulated school setting. It was found that this type
of simulation can be used to predict the inquiry behavior of teachers. (222) How efficient are simulation techniques in elementary preservice education? Girod (223) conducted an investigation to answer this question using sophomores, juniors, and seniors as he was particularly interested in using simulation to train teachers to identify and correct classroom management problems. Films and tapes were used but no significant effects were identified. (223)

Microteaching is often used in preservice education as a simulated training procedure. Allen and Cooper (224) have summarized the many uses of microteaching and define the use of peer group students instead of real ones as simulation and not microteaching. The authors indicated that more research is needed in this area. (224) This technique is utilized with the goal of preparing students for their student teaching experience.

Cruickshank and Broadbent (225, 226) examined training techniques of simulation in an attempt to determine the effect of critical teaching problems on the participant's teaching behavior. They concluded that:

Simulation training when tested under the most stringent conditions was an unqualified success as a teaching device that motivates and involves students and that, although simulation was only partially successful in changing the student teacher's behavior, it was at least as effective as an equal amount of student teaching. (22, p. 110)
The Twelker (227) study, after four years of a simulation program using films of classroom situations, suggests realism and prompting are not important variables in enhancing transfer of training in comparison to instructor differences and length of training. Although there is considerable transfer of the simulation training, more research seems imperative. Twelker (228) also discovered that students receiving only simulation training spent more time than others on management behaviors. This particular study needs to be replicated according to the author.

Wood (229) found that microsimulated teaching experiences which were concurrent with the student teaching experiences were more effective than a sequential plan when it was offered with training in interaction analysis.

Four goals of classroom simulation were identified by Twelker (230) and practiced in three different ways (i.e., simultaneous mode - all at one time, combination mode - two separately and two together, and the successive mode - one at a time). His study indicated that the simultaneous mode was more efficient.

Gustafson (231) used anxiety inducing films as a simulated experience as a preservice training situation to reduce anxiety in student teachers. Although the interaction with their students was increased, it did not reduce their anxiety or concern for classroom discipline.

In reviewing simulation and preservice education the
trend seems to be to simulate classroom situations for the training of teachers. The literature is still limited and some of the studies, although different, tend to contradict other studies as to the value of simulated classroom experiences. More research is definitely necessary before closure can be achieved on this issue.

Content Areas and Simulation

Many different areas such as driver education, social studies, economics, math, physics and the biological sciences have used some form of simulation as part of the instructional mode. For example, simulation in the driver education course reduced instructional time to six hours of simulation and four hours of actual driving. (232)

In the area of social studies and economics instruction games and role playing tend to be the forms of simulation utilized. (233) At Nova High School a computer simulated model was designed to evaluate the course as an instructional sequence and the simulated data seemed to be valid. (234) An economics class at a junior college was taught using gaming techniques and compared to a conventionally taught class with the result that the simulated exposure had a greater impact on the students. (235) The research suggests in a number of cases that simulation with games is possible, is as effective as conventional instruction, and may shorten learning time. (236) If these are accurate, simulation
needs careful consideration in economics education.

In the arena of the social services social work, sociology and the political sciences have been experimentally using simulation. Florida State collected base line data on entering graduate social work graduate majors using simulation tests. (237) Coleman (238) believes simulation games mirror certain social processes and are advantageous for use by the sociologist. An experimental course titled like the book *American Political Behavior* is used as an alternative to a two-quarter civics course and uses simulation as one mode of instruction. (239) Political Science at Case Western University uses a game simulation in order to involve political science majors in the dynamics of international policy making decisions. (240) Thus, a variety of schools are using simulation for the social sciences but research has not been a part of this new innovation technique for this field.

Reading has been taught to elementary teachers using video-tapes and responding to the tapes while later the majors work with actual children. (241) Another simulation model in reading assigns elementary students to remedial reading situations. (242) Silverberg (242) reports that when 3 groups using 3 different remedial methods were analyzed by the simulated model, it was predicted that more than half the pupils would have significantly improved, from seven to twelve months higher in reading levels, if they had
been in another program than the one they were assigned. This simulation technique can be diagnostically used to assign pupils to certain remedial methods.

Uninterested English students were exposed to simulation games and an evaluation indicated an attitudinal change resulted. (243) This technique might be a solution for disadvantaged youth who dislike school.

A college level physics course has been designed that utilizes computer simulations in various experiments such as mass spectrometers and physical systems. Blum (244) has developed a guide for instructors who wish to explore this type of simulation.

Kuhn (245) has developed a game which simulates natural selection. Experiments are conducted during the game which leads to understanding that the environment is a selective factor in evaluation. (245)

It is evident that simulation is new to the content fields by the limited research and diverse experimental nature of the miscellaneous programs. Another decade will provide the type of information needed before deciding to adopt a simulation model.

Learning and Role Behavior

Simulation is truly an innovative kind of instruction and can be viewed as a way in some cases to individualize instruction. (246) The student role in many institutions
is static and yet theory indicates that we need to have a dynamic situation. Turney (247) suggests that since culturally disadvantaged children often have an aversion to school and simulation which often has a void of human authority may create a type of learning environment to which this group can identify. McFarlane (248) discovered that a simulation game entitled Parent-Child is a research tool for studying roles of students particularly those in the inner city. (248) Another technique suggested by Kirschenbaum (249) for student behavior training was a riot simulation which alerts students to mob feeling and he felt that this along with other experiences could generate empathy for inner city blacks.

Concept learning investigations using computer simulation have been conducted in various content areas and research will be an integral part of these experiences. (250) Baker (251) has developed a simulated program titled CASE that will be part of the total program for concept research at the University of Wisconsin.

Boocock (252) used simulation games to investigate students' sense of control over their own destinies and discovered that simulation can give students the feeling of this control.

How do we learn a language? Perhaps we will understand the mechanism for language developed more fully after Linesay (253) completes his program which will simulate the
language learning behavior of humans. (253)

The research in this area is just beginning as simulation programs are developed for research purposes. At this time various developers are busy working on their own interests and pursuing a wide variety of different ideas.

Summary

Simulation has become increasingly important since the middle sixties for educators. The United States Office of Education supported eleven projects in the area of computer models and simulation during the last three years of this past decade. (254) It is quite easy to predict after looking at the literature that simulation will continue to increase in the schools of the seventies at all levels and in all areas.

Although this is a relatively new arena for educators, investigators have identified some guidelines. Cruickshank and Broadbent list the uses of simulation:

1. Instructional
2. Situational testing
3. Orientation or exposure to reality
4. Research
5. Design and Operational Analysis (255, p. v)

The have identified the instructional simulations as:

1. Make content of instruction more relevant by involving participants in lifelike experiences
2. Wed theory and practice
3. Modify behavior
4. Teach principles, procedures, criteria, or other higher cognitive level materials

(255, p. v)

The advantages and disadvantages of simulation have also been listed:

Advantages
1. Relevant since they are based on reference system
2. Permit the trainee to be himself
3. Safe
4. Permit control of what happens to trainee
5. Permit wedding of theory and practice
6. Are economical when compared to laboratory experience
7. Are engaging psychologically
8. Promote knowledge of and skill in group dynamics

Disadvantages
1. Do not fit neatly into existing programs
2. Often fail to provide empirically derived feedback
3. Directors may not be well prepared
4. Simulations may not be well founded or valid

(255, p. vii)
A structure for working in the area of simulation is gradually emerging and as these creative, interesting educators continue to design, experiment, and research a simulation, the resulting effect should eventually be a variety of simulation packages that can be effectively used by many different educators. As the literature reflects, most of the work is currently being conducted by educators with creative ideas of how they can use simulation. With the expansion of the field, more pertinent questions will be pursued.

Cruickshank and Broadbent suggest the following questions:

1. What should be simulated?
2. When should it be used in a training program?
3. What is learned best utilizing simulation?
   By whom? Under what conditions?
4. Do persons react under simulated conditions in the same way as they do in real life?
5. What can be done to increase feedback capability?
6. What effect does simulation have on subsequent performance? (255, p. vii)

Much more work needs to be done before these questions will be answered but with the introduction of simulation being of recent origin quite a lot has been accomplished in a relatively short period of time. If this trend continues, more of these problem questions will be answered within this decade. It will be easy to use simulations incorrectly:
thus, research must be conducted by educators to answer these crucial questions in order to provide an effective education for each pupil.

**Cognitive Functioning and Piaget**

**Introduction**

Jean Piaget is a Swiss psychologist who was trained in zoology but whose major interests are philosophical. (256) His first publication on cognitive development was issued in 1927. Since that time, he and his associates have published extensively in this area. He is associated with the Institute de J. J. Rousseau in Geneva, Switzerland where he pursues his research.

During the past decade American educators have continued to explore, discuss, debate, and think about the work of Piaget and its implications for our own educative system. It is crucial for teachers to know as much as possible about the cognitive development of children in order to identify and select appropriate instructional techniques and materials for each pupil. Because of this, cognitive studies have been and are being conducted. Ripple says that:

The influence of theories and methodology developed by Piaget in Europe and Guilford in the United States, emphasizing the qualitative (as opposed to the quantitative) aspects of cognitive functioning is discernible in recent studies . . . Methodologically, the trend has been away
from paper and pencil tests, which are aimed at quantifying, to the "clinical method," which involves interviewing subjects at work on a task. Knowledge about the nature and development of cognitive functioning is inferred from the subject's verbal responses as he is performing the task, solving the problem, or whatever. Emerging studies . . . reflect even more of Piaget's influence. These studies are mainly attempts to test or confirm his findings with more rigorous experimental design, or to apply his theory to new kinds of concepts. (257, p. 188)

The early publication in this century of Piaget's writing and the lag in interest of his work was mainly due to the fact that his writing was not translated from French to English until the early fifties by Berlyne and Piercy who then went to Switzerland in 1958 to spend a year with Piaget in Geneva. (258, p. 1)

The impact of Piaget's writing can be seen in the ideas of many important psychologists, i.e. Ausubel and Bruner. (258, p. 1) At most science education meetings today the ideas of Piaget are part of several presentations. His influence will continue to be felt for many years.

Piaget has been studying children for fifty years and is still interested in how children acquire knowledge. When Piaget talks about intelligence, he means the development of logical thinking which he regards as man's highest attribute. (259, p. 335) Teachers are concerned about logical operations and this is particularly true of science and math
teachers. The implications of his psychology that Piaget would support for education are:

1. Children go through certain stages of intellectual development.
2. Good pedagogy can have an effect on this development. (259, p. 317)

He believes that the development of intellectual capacity goes through a number of stages whose order is constant but whose time of appearance may vary both with the individual and with the society. (259, p. 317) The four factors which contribute to this development are: nervous maturation, encounters with experience, social transmission and equilibration but Piaget's findings have led him to conclude that an individual's intellectual development is a process of equilibration. (259, p. 318) Equilibration is a balancing, dynamic relationship between the child's assimilation of his world (i.e. how he incorporates what he sees into his own frame of reference) and his accommodation (the way his own patterns of response change with new knowledge). (260, p. 36)

Hunt has identified five main themes which he says dominate Piaget's theoretical formulations, namely:

1. The continual and progressive change in the structure of behavior and thought in the developing child.
2. The fixed nature of the order of the stages.
3. The invariant functions of accommodation.
(adaptive change to outer circumstances) and of assimilation (incorporation of the external into the inner organization with transfer of generalization to new circumstances) that operate in the child's continuous interaction with the environment.

4. The relation of thought to action.

5. The logical properties of thought processes. (258, p. 2)

Americans sometimes misinterpret the work of Piaget and erect time limitations. Teachers should grasp the concept of sequence without the constraints of time boundaries, especially in view of the long standing force in American psychology: the Gesellian interpretation of stages with firm upper and lower time limits. The maturationist view of fixed intelligence and predetermined development is no longer considered valid. Stages, as identified by Piaget, appear to occur in a constant, invariant sequence, but there are no time boundaries. (258, p. 3)

Piaget insists that children learn by reinventing and reorganizing experience, not merely putting new increments of learning on top of old knowledge. (260, p. 102) The stages he has identified that children go through are:

1. From 0 to age two is labelled the sensorimotor period. (260, p. 37)
2. From two to eleven he is in the period of concrete operations which is divided into several substages: preconceptual (2-4), intuitive (4 to 7 or 8) mental concrete (8-11). (260, p. 102)

3. Propositional thinking (11 or 12 into adolescence). (259, p. 338)

Duckworth says:

As far as education is concerned, the chief outcome of this theory of intellectual development is a plea that children be allowed to do their own learning. Piaget is not saying that intellectual development proceeds at its own pace no matter what you try to do. He saying what schools usually try to do is ineffectual . . . Good pedagogy must involve presenting the child with situations in which he himself experiments in the broadest sense of that term. (259, p. 318)

Research

Program Evaluation

Although the point has been made that Piagetian evaluation was clinical and avoided the paper-pencil test, various researchers have been attempting to develop a paper-pencil test that could be used with a total group. Karplus and Peterson (261) have developed a test called the Island Puzzle which indicates that intellectual development in abstract reasoning progresses gradually from grade five to
grade twelve where little further progress is made and abstract reasoning reaches a plateau. Stephens and Kowatrakul report that in a comparison of the ETS paper and pencil exercises with Piagetian concrete tasks the students performed significantly better on the concrete form. (262) De Avila and Struthers (263) developed a critical thinking instrument to measure four Piagetian tasks but found that although the conservation and casuality were satisfactory the statistical analysis showed the logic and relations scales were too dissimilar. The development of this type of evaluation should be continued as it seems promising. Erdmann and Buchi (264) report that the Loyola University model for testing Piagetian level was ineffective in distinguishing the major stages. (264) Thus, there are interesting, creative evaluative instruments being developed but they are still at the developmental stage. With the interest on research in developmental psychology satisfactory instruments of the type will eventually be developed. At the Stanford University Kuhlen Memorial Symposium it was indicated that serious attention is being given ages and stages due to the formulations by Piaget. (265) This interest will certainly promote more group administered instruments and research.

The first American research in the area of cognitive development and Piaget was conducted by the S-R psychologists. In fact, a large portion of the work has been done by psychologists which does not directly help teachers with
instructional programs but does establish the work of Piaget in cognitive functioning as important to the process of education.

Postman, Kendler, and Whilmarsh (257) all have conducted research to relate S-R theory with concept formation. Their work with modifications of the model illustrates how S-R theory can be related to the cognitive studies. (257, p. 190) Piaget on the other hand says that the stimulus response theory is incapable of explaining cognitive learning. (259, p. 329) Piaget indicated:

Berlyne spent a year with us in Geneva during which he intended to translate our results on the development of operations into stimulus-response language, specifically into Hull's learning theory . . . The essence of Berlyn's results is this: Our findings can very well be translated into Hullian language but only on the condition that two modifications are introduced. Berlyne himself found these modifications quite considerable, but they seemed to him to concern more the conceptualization than the Hullian theory . . . Berlyne wants to distinguish two sorts of responses in the S-R schema: (a) responses in the ordinary classical sense, which I shall call "copy responses"; (b) responses which Berlyne calls transformation responses . . . These transformation responses are what I call operations and you can see right away that this is a serious modification of Hull's conceptualization . . . The second modification . . . is what he calls internal reinforcements . . . They are what I call equilibration . . . so you see that it is indeed a stimulus-response theory, if you will, but first, you add operations and then you add equilibration. That's all we want. (259, pp. 333-334)
As Ripple says:

In summing up the current conception of S-R theory as applied to more complex learning such as concept formation, it appears that a single-unit model of stimulus-response association is not adequate. (257, p. 190)

Another approach to cognitive research is being conducted at the Center for Cognitive Studies under the directorship of Jerome Bruner. (257, p. 190) The studies by Bruner, Kennedy, Frank, and Nair (257) all demonstrate the importance of language. On the basis of this kind of evidence it is suggested that:

We can most fruitfully look upon cognitive growth as consisting in part in the development of systems of representation as means for dealing with information. (257, p. 193)

Birns (266), Liedtke (267), Shipman (268), Wolff (269), and McNeill (270) all conducted language related investigations. The Birns' study using the Piaget Object Scale supported the findings that social class differences in intellectual development do not appear during the first two years. It was also found that after two years language becomes important for learning. Differences in patterns of motivation and cognitive style occur early but show up in later learning. Education should foster the kinds of motivations and cognitive skills which will be needed for abstract thinking and cognitive skills. (266) Liedtke (267) used Piagetian tasks to determine whether a second language
for a young child is beneficial. This study agreed with Peal and Lambert's (267) finding that bilingualism has favorable effects on intellectual functioning. (267) Shipman (268) found that bilingual or non-English speaking children from a disadvantaged background did poorly on the Piagetian tasks. Wolff (269) used college undergraduates for a nonsense symbol learning exercise which demonstrated support for Piaget's processes of assimilation and accommodation. The McNeill (270) study indicated that the language of a Japanese child is not egocentric which tends to favor Vygotsky's theories.

Elkind and Deblinger (271) using nonverbal perceptual training for second graders in reading found that it did not affect reading comprehension. Stauffer (272) points out that reading is related to cognitive functioning as it requires problem solving abilities that are logical and it is not a passive process. (272)

Mathematics is an area in which research is being conducted too. Souder's (273) study using grades 4-7 indicated that the optimal grade level at which generalizing tasks should be offered is grade 6 or above. (273) This supports the Piagetian beliefs. Steffe (274) conducted a study with first graders in an attempt to determine whether conservation is a prerequisite to mathematical understanding. She found that the children who did poorly on the conservation task performed poorly on the math test. In addition the
study indicated that actual problem-solving rather than simple drill was necessary to learning addition facts. Substantial work has been done by Piaget and Inhelder (275,276) to develop these theories of space and number.

Music and Piaget's concept of conservation may not seem related but a study by Zimmerman (277) showed that the musical tasks improved from younger to older groups, improvement in conservation of tonal patterns preceded rhythm patterns, training to enhance conservation was most effective at ages 5 and 7 and a plateau in music conservation skills was reached in grade four. This research is an example of the importance of educators researching their own fields for instructional guidance.

Adelson (278) found that the political perspectives of adolescents move from the concrete to the abstract modes when analyzing political problems. English, German and American youth were all part of this study which is unique in its area.

Spontaneous play for young children is another interesting area of investigation. Almy (279) suggests that many levels of development are represented in a nursery school class which requires a wide range of toys since both the psychoanalytic and Piagetian view of the value of play support the need of play is early childhood education. (279) Piaget (280) views play as a means of transition from egocentrism to socialization.
The studies utilizing Piagetian tasks are quite diversified and represent a movement by educators to explore this area for guidance and confirmation.

Supportive and Nonsupportive Evaluation

The confirmation or support studies are much more numerous than the other kinds of studies. Almy (281) reports a study involving children from kindergarten, grade one and grade two that confirms the relevance of Piaget's theory to young children. The Lovell (282) research and literature review exploring number concepts, quantity, weight, time, and space also support Piaget's work. Palmer (283) found that his research with elementary children in the area of cognitive conflicts indicated support for the theory of Piaget that misconceptions of children when displaced by evidence contrary to the misconception give rise to cognitive conflicts. Sigel (284) found that the social science curriculum can incorporate the fundamental ideas of Piaget into the program. Wheatley (285) illustrated in his study that first graders who do well on a Piagetian type number concept test do well on the year end math achievement test, and it also supported the theory that first graders make significant growth in number concepts but they still vary greatly at the beginning and end of the school year. Achenbach (286) replicated an earlier study that was criticized by Piaget and Bielen where conservation was observed
in very young children and demonstrated that conservation behavior in children under three appears to have been an artifact. Boe (287) using secondary pupils investigated their perceptions of the plane sections of selected solid geometric figures their predicted responses described by Piaget and Inhelder were not validated. Shantz (288) conducted an egocentric study with young children and found that children below seven years of age usually cannot take the viewpoint of another which corroborated the Piagetian findings.

In the Towler (289) study Piaget's conservation theories were again supported using 100 5-7 year olds, and it was also suggested that these mental processes may exist earlier than Piaget predicted. The research by Fowler and Kohlberg (258) at the University of Chicago also support the work of Piaget to the development of intelligence. Dodwell (290) reported that 5-8 year olds showed little consistency in the level of conceptual development across five conservation tasks which is in disagreement with the findings reported by Piaget and others. In contrast Sigel (291) demonstrated replication studies which support Piaget's work in the area of conservation. (291)

The research replicating the work of Piaget is, in general, supportive of his studies of cognitive development. A few do not support his work and need to be replicated either by the authors as Achenback (286) did or by others.
These few inconsistencies related by the writer may be caused by other factors and should be viewed carefully as answers may be found which will be important to this total theory.

Training Evaluation

An aspect of Piaget's theory that is continually questioned is that of acceleration. Piaget says that some investigators have succeeded in teaching operational structures but before being convinced ask these three questions:

1. Is this learning lasting?
2. How much generalization is possible?
3. In the case of each learning experience what was the experience and what more complex structures has this learning succeeded in achieving? (260, p. 332)

There are a number of studies which explore the training for acceleration question. White's (292) study indicated that environment can affect the rate of sensorimotor development in infants. Raden (293) is conducting a study with 100 disadvantaged black and white children to discover if they can through training be moved into the preoperational period. Weikart (294) discovered that in a preschool using Piaget's cognitive development theories that some children benefit from this type of program while others do not. In the Stone (295) study of grades 1 through 9 students receiving discrimination training in the area of
classification significantly increased their scores. Kindergarten pupils in the Shantz (296) study received conservation training and improved their conservation task operations. Gilbert (297) also found that with training kindergarten children could improve in the area of conservation. Carey (298) using preschoolers found that experience in conservation of necessary but not sufficient for the development of logical thought. The kindergarten and first grade pupils in the Engelmann (299) study showed significant improvement in the area of conservation after instructional sessions. However, Mermelstein (300) worked with kindergarten children and concluded that training techniques were not successful. Muktarian (301) demonstrated that 5 and 6 year olds conserve quantity when given the proper experience. Dyrl (302) discovered in his study that combinational schema skills as defined by Piaget can be improved significantly for 6th graders when instruction was provided. Mermelstein (303) found that training of three + six year olds for the concept of conservation of substance concept was ineffective. Almy (304) reported a three year study using kindergarten and first graders in a longitudinal study which produced ambiguous results. The Resmick (305) study showed that perceptual integrated abilities can be accelerated in first grade boys with training. Howe (306) evaluated AAAS elementary fourth and sixth graders but found that training did not improve their conservation skills. (306)
Engelman (307) found that formal operations for preschool is a function of instruction and not development.

What can be said about the diverse conclusions of these numerous studies? The question is still not solved. Can instruction accelerate cognitive development according to the theory of Piaget? Although there are many studies, the results are contradictory. What is the problem? When a group of studies conducted by good researchers show inconsistent results, the answer may be that other variables are causing the difficulties. Additional variables need to be isolated and analyzed. Path analysis would be a useful statistical technique to use in the review of this problem.

Formal Operations

The Formal Operations level usually doesn't occur until a child is 11 or 12. Phillips says:

The adolescent begins where the Concrete Operations child left off—with concrete operations. He then operates on those operations by casting them into the form of propositions. These propositions then become a part of a cognitive structure that owes its existence to past experience but makes possibly hypotheses that do not correspond to any particular experience. The Concrete Operations child always starts with experience and makes limited interpolations and extrapolations from the data available to his senses. The adolescent, however, begins with the possible and then checks various possibilities against memorial representations of past
experience, and eventually against sensory feedback from the concrete manipulations that are suggested by his hypotheses. (256, pp. 103-104)

Unfortunately, relatively few investigations have been concerned with the logical operations attained during the stage of concrete operations or with formal operations. Most of the evaluation has been concentrated on the early development levels. Elkind (290) in a study of American college students found that only a little more than half of the subjects, all of whom should have been at the stage of formal operations, had attained the conservation of volume quantity concept. However, this finding is inconsistent with the studies by Uzgiris, Lovell, and Ogilvie. (290, p. 15) Broadbent and Skager say that:

Conceptual development at the level of formal operations has thus far been virtually ignored. This gap in our knowledge is to be deplored, since there is some reason to believe that educational and cultural experiences have greater influence at more complex levels of performance. The level of formal operations appears to be a suitable field for future investigations into factors relating to the development of the cognitive operations comprising Piaget's system. (290, p. 31)

Skager (308) in another publication says that some findings suggest that research should concentrate on the more advanced stages of formal operations as it may be possible to develop more efficient and precise measures than those of Piaget. The limited studies available once
again either support or conflict with Piaget's theory but only a limited number are even available. Thus, more studies are definitely needed.

Summary

Gunnells (309) conducted a study in grades four through nine of the development of logical judgment in successful and unsuccessful problem solvers. His data supported Piaget's findings regarding levels of development. However, a review of the research has indicated that this support for Piagetian theory is not always an outcome of these studies. Researchers often suggest that other variables may be important when this inconsistency continually occurs.

Broadbent and Skager suggest that:

The environmental orientation of many developmental researchers is doubtless at the roots of the considerable interest in the effects various training procedures have on performance on some of Piaget's tasks. There is a general impression that Piaget's own orientation is contrary to the environmentalist position. This is probably valid, even though one would be hard put to find a definitive statement in the matter in any of his writings. That culture and education effect cognitive development is certainly admitted, though this topic is evidently of minor interest to the Genevans . . . The evidence for cultural and training effects is obviously critical if any of Piagetian concepts are to be useful in the educational evaluation . . . Experimental subjects
spend very little time in the laboratory as compared to the magnitude of the influences exerted by the experiences of their everyday lives. Perhaps many educational variables are more in the cultural than the laboratory category. There has, nevertheless, been very little cross-cultural work on Piagetian concepts. (290, pp. 19-20)

McGuire states that:

The order in which the Piagetian stages succeed one another are usually constant. The word "usually" should be stressed since cross cultural research has not yet been carried out. (258, p. 5)

Harris (310) worked with the development of more attitudes of 200 white and Negro children using Piagetian theory. The results indicated that social class has a greater influence on the maturity of moral attitudes than race but that the lack of consistency in some areas suggests the influence of socio-cultural factors.

Other variables seem to be important in this theory but they have not been identified and evaluated satisfactorily. The study by Naville (311) indicated that more research was necessary in order to establish the relationship between mental and motor development. Langer (312) suggests that the processes of thought, concept development, and vocabulary development are interrelated since a well defined concept structure is a function of vocabulary-concept relationships. Although the importance has been
identified no research has been completed.

Broadbent and Skager also remind us that:

There is very little evidence as to the relationships between performance on Piaget's tasks and standard measures of general intellectual capacity. What evidence there is covers a very limited set of tasks, again mainly ignoring the level of formal operations, and has been provided on samples of subjects selected for special purposes. While the issue must remain open, particularly at the level of formal operations, there are at least preliminary grounds for anticipating that correlations between aptitude measures and performance of Piagetian tasks will prove to be substantial. (290, p. 35)

Harris (313) found that, with children ages 6 to 18, conservation measures of performance were distinct from that measured using the Wechsler Scales.

According to Senn (314) there is presently conflict among childhood educators since they do not know whether they should emphasize intelligence and narrow skills or intellect and understanding. Obviously, there is not enough evaluative support to answer this question. More research needs to be done before answers concerning these variables are found.

After reviewing the literature and research it can be said that (a) there seems to be a development of logical ability as children grow older, (b) development comes in stages, and (c) other variables may influence evaluations of programs especially at the upper levels. More research
is the phrase that consistently is requested by investigators at the conclusion of their studies. More research at the formal level using carefully identified variables seems to be the crucial research that is currently needed. Thus, this study should expand the knowledge that is known about the relationship of variables at the formal or abstract level of thinking.
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CHAPTER III

DESIGN OF THE STUDY

The Problem

This study is designed to accomplish two purposes: 1. to examine the Piagetian level of propositional thinking through the development of an instrument designed to identify levels of cognitive functioning with the broad category, propositional thinking, and 2. to determine the possible relationship (direct or indirect), of the following factors to an individual's level of propositional thinking:

a. Intelligence
b. Academic Achievement
c. Sex
d. Age
e. Reading
f. Piagetian Task Scores
g. Grade Level

Pilot Study

Twenty seventh and eighth graders in Lakewood and Columbus, Ohio were given the CSE background information and
investigation sheets by either their teacher or the writer. Both sexes were used and students with a variety of abilities participated in this aspect of the study. They were told to follow the terminal instructions and were asked what they could find out through experimentation. The open-ended aspect of this procedure identified problems that students encountered using the directions for terminal operation as well as parameters that the writer could use to develop an evaluative CSE instrument. On the basis of this study, four goals were accomplished: 1. An evaluative instrument was evolved using the students' investigations as a reference, 2. The background information for each computer simulated experiment was rewritten and revised, 3. The directions for terminal operation were revised and expanded to eliminate potential problems, 4. The pilot study provided some feedback which indicated a suitable strategy for instruction.

Initiating the Study

In the spring of 1970 the students were selected for the study from the total sixth and seventh graders in the Dublin Elementary School and the Dublin Junior High School. The population to which the Computer Simulated Experiments were administered contained two groups:

(1) A group of 32 sixth graders, 19 females and 13 males, enrolled in the Dublin Elementary School. Their ages ranged from 11 to 13.
A group of 30 seventh graders enrolled in the Dublin Junior High School. Twelve were females and eighteen were males. Their ages ranged from 12 to 16.

The sample was restricted to sixth and seventh graders since it is within this age range that students move from the concrete to the abstract level of cognitive functioning. The size of the sample was set at 30 as a minimal number but 62 was used since two grade levels were involved. According to Gage, a small sample of perhaps 25 or less may not have a normal distribution but that 100 or even 50 may qualify as a large sample. (1, p. 150) When the sample size N is less than about 30 the sampling distribution of means is not adequately represented by the normal curve table. (2, p. 160) Since a comparison of grade level was deemed important a minimum of 30 from each grade were selected.

In small groups of three to five the writer met the students and oriented them to the topic and problems. Students scheduled times were determined by using their study hall periods. The entire school day from 8:00 A.M. to 3:00 P.M. was available and utilized in half hour segments which provided fourteen periods a day. This was possible because of the staggered lunch periods. Thus, the total day three times a week was used effectively.

The close proximity of the two schools sharing the same grounds made it possible for the investigator to use one room equipped with a large table for working and a computer
terminal. This area was available for the entire day as it was originally the conference room for the executive offices.

The superintendent, two principals, and two science teachers approved the study and cooperated in every way in order to make it an integral part of the participants' program. This type of consistency and cooperation strengthened the study as it was conducted as part of their ongoing program. In order not to disrupt the students' regularly scheduled classes, one of their study periods was assigned for this project.

All of the students had experienced a variety of teachers during their daily schedules. The junior high students had a conventional schedule where they were assigned different teachers for each subject. The elementary pupils had an assigned self contained classroom setting but numerous special area teachers came to the classroom to conduct their sections. In some cases the students moved to other rooms for certain classes. The teachers seemed very knowledgeable about each student and interested in working together for the benefit of each pupil. This attitude was constantly reflected as the writer observed teachers working with their students.

A ten week period of time was blocked out for the purpose of this study and each group of not more than five students met three times a week for a total of thirty sessions. They worked individually on hypothesis development, data
collection, or data interpretation. This meant fourteen sections of students, three days a week for a weekly total of forty-two periods. Thus, each student worked on his investigation three times a week for a total of 1 1/2 hours.

Organization and Procedure

The students met with the writer three work periods each week for ten weeks. During these regularly scheduled periods, the students identified their hypotheses, collected data, and interpreted the data on their print-out sheets. All of the work was conducted within the terminal classroom and none of the work was removed from the classroom setting. The classroom was always available as the terminal was located in the superintendent's conference room along with chairs and a table that provided suitable working space. During the time of the classes, his conferences were scheduled for other locations. The terminal was new and none of the staff used it for any instructional purposes. This made it very convenient as it was always ready to be used for the purpose of this study.

By scheduling the pupils in small groups they could work independently asking questions of the writer instead of their peers. This grouping assured the writer of the fact that they were not helping one another which was important for this study.

Each investigation was initiated by the writer carefully
discussing the printed materials, defining vocabulary, and answering general questions. Since reading abilities varied considerably, the activities were each verbally explained using concrete objects for demonstration purposes. Questions were openly asked and answered. The pupils seemed to be very frank about admitting any confusion or asking clarification questions. This evidently was a normal way they functioned in other classroom settings.

After the demonstration and explanation sessions the students were asked to identify a hypothesis or hypotheses and decide how to proceed with their data collection. Some students would collect data, look at it and decide that it needed to be expanded for clarification; therefore, they would often collect additional data until they felt they were ready for data analysis. No attempt was made to limit nor encourage more data collection. This was always an individual decision.

No help was provided in the writing or wording of the hypotheses. Interestingly enough, none was ever requested. The early demonstration time seemed to provide the necessary instruction. Using the background sheets the subjects proceeded quite independently after the introductory sessions. When questions were asked about the conclusions they were directed to write down what the data tells you about the study. The students seemed to work very diligently to do this and no one requested anyone else to analyze their data
for them. This procedure worked very satisfactorily, and the problems encountered during the pilot study with little initial directions were circumvented.

Each student initiated and completed three investigations, i.e., Oceanography, Mazler, and Paramenium Population. (See Appendix I) The three investigations cut across disciplinary lines using aspects of biology, chemistry, and the physical sciences.

A Description of the Study

The School Setting

The school from which the students were selected draws from a fairly heterogeneous population. The majority of the students are bussed to school and come from either the local village, rural farming community, upper middle class suburban area, or from wealthy families who own estates along the river. Both blacks and whites are present in the school and the study. The socio-economic heterogeneity of this area makes it an ideal place to use for research purposes rather than the usual more homogeneous school population.

Since both sixth and seventh graders are involved in the study, another factor made this setting unique. The elementary and the junior high structures are built beside one another and the students share certain common facilities. Thus, all the students were familiar with the area in which
the computer work was conducted and a common facility was utilized for all classes.

Characteristics of the Students

The students came from very diverse socio-economic backgrounds. Some parents were extremely wealthy; others were very poor. Some pupils had divorced parents while others had lost a parent through death by accident or illness. All types of home situations were represented in this population of sixth and seventh graders.

The pupils had a wide distribution of abilities and characteristics which made this sample very heterogeneous. Size, age, academic abilities, athletic facility, and cultural backgrounds were all quite diversified.

Sixty-two pupils were part of this study. Thirty were from the seventh grade and thirty-two from the sixth grade. Some of the sixth graders were older than the seventh graders while a few of the seventh graders were the age of the sixth graders. Again, it was a diverse group. With the exception of the students living within the village, they were bussed to and from school each day which meant a long ride for many both at the beginning and end of the school day.

The students range of intelligence was very wide. The scores ranged from considerably below average to the gifted area. Their academic achievement scores showed the same
range and pattern. This sample seemed to be very heterogeneous in all quantifiable characteristics.

Materials

The Computer Simulated Experiments (CSE) materials utilized on the computer were originated by Dr. Victor Showalter, Science Director of the Educational Research Council of America. He received first prize in the 1970 NSTA Gustav O'Haus Awards for the development of these unique open-ended, inquiry-oriented materials. (3)

The format of the CSE materials is such that they are open ended investigations that can be conducted by individuals within certain parameters. Each individual designs his own experiment using the variables that are available to him. The student collects his data using the computer instead of concrete materials. The print-out records the data collected and permits the pupil to analyze that data in order to draw conclusions from the investigation. (See Appendix III)

Prior to conducting each investigation, the students were given background instruction sheets which provided information concerning the parameters of the experiment and additional information that was useful to know. These materials were checked using the Dale-Chall Scale for Readability. (4) Each investigation was preceded by a demonstration using real materials and answering questions. The background sheets were carefully read with each group and
questions answered. They kept these materials for guidance while they pursued their individual studies. The materials seemed to make the tasks more realistic and helped to orient the student to the problem. (See Appendix I)

Step-by-step instructions were provided in verbal and written form on how to use terminal from signing on to the sign-off period. None of the students had any difficulty using the terminal although some were much slower than others in punching out their data collection instructions. The use of the printed materials provided reference points as the pupils worked toward investigation completion.

Development of Analysis

The PAL Instrument

Purpose

The student's investigations were quantified using an instrument developed by the writer. The PAL Scale (Propositional/Abstract Level Scale) was developed to analyze subjects performance in computer simulated experiments in three areas: hypothesizing, data collection, interpreting data. The pupils identified a hypothesis, gathered data, which the terminal recorded on print-out sheets, and then analyzed the print-out sheets to reach conclusions. When each investigation was complete, it was stapled together as a total package ready for PAL scoring. A total score using
the three components was derived by the judge applying the PAL Scale.

**PAL Criteria**

The Propositional/Abstract Level Scale consisted of three sections or subscales. The sections were of equal length in order to give the same weighting to each of the three areas of propositional thinking, i.e., hypothesizing, data collection, and interpreting data. The scale was evolved during a pilot study. It was modified to make each analysis section very specific. The criteria used during the development of this scale were:

1. **Objectivity**
   
   Use of the instrument should yield verifiable, reproducible data.

2. **Reliability**
   
   It should yield the same value, within the limits of allowable error under the same set of conditions.

3. **Sensitivity**
   
   It should yield as fine distinctions as are typically made in communicating about the object of investigation.

4. **Validity**
   
   Its content, in this case the categories in the rating scale, should be relevant to a defined area of investigation.
5. Utility

It should efficiently yield information relevant to contemporary theoretical and practical issues; i.e., it should not be so cumbersome and laborious as to preclude collection of data at a reasonable rate. (1, p. 330)

Attention was given to each of these areas during the development of the scale and each of the criteria was met as carefully as possible. Each section is clearly stated making independently reproducible scores possible and providing similar values from trained independent judges. This type of rating scale is categorized as a Cumulated-Points Rating Scale. (1, p. 339) Each of the sections has a rating of one, two, or three points and the three sections are summed for a total rating score. Appendix V contains the PAL Scale.

Validity

When developing an instrument the major concern of the investigator is if the instrument measures what it claims to measure. The essential question for this study is whether or not the instrument (PAL Scale) correctly assesses the individual's ability to function in the area of propositional thinking. Three types of validity (pragmatic validity, construct validity, and face validity) may be considered in the assessment of instrument validity.
**Pragmatic Validity**

A test that helps the investigator distinguish individuals who differ in their present status is said to have concurrent or pragmatic validity. (5, p. 157) This type of validity is also termed criterion-related. It is a correlation between a set of scores or some other predictor with an external measure and the external measure is referred to as a criterion. There is no independent criterion suitable for comparison to the PAL Scale to test the level of propositional thinking. Goode and Hatt indicate, "... if there is already a single criterion available to measure the continuum in question, there is no need to construct a scale." (6, p. 233) What is essential in this approach to validation is that there be a reasonably valid and reliable criterion with which the scores on the measuring instrument can be compared. (5, p. 157) Since this does not exist this type of validation is not suitable for this study.

**Construct Validity**

In the Selltiz explanation of construct validity she says:

Frequently, however, the investigator is interested in the test of performance not as a simple predictor of behavior but as a basis for inferring the degree to which the individual possesses some characteristics presumed to be reflected in the test performance. The presumed characteristic is not something which can be pointed to or identified
with some specific kind of behavior; rather it is an abstraction, a construct. (5, pp. 158-159)

In this study propositional thinking can be identified with a specific behavior such as hypothesis identification, data collection, and conclusions based on the hypothesis and analysis of the data. As it is related to a specific kind of behavior, it is not appropriate to consider construct validity to accomplish this goal.

**Face Validity**

Although there is some criticism of face validity, Selltiz says:

> We usually do not know the subject's true position on the variable we are attempting to measure. If there were some other source of information as to the true position on the variable, there would often be no need for another measure of the variable. (4, p. 156)

Because there is no other measuring instrument of this type, face validity was used. The attribute we are interested in is directly measured using the PAL Scale with the Computer Simulated Experiments (CSE). A measure of this type is often said to have face validity, "... that is, the relevance of the measuring instrument to what one is trying to measure is apparent on the face of it." (5, p. 165)

The face validity approach to validation was used in pursuing the validation of the PAL Scale. However, Goode
and Hatt indicate that logical validation should not be relied upon solely. (6, p. 237) Thus, a jury of thirty miscellaneous individuals was selected for validation purposes and asked to complete a CSE. If the scale accurately measures what it is supposed to measure, the top five scores from the CSE samples should be obtained by the subjects with the greatest amount of science background while the lowest scores should be made by the subjects with the least amount of science background. Five of the panel members were science educators. All of the members were adults ranging in ages from 22 to 45. The backgrounds of the subjects were rated as weak, average, good or excellent on the basis of the previous science experiences and the type of science magazines they presently read on a regular basis. From the sample of 30, five from the weak category should receive the lowest scores while the five science educators who were in the excellent category should receive the highest scores. This technique will resolve the problem of validity. The five highest scores were obtained by those individuals who were in the highest category and the five lowest scores were made by those in the lowest category. This nonstatistical comparison supports the validation of the instrument.

A t test was used as a test of significance to compare the scores of subjects with strong science backgrounds with those having weak science backgrounds. Table 1 presents the data and results obtained by using the following formula:
Table 1
PAL Score Comparisons

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<th>Strong Science Background</th>
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<th>Weak Science Background</th>
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<td>Subject #</td>
<td>PAL Score</td>
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\[ \bar{x}_1 = 16.4 \]
\[ \bar{x}_2 = 8.7 \]

\[ S_{\bar{x}_1} = .48 \]
\[ S_{\bar{x}_2} = .88 \]

\[ t = 7.7 \]
\[ P < .001 \]
The results indicated that these scores were significant at the .001 level of significance. Thus, the validity of the instrument was established through the utilization of the t test.

Reliability

Reliability, the second aspect for consideration is not as difficult to determine as validity. Reliability is the accuracy or precision of an instrument. According to Selltiz, the more relationships tested, such as reliability as well as validity, the greater the support for the measuring instrument. (1, p. 163) In this study both aspects of reliability, stability and equivalence, were considered.

Stability

The stability of results of a measuring instrument is determined on the basis of the consistency of measures on repeated applications. (1, p. 168) A common and appropriate method for determining stability is comparison of the results of repeated measurements. A common technique which seems to be the most appropriate for the study is the test-retest method. A parallel forms method is probably not as reliable for this particular type of investigation since
each of the computer simulated experiments (CSE) is from a different area of scientific study (i.e., Oceanography-interdisciplinary; Mazler-behavioral science; and Paramecia Population-biological). None of the three computer simulated experiments can be considered to be parallel enough to use for stability purposes; consequently, using the Oceanography CSE, the test-retest method was employed.

In the test-retest method a test is administered and then at a later date the same test is readministered to the same individuals. A Pearson product-moment correlation coefficient is computed between the two sets of scores. (2, p. 242)

Using a random table of numbers, 30 individuals were selected from the 62 subjects for the purpose of the retesting. The Oceanography Computer Simulated Experiment (CSE) was utilized for the test-retest aspect of this study. Ten days after the completion of the first run, the second investigation was given to the subjects again. Due to the open-ended design of the Computer Simulated Experiments (CSE) the pupils could be very diverse in their responses and still have scores similar to their first experience. These scores were used to establish a measure of reliability for the PAL scale and for the stability aspect of reliability. A Pearson product-moment correlation coefficient was computed between the two groups of raw scores to obtain stability measure.
The results, which are reported in Table 2, yielded an $r$ of .925. The stability of this measuring instrument seems to be very satisfactory.

**Equivalence**

Estimates of equivalence concern the extent to which different investigators using an instrument to measure the same individuals yield consistent results. (5, p. 173) The notion of a reliable measurement procedure requires that it yield comparable results from administrator to administrator, provided each has been properly trained. (5, p. 172) This factor was solved by training a science educator in the use of the PAL Scale. Reliability was increased by the careful training of raters. (5, p. 353) The raters independently scored a set of papers and a correlation coefficient was used as an index of the equivalence of a pair of observers. (5, p. 173) Interjudge reliability was determined by obtaining the PAL scores of two trained independent judges. The Pearson product moment correlation coefficient was computed for these scores and an $r$ was obtained. The formula that was used is presented below: (7)

\[
r = \frac{\sum_{i=1}^{N} (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{[\sum_{i=1}^{N} (X_i - \bar{X})^2][\sum_{i=1}^{N} (Y_i - \bar{Y})^2]}}
\]
Table 2
Test-Retest Comparisons for Reliability

<table>
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<th>$x^2$</th>
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\[ \sum x = 348 \quad \sum y = 346 \quad \sum x^2 = 4278 \quad \sum y^2 = 4188 \quad \sum xy = 4216 \]

\[ r = .925 \]
The results are reported in Table 3. The correlation coefficient obtained was .817 which established reliability in the area of equivalence.

Equivalence is also concerned with the administration of materials since different administrators can cause undesired variations. (5, p. 182) This problem was solved by having the writer assume all the teaching and administrative responsibility over the ten week period.

Path Analysis

Path Analysis and causal inference procedures are based on ideas developed originally in biology by Wright. (7, p. 38) The essential idea of the causal model involves the construction of an over-simplified model of reality in the sense that the model considers only a limited number of variables and relations. The causal model is written as a set of structural equations that represent the causal processes assumed to operate among the variables under consideration. (7, p. 4) The structural equations, in turn, lead to parameter estimation procedures and evaluation of the model. (7, p. 4) The outcome of the empirical evaluation process is either the corroboration or reformulation of the causal model. (7, p. 4) Land states that:

Although it may be as Blalock argues there are 'inherent difficulties that produce such a gap between scientific theory and empirical research not only
### Table 3

**Interjudge Reliability**

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$\bar{X} = 362 \quad \bar{Y} = 349 \quad \bar{X}^2 = 4374 \quad \bar{Y}^2 = 4063 \quad \bar{XY} = 4190$

$r = .817$
in sociology but in all disciplines,' causal models seem to offer one promising strategy to the sociologist for increasing the interaction between theory and research. (7, p. 4)

In 1966 Duncan showed the relationship of Boudan's work of structural equations to what is known in genetics as path analysis and gave several convincing examples of the utility of the method of path analysis. (7, p. 4) Wright defined it as: "The purpose of path analysis is to determine whether a proposed set of interpretations is consistent throughout." (7, p. 5) The term "path model" is used to refer to a set of structural equations representing the postulated causal and noncausal relationships among the variables under consideration. (7, p. 7)

The assumptions of path analysis are:

1. In the system, change in one variable always occurs as a linear function of changes in other variables. Linear equations are those in which the value of one variable is defined simply in terms of the values of other variables.

2. The system of concern contains no reciprocal causations of feedback loops; that is, if x causes y, y cannot affect x either directly or through a chain of other variables. With a recursive model, the direction of effects is always outward away from the central input variables. (7, p. 45)

A model using time-ordered sequence and theory was arrived at using the Heise and Land (7) directions. The postulated causal relations among the variables of the system
are represented by unidirectional arrows extending from each determining variable to each variable dependent on it. (7, p. 6) This was done and a model was established on the basis of time sequence and theoretical assumptions. There are three primary sources of information from which causal assumptions may typically be derived:

1. Time order of the variables
2. Experimental or case-study results
3. Theoretical assumptions of the particular substantive area. (7, p. 34)

Once the model has been established, any decision to delete a postulated path must be based on a statistical test of significance or on an arbitrary criterion of size of the retained paths. (7, p. 34) Only those path coefficients which are statistically significant are retained in a reformulation of the path model. (7, p. 35) Thus, following the instructions the following model was established:

In recursive systems the problem reduces to the problem of ordering the variables in terms of causal priority so that the structural equations can be set up with a triangular format. (7, p. 51) The notion of recursive systems of simultaneous equations provides a tool for the development of a general type of model for such causal systems which may be referred to as the multistage, multi-variate path model. Thus, the equations for Model I are:

1. \[ IQ = b_1 \text{Sex} + b_2 \text{Age} + e \]
2. \[ GR = b_1 \text{Sex} + b_2 \text{Age} + b_3 \text{IQ} + e \]
3. \[ A.A. = b_1 \text{Sex} + b_2 \text{Age} + b_3 \text{IQ} + b_y \text{GR} + e \]
4. \[ \text{Read.} = b_1 \text{Sex} + b_2 \text{Age} + b_3 \text{IQ} + b_y \text{GR} + e \]
5. \[ \text{P.T.} = b_1 \text{Sex} + b_2 \text{Age} + b_3 \text{IQ} + b_y \text{GR} + b_8 \text{AA} + b_6 \text{Read.} + e \]
6. \[ \text{PAL} = b_1 \text{Sex} + b_2 \text{Age} + b_3 \text{IQ} + b_y \text{GR} + b_8 \text{AA} + b_6 \text{Read.} + b_y \text{P.T.} + e \]

The OSU/ECON Step-Wise Regression Program performs classical least-squares regression, multivariate normal correlations, time series simulation and forecasting analysis. (8, p. 1) This program was utilized with the raw data to obtain a correlation matrix. The path coefficients were used following the Heise (7, pp. 70-71) directions for constructing a \( P \) matrix. The two matrices can then be compared for a significance of fit. This information provides additional guidelines for developing a new model that will be even more satisfactory.

According to Heise:

Old techniques of tubular elaboration, partial correlations, and stepwise regressions all involve similar assumptions and these old techniques now seem almost archaic in comparison. . . . path analysis provides a powerful, meaningful approach to analyzing causal relationships and correlations, and it is assured of wide acceptance as a tool for abstract analysis. (7, p. 69)
Summary

Each of the sixty-two sixth and seventh graders using computer simulated experiments (CSE) completed three investigations, (i.e., Oceanography, Mazler, Paramecia Population). These investigations were analyzed using the PAL Scale in order to obtain a score for each of the studies. Samples of the investigations and the PAL Scale can be found in the Appendices. Two judges independently applied this scale to the studies and scores were derived for each student. These scores were used along with other variables to analyze the relationship Piagetian task scores, sex, age, intelligence, academic achievement, reading, and grade level have to the PAL scores. A model utilizing time order and theory was devised for the variables and Path Analysis was used to test the fit of the components within the model.
Bibliography


CHAPTER IV

THE FINDINGS OF THE STUDY

Introduction

As explained in chapter one, the purpose of this study was to develop an instrument to diagnose sixth and seventh graders' levels of propositional or abstract thinking using computer simulated experiments (CSE) and to identify the direct and indirect effects of academic achievement, intelligence, sex, age, reading, grade level, and Piagetian tasks to propositional thinking.

An instrument was developed for propositional thinking diagnostic evaluation which was designated the Propositional/Abstract Level Scale (PAL). The PAL Scale was used to evaluate each of the 186 science investigations conducted by the 62 sixth and seventh graders. This resulted in a PAL score for each computer simulated experiment (CSE). The reliability and validity of the PAL instrument was established using appropriate statistical techniques. (See chapter three) Thus, the PAL Scale was used to evaluate the cognitive functioning of the students in the area of propositional thinking through an analysis of their computer simulated experiments (CSE).
This chapter is devoted to an explanation of the data treatment and an analysis of the data collected for this research study. The findings of this study are grouped into three sections. The first section deals with Model I which was the theoretical, time ordered model that was presented with the theoretical or research hypotheses in chapter one. (Figure 1) The second section analyzes a new model designated as Model II which was developed after the findings for Model I were analyzed. Model II is a synthesis that resulted from the strengths identified in Model I and careful statistical analyses of each variable. Section three is a presentation of the findings in relationship of the hypotheses. The null hypotheses are either rejected or accepted as determined by the findings of this study in this section.

**Model I**

Path analysis was used to test the theoretical model identified in chapter one. (See Figure 1) The underlying mathematical framework in a path analysis is multiple-regression analysis. The data derived from reading scores, PAL scores, Piagetian scores, sex, age, IQ, and academic achievement variables were coded and analyzed using the OSU/ECON Regression Program. (1) The dependent variables were analyzed against the independent variables according to Model I which enabled the researcher to obtain a beta weight.
or path coefficient for each direct path drawn in the model. A path coefficient can be defined as a standardized regression coefficient or beta weight. Each path coefficient reflects the magnitude of the direct or unique effect of that particular variable on the dependent variable with the independent variables considered simultaneously in the multiple regression equation. (2, p. 5) Thus, the path coefficients or beta weights (See Table 4) were used to estimate the empirical correlations among the variables in the system. (3, p. 70) The R or predicted matrix that resulted was the matrix of correlations as estimated from path coefficients among inputs. (3, p. 71)

The OSU/ECON Regression Program (1) was also used to obtain a coefficient correlation matrix or observed correlation matrix. This was obtained by running the regression analysis using all the variables. (See Table 5) The observed matrix and the R matrix were then compared by translating the scores from the two matrices into z scores and correlating the z scores using a computer program that correlates and computes regression coefficients. The fit of the two matrices was reflected in the correlation. Thus, it was possible to statistically determine the accuracy of the model and its direct paths by using the path analysis technique.

In Model I the diagram (Figure 2) illustrates that there are direct paths from sex and age to IQ; from IQ to
grade, reading, and academic achievement; from grade to reading and Piaget; from academic achievement to Piaget and PAL scores; from reading to Piaget; and from Piaget to the PAL scores.

Figure 2 illustrates the time ordered theoretical model shown in chapter one (Figure 1). It was assumed that sex #1 and age #2 are exogenous variables, i.e. they are not determined by any other variable in this model. The remaining variables are all endogenous, i.e. they are determined by at least one other variable measured in this model. The model itself is recursive; i.e. the causal flow all moves in one direction with no reciprocal links among the endogenous variables in the model. (2, p. 4) The arrows on the model reflect the hypothesized direct paths among the testable variables. To obtain beta weights or path coefficients necessary to test Model 1, all independent variables illustrated in Figure 2 were forced into the regression. Otherwise, variables that were not significant at the .05 level would have been dropped during the analysis by the computer program and no path coefficient scores would have been obtained for certain variables. Since Model I is the time ordered theoretical model, it was necessary to analyze it using path analysis with no alteration of the paths. In order to determine whether or not it is a statistically satisfactory model to use for sixth and seventh graders the model had to be kept intact. To test the fit of Model I,
Model I

Figure 2
Table 4  
Path Coefficients for Model I

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Predicted and Observed z Scores for Model I

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Correlation = .76
it was essential to have path coefficient scores to generate the R matrix as described by Heise. (3, pp. 70-71) Table 4 lists the path coefficients used for Model I. (See Table 4)

The arrows leading to the variables in Figure 2 each contain a path coefficient (a standardized regression coefficient or beta weight). Each path coefficient reflects the magnitude of the direct or unique effect of that particular variable on the dependent variable with the independent variable considered simultaneously in the multiple regression equation. (3, p. 5) Model I (Figure 2) illustrates the direct and indirect effects of the variables. The direct effects are listed on the arrows as path coefficients ($P_{xy}$). It should be noted that some of the path coefficients are quite small while others are much larger. The magnitude of the coefficient is an estimate of the net degree of change in the dependent variable that would result from a one standard deviation change in the independent variable. The greater the coefficient the greater the change; hence, the more powerful the variable. (2, p. 5)

The lines to the dependent variables from the squares in Figure 2 denote the residual ($r$). This residual is $1-r$. The square of the residual is the percentage of variance in the dependent variable which is not explained by a linear combination of the independent variables. (2, p. 5) It should be noted that some of the path coefficients are quite small while some of the residuals are quite large. It can
be inferred even at this stage that a better model may be possible.

The observed correlation matrix derived from the OSU/ECON Regression Program (1) is reproduced in Table 5. This is sometimes referred to as the original correlation coefficient matrix. The original or observed zero order values are presented in Table 5. The generated values obtained by following the Heise (3, pp. 70-71) and Spady, Greenwood (2, p. 7) directions were placed into a matrix of generated values designated as R or the R matrix. (See Table 6) The values from the two matrices were translated into z scores and a correlation was computed for the two matrices. (See Table 7) The observed values were correlated with the predicted values. This analysis resulted in the correlation of .76 between the two matrices of Model I. In looking closely at Model I, it was inferred, that through a beta weight analysis, a new model could be identified that would have a higher correlation and more accurately represent the direct effects of the variables.

Model II

Model I had some apparent weaknesses that were indicated by the low beta weights of certain paths and the high residuals. Spady and Greenwood (2) have developed a technique for model identification which they have labelled "instant path". Using their technique, the writer ran the
regression analysis program for each dependent variable using all the independent variables. For example, using the Piagetian scores as the dependent variable, the independent variables were PAL, academic achievement, reading, grade, IQ, age, and sex. The OSU/ECON Regression Program (1) was used to run the regression analysis. Whenever the beta weight or path coefficient was considerably less than twice the standard error (this is a convenient test of the statistical significance of a path coefficient at the .05 level), this path was deleted and the variables were again analyzed with the remaining variables receiving new beta weight values from the analysis. (2, p. 5) This procedure was followed until the total new model (Model II) had been generated. (See Figure 3) Thus, this technique was used to establish a new model for testing. It was assumed that sex and age were exogenous variables, (i.e. they were not determined by any variables in this model).

Model II (Figure 3) became more complicated than Model I using the generator Spady, Greenwood technique. (2) Some of the theoretically supported paths, (i.e. Piaget to PAL) were no longer present. According to Model II, there is a direct path from sex to IQ, PAL, and Piaget; from age to academic achievement, IQ, reading, grade, and Piaget; from IQ to grade, reading, academic achievement, and Piaget; from grade to reading and Piaget; from academic achievement to reading and PAL, from reading to Piaget. To generate Model
Model II

Figure 3
II all of the low beta weights (standardized regression coefficient) were deleted after regression analysis and the analysis was made again without the deleted variable to obtain the new beta weights.

The observed matrix (See Table 9) was obtained by using the OSU/ECON Regression Program. (1) Also in Table 9 are the generated values obtained from the beta weights in Figure 3. The predicted matrix (Table 9) for Model II was generated from the path coefficient in Table 8 using the Heise (3) and the Spady and Greenwood (2) directions which both result in identical values. However, the Spady and Greenwood equations are shorter and, thus, easier with which to work. The values from the two matrices in Table 9 were then converted to z scores which were correlated. Table 10 shows these matrices and the correlation of .93 for Model II. This is higher than the .76 obtained from Model I and indicates that Model II is a more accurate representation of the direct paths among the tested variables for sixth and seventh graders.

Analysis of the Findings

Path analysis was the statistical technique used for estimating the magnitudes of the direct and indirect effects of certain variables on others. Model I was designed using time ordered and theoretical factors for a network of paths among the variables illustrating direct paths for certain
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<td>.80</td>
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<td>Reading</td>
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<td>0</td>
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<td>0</td>
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*\textit{r}_{12} = .347
Table 9

Predicted Correlation Matrix for Model II

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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>.2245</td>
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<td>.1358</td>
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<td>.1253</td>
<td>.2567</td>
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<td>.0841</td>
<td>.7532</td>
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<td>Reading</td>
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### Table 10

Predicted and Observed z Scores for Model II

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<th>3</th>
<th>4</th>
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<tbody>
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<td>.228</td>
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<td>Age</td>
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<td>IQ</td>
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<td>.136</td>
<td>1</td>
<td>.240</td>
<td>.539</td>
<td>.126</td>
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<tr>
<td>Pre-</td>
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<td>.122</td>
<td>.084</td>
<td>.977</td>
<td>.279</td>
<td>1</td>
<td>.814</td>
<td>.190</td>
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<td>A.A.</td>
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<td>.127</td>
<td>.156</td>
<td>.669</td>
<td>.593</td>
<td>.812</td>
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<td>.203</td>
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<tr>
<td>Reading</td>
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<td>-.271</td>
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<td>.363</td>
<td>-.004</td>
<td>.296</td>
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<td>1</td>
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<td>Piaget</td>
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<td>.694</td>
<td>.174</td>
<td>1.05</td>
<td>.576</td>
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</table>

Correlation = .93
variables. The correlation for the observed and predicted matrices of Model I was .76 and it was inferred that a new model could be identified that would explain more effectively the direct effects than were explained by the paths of Model I.

Model II, using the technique for establishing direct paths explained earlier, is a more complex structure with additional direct paths as well as deleted paths. The .05 level of significance was used to retain, delete, or add significant paths.

The comparison between the predicted matrix and the observed matrix of Model I produced a correlation of .76. A comparison between the observed and predicted matrices yielded a correlation of .93 for Model II. Model II is, therefore, a more satisfactory model to use to explain the relationship among the variables than Model I. Thus, Model II has been used to analyze the null hypotheses:

1. The null hypothesis—Piagetian tests have no direct or indirect effect on the PAL scores was accepted. Model I had a theorized direct path from Piagetian tests to the PAL scores but due to the insignificant beta weight, it was deleted for Model II which indicated that a direct path should not exist. The diagram also shows that an indirect does not exist from Piaget through other variables to the PAL scores.

2. The null hypothesis—academic achievement has no
direct effect on the PAL scores was rejected. There is a strong direct path of .81 from academic achievement to the PAL scores. There are no indirect effects from academic achievement through other variables to the PAL variable so the second part of the null hypothesis, that academic achievement has no indirect effect on the PAL scores was accepted.

3. The null hypothesis—that academic achievement has no direct effect on the Piagetian scores was accepted as Model II showed that there is no direct path. The null hypothesis that academic achievement has no indirect effect on the Piagetian scores was rejected since there is an indirect path from academic achievement through reading to the Piagetian variable.

4. The null hypothesis—that grade has no direct effect on the Piagetian scores was rejected as there is a direct path from the variable, grade level. The null hypothesis concerning the indirect effect was also rejected as grade level has a direct path to reading which has a direct path to the Piagetian scores.

5. The null hypothesis—that grade has no direct or indirect effect on the PAL scores was accepted as there are no direct nor indirect paths from the variable grade level to the PAL scores.

6. The null hypothesis—reading has no direct effect on the Piagetian scores was rejected as there is a direct path of .11 from reading to the Piagetian scores. The null
hypothesis that reading has no indirect effect was accepted.

7. The null hypothesis—reading has no direct or indirect effect on PAL scores was accepted as there are no direct or indirect paths.

8. The null hypothesis—IQ has no direct effect on reading, grade, or academic achievement was rejected because there are direct paths from IQ to each of these variables. The null hypothesis that IQ has no indirect effect was accepted for academic achievement and grade but was rejected for reading since IQ has an indirect effect on reading through the grade level variable and the academic achievement variable.

9. Both the null hypothesis—IQ has no direct effect on Piagetian scores and the null hypothesis that IQ has no direct effect on PAL scores were rejected. The null hypothesis that IQ has no indirect effect on the Piagetian or PAL scores was rejected. IQ has an indirect effect on the PAL scores through academic achievement, reading and the grade variables.

10. The null hypothesis—sex has no direct effect on IQ was rejected as there is a direct path from sex to the IQ variable. There is no indirect effect from the sex variable to IQ; therefore, that part of the hypothesis was accepted.

11. The null hypothesis—sex has no direct or indirect effect on reading, grade level, academic achievement, Piagetian tests, and PAL scores. The null hypothesis that
sex has no direct effect on Piagetian or PAL scores was rejected as there are direct paths to these two variables. The hypothesis that sex has no direct effect on reading, grade level and academic achievement was accepted. The hypothesis that sex has no indirect effect on Piagetian tests, PAL scores, reading, grade level and academic achievement was rejected. The sex variable has an indirect effect on Piagetian scores through IQ, grade, and reading. Sex has an indirect effect on PAL scores by passing through the two variables IQ and academic achievement. Sex has an indirect effect on reading, academic achievement and grade level through the IQ variable.

12. The null hypothesis—age has no direct or indirect effect on IQ was rejected since it has a direct effect on IQ. There are no indirect effects; therefore, that aspect of the hypothesis was accepted.

13. The null hypothesis—age has no direct or indirect effect on reading, grade level, academic achievement, Piagetian tests and PAL scores. The null hypothesis that age has no direct effect on grade level, reading, academic achievement, and Piagetian scores was rejected due to the direct paths from age to each of these variables. The null hypothesis that age has no direct effect on PAL scores was accepted. The null hypothesis that age has no indirect effect on reading, grade level, academic achievement, Piagetian tests or PAL scores was rejected. Age has an
indirect effect on reading through both IQ or grade, on grade level through IQ, on academic achievement through IQ, on Piagetian tests through grade level, and on the PAL scores through academic achievement.

**Summary**

With the deletion of certain nonsignificant paths and the addition of other significant paths a new model (Model II) was established and tested. Since Model II had a high .93 correlation, it was used to accept or reject the null hypotheses. During the evaluation of Model II using a step-wise regression program, the significance level of .05 was established to determine whether a path was significant. Model II became more complex in structure than Model I but some paths which were hypothesized as being important in Model I were deleted while additional significant paths were identified and added to the structure. The resulting .93 correlation for Model II indicated that the deletion and addition decisions were mathematically accurate.

The dependent variables in Model II can be viewed in terms of the percentage of the variance that was explained by the independent variables. (See Table 11) Only 10% of the variance for IQ was explained by the variables age and sex. A beta weight of .13 represented the sex variable and -.24 the age variable. Both of these are low but still significant beta weights resulting in direct paths. Other
Table 11

Dependent Variables for Model II

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Percentage of Variance Explained by the Independent Variables</th>
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<td>IQ</td>
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<td>Grade Level</td>
<td>63%</td>
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<tr>
<td>Academic Achievement</td>
<td>59%</td>
</tr>
<tr>
<td>Reading Level</td>
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</tr>
<tr>
<td>Piagetian Tasks</td>
<td>27%</td>
</tr>
<tr>
<td>PAL Scores</td>
<td>59%</td>
</tr>
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</table>
unidentified variables are definitely necessary before the IQ variable can be explained. Sixty-three percent of the variance for grade level was explained by IQ and age. Age is a more important variable with a beta weight of .74 as opposed to .28 for IQ. This is easy to explain since most pupils are placed in a grade according to age. The variance of academic achievement was explained by a 59%. IQ and age were the two independent variables explaining the variance. Age has a beta weight of .24 and IQ one of .80. IQ is an important explanation for academic achievement. Sixty-one percent of the variance for reading was explained by four variables, i.e. grade, age, IQ, and academic achievement. The beta weights for these variables were: (a) IQ -.13, (b) academic achievement .44, (c) age .14, (d) grade .56. Grade level and academic achievement were very significant factors in explaining the reading scores. Only 27% of the variance was explained by the five direct paths leading from the independent variables to the dependent variable, Piagetian scores. The beta weights for the independent variables were: (a) age .16, (b) grade -.23, (c) IQ .39, (d) reading .11 and (e) sex -.37. Sex and IQ seem to be strong predictors of how well pupils will do on Piagetian tasks. However, some important variables are missing as only 27% of the variance was explained. Fifty-nine percent of the PAL Scale variance was explained by two variables, i.e. sex with a beta weight of -.18 and academic achievement
with a powerful beta weight of .81.

It is quite evident that with the Piagetian scores it is important to consider many variables, of which only five have been identified in this study. With propositional thinking and experimentation a large amount of the variance is explained primarily by academic achievement but sex also has a direct effect. These findings should be of interest to teachers with sixth and seventh graders. However, readers must be careful to note that other unidentified independent variables are very important especially to the dependent Piagetian variable since only 27% of the variance has been explained by this model.
Bibliography

1. Cunnygham, Jon. "OSU/ECON Regression Program," Data Center, College of Administrative Science, Ohio State University, October 1969, 22 pages. (Mimeographed)


CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS,
AND RECOMMENDATIONS FOR FURTHER RESEARCH

Summary

This study was designed to develop an instrument to diagnose sixth and seventh grader's levels of propositional or abstract thinking as defined by Piaget (1), Stendler (2), and Kuslan and Stone (3) using computer simulated experiments (CSE). The second aspect of the study was to identify the direct and indirect effects among the variables reading, IQ, age, sex, grade, academic achievement, Piagetian tests, and PAL (Propositional/Abstract Level) scores, in order to develop a model to illustrate these effects.

Two models were developed as part of this study. Model I was structured to coincide with time order and theoretical considerations. Model II was evolved, after the testing of Model I, to demonstrate more accurately the direct and indirect effects. (See Figures 2 and 3) Path analysis was utilized to determine the most effective model. (4,5)

Sixty-two sixth and seventh graders enrolled in the Dublin, Ohio elementary and junior high schools participated for ten weeks in this study. Each of the students conducted
three computer simulated experiments (CSE) which were analyzed and scored using the Propositional/Abstract Scale (PAL) developed specifically for this purpose. A total of 186 computer simulated experiments were analyzed using this scale. The reliability and the validity of this instrument were established using statistical techniques.

Data were collected on each of the eight variables from all of the 62 subjects. These data were utilized to test a theoretical model designed to illustrate the direct and indirect effects of the variables. Model I was designed on the basis of a time-ordered and theoretical sequence. The model was tested by path analysis as described by Spady and Greenwood (4) and Heise (5). A predicted and observed matrix was determined for Model I and they were correlated. The results of .76 indicated that a more effective model could be developed. Model II was developed using the Spady and Greenwood (4) and Heise (5) instructions and the correlation indicated that the mathematical adequacy of Model II was .93, a more accurate model than the first one. Model II was then used to accept or reject the null hypotheses at the .05 level of significance.

The value of this study is threefold. The sixth and seventh graders can use the computer simulated experiments to conduct science investigations successfully. The PAL Scale can be used by teachers to diagnose and evaluate their students' computer simulated experiments to determine how
well they are functioning in the area of propositional thinking. This evaluative instrument can assist teachers in making periodic checks on pupil progress in this area and also evaluate whether the prescribed experiences the teacher has been providing is actually helping the pupils to make progress. Model II is the third contribution made by this study as it has identified the direct and indirect effects for sixth and seventh graders for eight variables. This model makes it evident that multiple variables are operating which in turn influence other variables. This should alert educators to the fact that the cause of behavior is multiple and complex and simple solutions are usually not found to complex problems of teaching. Model II provides some interesting information concerning the direct effects of eight variables for sixth and seventh graders. But, most of all, Model II provides many fruitful ideas for additional research which are necessary for teacher and pupil effectiveness in this area. Implications for further research are discussed at the end of this chapter.

Conclusions

An analysis of Model II was made and the following conclusions were identified based on Model II and the .05 level of significance:

1. Using path analysis Piagetian tests have no direct or indirect effect on the PAL scores of sixth and seventh
2. Using path analysis academic achievement has a direct effect on the PAL scores for sixth and seventh graders.

3. Using path analysis academic achievement has an indirect effect on the Piagetian scores for sixth and seventh graders.

4. Using path analysis grade level has a direct effect on the Piagetian scores for sixth and seventh graders.

5. Using path analysis grade has no direct or indirect effect on the PAL scores for sixth and seventh graders.

6. Using path analysis reading has a direct effect on the Piagetian scores of sixth and seventh graders.

7. Using path analysis reading has no direct or indirect effect on the PAL scores of sixth and seventh graders.

8. Using path analysis IQ has a direct effect on reading, and the Piagetian tests for sixth and seventh graders.

9. Using path analysis IQ has an indirect effect through academic achievement on the PAL scores for sixth and seventh graders.

10. Using path analysis sex has a direct effect on IQ, the PAL scores and Piagetian tests for sixth and seventh graders.

11. Using path analysis sex has an indirect effect on reading, grade level, and academic achievement through the variable IQ for sixth and seventh graders.
12. Using path analysis age has a direct effect on IQ, grade level, reading, academic achievement, and Piagetian scores for sixth and seventh graders.

13. Using path analysis age has an indirect effect on the PAL scores through the variable academic achievement for sixth and seventh graders.

**Implications**

In reviewing the Piagetian studies for this research, the developmental theory of Piaget was consistently supported. However, the research necessary for implementation of Piagetian theory into educational practice reflected many inconsistencies. The research concerning the training of pupils to function at certain levels indicated that sometimes it was successful while other research indicated that it was unsuccessful. Attempts to answer the question concerning the possibility of acceleration of pupils through various levels also shows inconsistent and conflicting conclusions. The unresolved research questions and the resulting conflict concerning the research conducted in this area suggests that many variables affect the developmental levels of children and that as they mature, the variables become more numerous and/or complex. Piagetian theory indicates that children should progress from one level to another at their own rate. This theory does not indicate which variables might enhance or restrict the developmental
progress. Whenever there are repeated inconsistencies in the research findings of statistical studies, statisticians suggest that there probably are crucial variables that are not being considered which are influencing the outcome of the various studies. Path analysis is an important statistical technique to use as a test for significant variables. It is also important since it provides the research with an estimate of the percentage of the variance explained by the variables and also provides an estimate of the percentage missing due to the lack of other significant variables. (2,3)

In this study a close look was taken, using path analysis at some academic/intellectual variables which have been identified as being important in the school curriculum. Each dependent variable was held constant while the independent variables were analyzed with a regression equation. The resulting significant beta weights were identified and Model I was tested using the observed matrix and predicted matrix to obtain a correlation of .75. Model II was evolved and tested with a resulting correlation of .93. Thus, Model II was identified as being more accurate in describing the direct effects of the variables than Model I. Therefore, Model II was accepted, the null hypotheses analyzed, and alternative hypotheses in the form of conclusions were drawn. The implications of this study are discussed in the following paragraphs. Model II was used for the analysis in order to derive implications for this study.
In Model II the first dependent variable is IQ with sex and age as the independent variables with direct paths to IQ. Both of the path coefficients are moderate in magnitude indicating that there are direct paths but neither variable can be considered powerful. The path from age to IQ suggests that the younger pupils tended to have the higher IQ scores. The independent sex variable indicated that the girls in this study had higher IQ scores than the boys. Teachers need to be aware of the IQ difference between boys and girls. More research must be conducted in this arena. Waetjen (6) found in his research that boys are different from girls in their thought patterns as well as other categories. Teachers must be aware that the variable sex is important in the total learning process. However, research concerning the sex variable that was gaining in popularity in the early sixties is not being pursued as diligently as it should be since very little is known about these learning differences in the area of cognition.

The next dependent variable in Figure 3 Model II is grade with two direct paths to it. One is from IQ with a path coefficient of moderate magnitude and one from age which is of powerful magnitude. The age variable indicates that the older children are found in grade seven which will be no surprise to educators. The IQ path to grade of moderate magnitude indicates that the pupils in grade seven have slightly higher IQ scores than the pupils in grade six. In
looking back at the age to IQ information it can be inferred that the highest IQ scores in the seventh grade will be among the young pupils in that grade.

The next variable in Figure 3 is academic achievement with two direct paths. The age to academic achievement path is of moderate weight and indicates that the older pupils had received the higher academic grades. The IQ path to the dependent variable academic achievement is very powerful (.80) and indicates that IQ has a strong direct effect on academic achievement for these sixth and seventh graders. This should suggest to educators that this indicates how unfair letter grades based on pupil competition are to pupils with low IQ scores.

Dependent variable six (See Figure 3) which is reading has four direct paths from independent variables. There is a direct path of very low magnitude from age to reading indicating that the older pupils tend to read better than the younger pupils. The IQ path indicates that the brighter students tend to score higher on reading tests too. The IQ path is also of low magnitude. The seventh graders read significantly better than the sixth graders which resulted in a large beta weight of .56. Grade level is a powerful variable. Academic achievement is another important variable with a beta weight of .44 indicating that high achievers also have high reading scores.
In looking at Model II, this may be a result of mainly age and grade level instead of the curriculum or it may be the influence of age, IQ, and grade level since age and IQ also directly effect academic achievement. If it is these three variables then teachers and the curriculum have only a limited influence for sixth and seventh graders in reading. This needs to be pursued carefully in another study also using path analysis and additional variables.

Piagetian scores is the next dependent variable in Figure 3 with five direct paths, i.e. sex, reading, IQ, grade level, and age. Age is a weak path indicating that older pupils do better with Piagetian tasks which seems to be supported by research. The sex variable indicates that the boys did better on the Piagetian tasks than the girls. The Waetjen (6) research is very crucial since this study is definitely identifying a sex difference. Teachers must be made aware of the fact that there are sex differences in the cognitive process and we know very little about these differences. Research needs to be conducted that will delve more deeply into these differences. In the meantime, teachers should be cognizant of this problem and provide a variety of instructional experiences for pupils until research indicates which experiences are the most effective for each of the two sexes. The grade level variable indicated that the sixth graders did slightly better than the seventh graders but this is a path of moderate weight. A very weak
but significant path is the reading (.11) path to Piagetian tasks. Students who scored high on the reading test were also high on the Piagetian task scores. Reading which is developmental is related to Piagetian scores for sixth and seventh graders. The last path in this category is the one from IQ to the Piagetian variable with a strong path of .39 indicating that the pupils with high IQ's tended to obtain high scores on their Piagetian tasks. Even though .39 is of large magnitude, it must be kept in mind that only 27% of the variance has been accounted for in this model. Researchers need to keep in mind other possibilities which are listed in the further research section. IQ has been an important predictor in Model II, for success in academic achievement, reading, and Piagetian tasks for sixth and seventh graders.

The last dependent variable in Model II is the PAL scores. Only two direct paths were identified for this variable. Both of them were a surprise to the writer since neither of them came from the Piagetian tasks. There is no direct path from the Piagetian tasks to the PAL scale indicating that there is no direct path for these sixth and seventh graders. Also there is no path from the PAL variable to the Piaget variable. Neither of these tested paths were significant at the .05 level, although both were investigated. There is a path from sex to the PAL variable indicating that boys were higher than the girls. This is
an interesting finding since it is also true for the Piagetian tasks. Thus, this sex related variable is an important one for teachers and researchers to consider carefully when selecting curricular materials for sixth and seventh graders. Perhaps boys and girls need some instructional time in science that is separate or they may simply need different instructional materials. Future research is imperative here. Academic achievement also has a direct path to the PAL variable of .81. This is a powerful path of large magnitude. Not only is the magnitude important but the fact that 59% of the variance for PAL is explained by these two variables illustrates even more emphatically their importance. This suggests that whatever the schools do to obtain high academic achievement from certain pupils is also influencing their performance in the area of propositional thinking. Further research is very important here.

Throughout this entire discussion the importance of further research has continually been mentioned but this is very important since path analysis of a model illustrates relationships which are difficult to view using other statistical treatments. It is crucial that the final model not only be discussed in terms of the findings but also in terms of additional research.

Further Research

This study has provoked more questions than it has
explored and many studies need to be conducted to expand this study. Below are listed a few of the questions which should be researched.

1. What is the relationship of the socio-economic variable to Model II?

2. Is self concept an important factor for success in propositional thinking?

3. What additional variables, besides the ones explored, affect the PAL scores?

4. What additional variables, besides the ones explored, affect the Piagetian scores?

5. Would a duplicate model result if new samples of sixth and seventh graders were randomly selected? This type of replication is very important.

6. Using the same variables, would younger pupils produce a similar model or is Model II unique for sixth and seventh graders?

7. What is the lower age limit for children to complete successfully the computer simulated experiments?

8. Can the PAL Scale be used in conjunction with computer simulated experiments and a variety of propositional thinking experiences to accelerate learning in this area?

9. Can computer simulated experiments be used to raise a pupil's level of propositional thinking?

10. Can a PAL Scale be developed that will make even finer distinctions for students in the three categories,
i.e. hypothesizing, data collection and synthesizing?

11. If CSE were used with inservice and preservice teachers prior to their teaching ESS, AAAS, SCIS or any of the other new curricular programs, would their attitudes toward science be changed?

12. Using CSE develop a method for quantifying the processes as defined by the AAAS program. Does the hypothesizing skill rely on the skills of inferring, predicting, etc.?

13. Would the use of CSE with a AAAS program help the student achieve the integrated process skills more effectively than a AAAS program without CSE?

14. Would the use of CSE with the SCIS program reinforce the objectives of the SCIS program?

15. Does extensive CSE training help to raise an individual's reading level?

16. Using appropriate statistical techniques, what is the relationship of the various components of the reading process to the Piagetian scores?

17. Will training and improvement in reading improve pupil's scores on the Piagetian tasks?

18. Does an individual's status in his peer group affect his PAL scores?

19. Does an individual's status in his peer group affect his Piagetian scores?

20. How does the learning of boys differ from the
learning of girls in computer simulated experiments?

21. Compare the use of CSE with coeducational classes and classes of only boys and only girls. Is there a difference?

22. With the Rosenfeld research on teacher attitude as a base, does the teacher's attitude toward pupils affect their Piagetian scores?

23. Does teacher attitude toward pupils affect their level of propositional thinking?

24. Will adults who are weak in the area of propositional thinking show significant growth after being trained with computer simulated experiments?

25. Will CSE exposure affect the scientific literacy of these adults? Their attitudes?

26. How would sixth and seventh graders' results of the Island's test developed by Karplus (7) fit into Model II?

27. What is the relationship between components of the PAL Scale and components in critical thinking?

28. Are computer simulated experiments as effective for learning purposes as conventional experiences?

29. Do the earlier experiences children have that help them to assimilate and to accommodate, influence their performance in sixth and seventh grades on the Piagetian tasks and CSE?

In conclusion it must be said that this study is a preliminary one to many that need to be pursued. Path analysis
allows educators to look at multiple variables and their relationships. It is in many ways like looking at the whole child which is essential if important questions are to be answered. The PAL Scale provides a diagnostic tool while computer simulated experiments provide a method for conducting an investigation where much of the laboratory difficulties can be eliminated for the purpose of research. A model has been generated for sixth and seventh graders using propositional thinking. This is only the first step.
Bibliography


APPENDIX I
SIMULATED EXPERIMENT

Topic: Maze Learning by Rodents

Background:

One way of studying learning is to observe an animal's behavior in a maze. Even humans have been studied this way.

The objective of the animal in the maze is to get from a beginning point to a goal (Point X to point 0 in Figure 1). The animal is usually rewarded when it gets to the goal.

In this experiment, four different kinds of animals may be used. There are many kinds of mazes but the kind used in this experiment is a T-maze like the one shown in Figure 1.

Assumed Conditions:

1. Animals are hungry at beginning of each trial.
2. Food is provided at the end of each trial.
3. Successive trials are at one-day intervals.
4. All trials in a given series are with the same animal.
5. Repeated trials are with inexperienced animals.
6. Temperature, light intensity, and other environmental variables are constant for all trials.

Controllable Variables:

A = kind of animal (1=hamster, 2=rat, 3=mouse, 4=gerbil)
M = number of T's in maze
N = number of trial with this animal

Readout:

A, M, N, time to complete maze (seconds), number of errors or wrong turns made by the animal

Experiment Code:

MAZLEM

Data Input:

700, A, M, N

Series H
5/11/70 VS
SIMULATED EXPERIMENT

Topic: Temperature and Salinity of Ocean Water

Background: Two characteristics of ocean water that are useful in studying the oceans are temperature and salinity, or saltiness. Temperature is a common characteristic and is easily measured using a thermometer.

Salinity can be measured by evaporating all the water from a sample and weighing the amount of salt left behind. In this experiment, one liter of water is evaporated and the salt weighed in milligrams. Salinity is then expressed as so many milligrams per liter.

A special sampling device is used to get a sample of water from any depth and bring it up to a ship where tests can be made.

In this experiment, there are three stations in the Atlantic Ocean where samples can be taken. The locations of these stations are shown in Figure 1.

Samples can be taken in January or July and from any depth. A sample from the surface would be taken from a depth of 0-meters.

Assumed Conditions:
None, other than those already mentioned.

Manipulable Variables:
- $S =$ station number
- $M =$ month ($1 =$ January, $2 =$ July)
- $D =$ depth of sample (meters)

Readout:
- $S$, $M$, $D$, temperature ($\text{degrees C.}$), salinity ($\text{mg/l}$)

Experiment Code:
NORATL

Data Input:
503, $S$, $M$, $D$

Figure 1 - Seawater sampling stations in Atlantic Ocean.

Series H
5/8/70 VS
SIMULATED EXPERIMENT

Topic: Paramecium Population in a Closed System

Background:
Paramecium are one celled animals that live in water. They are barely large enough to be seen by the unaided eye.

Paramecium can live and reproduce in water in which lettuce has been boiled. This boiled and cooled solution is called a culture medium.

In this experiment, a measured amount of liquid in which paramecium are living is put into a measured amount of culture medium. The liquid containing the original paramecium is called an innoculant. The combined liquids are placed in a flask which is closed with a loose fitting cork.

At any time after the experiment starts, the flask can be opened and some of the liquid taken out with a medicine dropper. One drop of the liquid is placed on a microscope slide and the number of paramecium in the drop are counted.

Assumed Conditions:
1. Volume of culture flask is 1000-ml.
2. Innoculant is a pure culture of Paramecium Aurelia.
3. Temperature is 25°C.
4. Sufficient oxygen is always available for the paramecium.
5. All other environmental variables, except those listed below are constant throughout the experiment.

Manipulable Variables:
V = Volume of culture medium (ml).
I = Volume of innoculant (ml).
T = Time after innoculation (days).

Readout:
V, I, T, Number of paramecium in one-drop sample.

Experiment Code:
PARP0P

Data Input:
900, V, I, T
APPENDIX II
Program Retrieval Instructions

1. Dial on the telephone dial
   1-216-881-6620

2. Give operator number on telephone

3. Push control button, listen for ring, answer and
   high pitched short signal which indicates connection.

4. Return carriage twice
   Computer types - SIGN ON

5. Type ID (space) Type 59, Depress control key, type ZSU
   (ZSU won't print on print-out sheet)
   Press return

6. Type create, (space) Name (no more than 5 letters)
   Return

7. Type Half

8. Type Create (space) Name

9. Computer types Begin

   Noratl - Type # of station 1 or 2 or 3
   Type Month 1 = January or 2 = July
   Type Depth in meters

   For more than one experiment continue typing data.

10. Type 2 returns

11. Type Basic Noratl

12. Computer types Run, Define File
13. \( l = \) (Type Name - Susan, Sam, etc.)
14. To conduct another experiment type
   Basic Noratl
15. Type \( l = \text{Name} \)
APPENDIX III
BEGIN
400,4,100,6,2,6,5,3,100,6,4,4,2,3,5,8,1,11,100,2,5,2000,4,7,9
500,3,9,10,3,500,4

?BASIC MAZLER
RUN
DEFINE FILE
1=DIAN
FILE DEF ERROR
DEFINE FILE
1=DEAN

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RUN
DEFINE FILE
1=TA

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<th>NUMBER OF ERRORS</th>
<th>NUMBER OF T'S IN MAZE</th>
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</thead>
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</table>

END OF DATA

1210 EXIT
Plaketen Task Administration Instrument
Science Education Dept. Colorado State College
Greeley, Colorado

Interviewer ____________________________ Child ____________________________ Sex M F
Date ____________________________ Age ____________________________
School ____________________________ Grade ____________________________

TO THE INTERVIEWER: Following each task there is a box to be used for evaluating the task. If the child has performed the task in a manner that would be correct to an adult's mind, i.e., the child was able to conserve mass or a liquid, this is indicated by placing a + (plus) in the box. If the child indicates an incorrect response, place an O (zero) in the box. These will be tallied at the end of this interview sheet.

Experiment 1 - Conservation of Quantity

Present the child with a ball of clay. Ask the child to observe it. Then roll the clay into a long cylinder. Ask - "Does the snake have less, more, or the same amount of clay as the ball?" (If the child is confused say, "Was the ball bigger, smaller, or the same size as the snake?")

RESPONSE
LESS MORE SAME

JUSTIFICATION - Ask the child, "Why do you think the snake was (bigger, smaller, or the same)?"

TASK 2

Experiment 2 - Conservation of Liquid Volume

Use two jars (a baby food jar and a tall cylinder) and enough colored water to fill the tall jar. Present the jars with the water in the short jar. Ask - "What will happen if I pour the water into the tall jar? Will I have more, less, or the same amount of water?"

RESPONSE
MORE LESS SAME

Pour the water into the jar. Ask - "What happened to the amount of water? Is there less, more, or the same amount?"

RESPONSE
LESS MORE SAME
Task 2

JUSTIFICATION - Ask the child, "Why do you think the amount of water was (more, less, the same)?"

Experiment 3 - Conceptualization of water level

Ask the child to look at the drawing of the jar. Tell the child the jar has water in it. (Point to water) Also tell him the jar is plugged. (Point to plug) Ask, "If the jar were tipped as you see in this picture, how would the water look? Make a line with your pencil showing how the water would look."

JUSTIFICATION - Ask the child, "Why do you think the water will look like that?"

Task 3

Experiment 4 - Ordering Events

Say, "For this problem, you will think about how a pencil falls. This is what I mean: (place a pencil in a vertical position and allow it to fall to a horizontal position on the desk). Here are some drawings of the pencil falling. Place them in order showing how the pencil would look as it falls."

JUSTIFICATION - Ask the child, "Why did you place the pictures in the order you did?"

Task 4

Experiment 5 - Displacement by Volume

Use a tall cylinder three quarters (3/4) full of colored water and two metal blocks of the same size (volume) but different weights.

Tell the child to compare the weights of the two blocks. Hand him the blocks and ask, "Which is heavier?"

Say, "If I take the light weight block and lower it into the water, what will happen to the level of the water?"
RESPONSE  HIGHER  LOWER  SAME

Ask the child, "Place the rubber band around the cylinder at the level you think the water will move to." You may wish to aid the child by holding the cylinder or helping with the rubber band.

Gently lower the block into the water and observe. If necessary, move the rubber band to the level of the water at this point. Then remove the block.

Ask the child, "Where do you think the level of the water will be when the heavier block is lowered into the cylinder? Will the water level for the heavier block be lower, higher, or the same as the water level for the lighter block?"

RESPONSE  LOWER  HIGHER  SAME

JUSTIFICATION - Ask, "Why do you think this will happen?"

Lower the heavier block into the cylinder and observe. List the child's comments about result.

Experiment 6 - Conservation of Length

Use a complete and a sectioned straw. Start both straws lined up parallel. Note with the child that both straws are the same length. Ask, "Would two ants starting a hike at this end of the straw (point to one end) and walking at the same speed both finish the hike at this point (point to other end of straw) at the same time?" (If the child is confused, ask, "Would they both travel the same distance?")

RESPONSE  YES  NO

Now move the whole straw into this position.

Ask the same question.

RESPONSE  YES  NO

JUSTIFICATION - "Why do you think so?"
Now move the straws into this position.

Ask the same question.

RESPONSE

YES  NO

JUSTIFICATION - "Why do you think so?"

**Experiment 7 - Conservation of Area**

Present the child with two identical pieces of green construction paper. Tell him these represent fields or pastures. Place one animal on each piece of paper.

Ask the child to compare the fields noting they are the same size. Comment that since the fields are the same size each animal will have the same amount of grass to eat. Tell the child you are going to use stoppers to represent barns.

Place four barns on each field as shown. (Leave the animals on the field)

```
A - CLUSTERED BARS  B - BARS SPREAD OUT
```

Ask, "Now which animal will have the most grass to eat or will the amount of grass be the same?"

RESPONSE

Field A  Field B  Same

JUSTIFICATION - "Why do you think this is true?"

Continue adding equal numbers of barns to each field. Each time repeat the question, "Which animal will have the most grass to eat?"
### SUMMARY AND ANALYSIS OF TASKS

<table>
<thead>
<tr>
<th>Task</th>
<th>Evaluation of Task</th>
<th>Cognitive Level</th>
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</tr>
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<td></td>
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<tr>
<td>TASK 4</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TASK 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At which level of cognitive development would you place this child? (0-2 tasks performed - pre-operational; 3-6 - transitional; 7-8 concrete-operational)

- [ ] Pre-operational
- [ ] Transitional
- [ ] Concrete-operational

Additional comments or observations:
I. Hypothesis

A. Statement Quality

3 Clearly stated, testable, easy to understand, improvement in statement would be difficult. Both dependent variables are mentioned.

2 Can understand hypothesis but not as clear as it could be, hypothesis is testable.

1 No hypothesis or hypothesis cannot be used to investigate CSE, hypothesis very difficult to test due to confusion in hypothesis statement.

B. Identification of Variables

3 Hypothesis statement included all dependent variables that could be used in the CSE.

2 Hypothesis statement included part of potential variables. Hypothesis did not include possible CSE variables or included additional variables which cannot be used for investigation.
II. Data

A. Hypothesis

3 Data is related to the hypothesis in a careful, excellent way.

2 Data begins to be related to hypothesis but some errors or weaknesses noted, i.e., replication missing.

1 Data is not related to the hypothesis; or related to the hypothesis in a vague way. Additional data requested which is unrelated. Variables not controlled.

B. Interpretation or Synthesis

3 Data collection carefully designed, can be analyzed for an excellent and accurate conclusion or interpretation.

2 Data collection not carefully planned, some weaknesses such as additional unrelated data but possibility for accurate conclusion or interpretation; no replication.

1 Data collection was not carefully designed, accurate conclusion or interpretation not possible when using data.
III. Interpretation of Data or Synthesis

A. Hypothesis

3 Conclusion is drawn from hypothesis, precisely from required, relevant data.

2 Conclusion is drawn from hypothesis but not all the consideration given to data, weak; perhaps due to deficient data base or quantity of data too extensive.

1 Conclusion is drawn from hypothesis with no regard to data, or answers a different hypothesis.

B. Data

3 Conclusion drawn from data which has been carefully analyzed and conclusion shows this.

2 Conclusion drawn from data. Data weaknesses create limited relationship between hypothesis and data, no replication.

1 Conclusion drawn from data, incorrectly or not very objectively. Perhaps error due to lack of replication in data, inaccurate data collection requests from which accurate conclusion is not possible.
APPENDIX VI
CONDUCTING SCIENCE INVESTIGATIONS USING COMPUTER SIMULATED EXPERIMENTS

Victor M. Showalter

Probably every science teacher in the United States believes that electronic digital computers will be of major importance in science education some day. In fact, individuals who have worked with computers in the direct instruction of students quickly agree that the potential value of the computer as an educational tool seems to be infinite. More specifically, the computer offers the only presently feasible mode of truly individualized instruction. [30]

However, the reality of a computer in every classroom remains, in general, an elusive goal. There are two factors that are responsible for the slowness in utilizing the educational potential of computers. The first is the high cost involved, and the second is a lack of appropriate software (i.e., programs to direct the computer in its interaction with the individual student). The magnitude of these factors is unduly large because of the limited ways educators have attempted to use computers in instruction.

The principal purpose of this paper is to propose a technique of using the digital computer in science instruction which may well obviate the constraints of unreasonable cost and demand for complex and extensive software. This proposed mode of capitalizing on the instructional potential of the computer (via shared-time terminals) has been given preliminary field testing in my efforts with students in grades 6 to 12. The results from these necessarily limited tests have been encouraging.

I have found it convenient to call the proposed technique Computer Simulated Experimentation (CSE) although the label is not fully descriptive. It would be more accurate, though less convenient, to refer to the technique as "Teaching Science Through Inquiry Using Computer Simulated Experiments." Description of the CSE technique in science instruction, an assortment of observations gathered during early development of the technique, and projections for further development constitute the major portion of this paper.

Computers are used in instructional programs in two distinctly different ways. In one, "The primary function of the computer is to assist the teacher and student in planning instructional sequences." [6] This use is referred to as Computer Managed Instruction (CMI).

The second way of using the computer is usually referred to as Computer Assisted Instruction (CAI). In this application, the computer is used as a direct means of instruction. CSE is of the CAI type.

CAI has been conveniently subdivided into three categories [19]: (a) drill and practice, (b) tutorial (i.e., programmed instruction), (c) dialogue.

The first two categories have received the major attention of educators to date [8] although cost has restricted classroom use to well-funded research projects. Little has been done with the dialogue category, although it is most promising because the user feels a greater personal involvement. CSE is a subset of the dialogue category.

Two other categories, computational and animation, have been used in science instruction, though both, with few exceptions [9], have been limited to college level work. [10, 11, 22] The three categories are generally self-descriptive, and they have been explained elsewhere. [8, 18, 19]

Application of the three basic techniques has not been limited to science instruction.
instruction. An interesting form of the dialogue technique has been used to teach economics principles to high school students by way of a computer-based game in which the learner is a player. [22]

With the possible exception of the game format, CSE techniques have been teacher centered. That is, the student is forced into preconceived patterns in which each individual is expected to arrive at more or less the same preconceived end-point. The learner himself in these formats typically makes no decisions in the learning process except to turn on the machine and to write, type, or otherwise indicate what he thinks the machine has in mind.

CSE, by contrast, enables learners to make a relatively large number of real decisions when the technique is used in a genuine inquiry approach. Thus, CSE opens a new arena for CAI.

What little work has been done using computer simulation techniques in science instruction has been concentrated at upper college levels and has been limited to physics and chemistry topics. [1, 10, 12, 14, 18] Several relatively recent publications devoted to CSE have overlooked completely the educational potential of simulation techniques. [5, 7, 8, 9, 11] Comprehensive reviews of research done during the past decade on instructional procedures in elementary and secondary school science report no studies on instruction using computer simulation. [15, 16, 17]

The CSE technique reported in this paper may well be the first directed to upper elementary and high school students and to include all sciences and on an open inquiry basis.

ONLY two components are needed for an individual to conduct CSE: (a) a digital computer and (b) a program.

Access to a computer is readily obtained through a shared-time terminal. The terminal itself is a teletypewriter (See Figure 1) connected by telephone to the computer and its accessory components. The shared-time arrangement enables upwards of 50 different users to use the computer on a nearly simultaneous basis.

It is not necessary to understand the inner workings of the computer hardware to use it. For all practical purposes it is a functioning "black box," as are telephones and automobile engines for most people. The mechanics of using the teletypewriter to control the computer are easily mastered by anyone who can use the hunt-and-peck system on a typewriter. All sixth-grade children I have worked with have been able to master the mechanics of operation.

The second component needed for CSE is a program, which is a series of instructions that control the computer. These instructions must be prepared in advance but, compared to programs needed for other forms of CAI, they are relatively simple to make. The program may be stored in the computer's long-term memory system for an indefinite length of time, or it may be stored on punched tape or cards and fed into the computer's short-term memory as needed.

The preparation of a CSE program demands that the writer first obtain some reliable information on the situation or phenomenon to be simulated. In the case of MAZLER (Figures 2, 3, 4), I obtained information on learning curves of rodents in mazes from several standard textbooks of experimental psychology. This information was then translated into equations which, in effect, described a composite of real research findings.

Programs are written in a "language" appropriate to the system being used. The program in Figure 2 is written in BASIC, which is almost unbelievably easy to learn. [13, 21] A more detailed description of the function of programming languages has been published elsewhere. [3] An interesting comparison of BASIC, FORTRAN, Hollerith, and PHL is available, in which each language is used in a computational format in teaching the same lesson in college level mechanics. [4]

THE student's action in conducting an investigation using CSE is very much the same as in an investigation using real experiments. The student initiates both types of investigation by stating a question or hypothesis related to a certain situation. He then designs an experimental procedure to produce data which will enable him to answer the question or test the hypothesis.

In an investigation using real experiments, the student goes to a real laboratory and manipulates apparatus to obtain the desired data. In an investigation using simulated experiments, the student manipulates a computer terminal to obtain the desired data.

Once the data have been obtained, and whether they were obtained via laboratory or computer, the succeeding phases of the investigation are the same. The student usually treats the data by computing averages, or by graphing, or by some other procedure and then comes to some conclusion regarding his original question or hypothesis.

The role of the computer in the investigation using simulated experiments is something like that of a remote laboratory technician. It conducts experiments designed by the investigator and reports the resultant data to him. One would expect data from a real laboratory assistant to contain some experimental error, just as data collected by the investigator himself would. The data obtained from simulated experiments can have this realistic characteristic if it is programmed. In fact, I have found that this realistic touch is necessary to establish and maintain the simulation.

I have tried several different approaches to introducing students to CSE. I am not certain that any one way is best once the mechanics of doing CSE are clear.

In one approach, I have described a single situation which can be simulated by the computer to the student and challenged him to answer a question which I pose. A second approach has been to describe a situation and let the student decide what question he will investigate. A third approach has been to give the student a catalog of topics that can be simulated and let him choose his topic and frame his own question.
Figure 1. General view of a computer terminal being used in a high school. The terminal itself is a teletypewriter connected by telephone to the computer and its accessory components.

Figure 2. Textbook information on the learning curves of rodents in maze formed the basis for one program called MAZLER.

Figure 3. A topic summary sheet from which the student-investigator works.

Figure 4. Experimental data from the computer in response to a student-designed series of three experiments dealing with rodent learning.
Figure 3 shows one example of a topic summary sheet that describes, for the student, a situation within which he may conduct an investigation using CSE. This particular topic summary sheet corresponds to the program shown in Figure 2.

I believe there is merit in keeping the student topic summary sheet simple enough to be limited to one duplicated page. Most of the information contained on the one illustrated is self-explanatory. The two items, “File Name” and “Input,” at the bottom of the page are used in the mechanics of making contact with the appropriate program and telling the computer the nature of the experiments that should be done.

A tentative “Guide for Conducting Science Investigations Using Computer Simulated Experiments” specifies step-by-step details and is now being tried in classrooms. Hopefully, it will get individuals started in CSE without requiring undue amounts of teacher time.

Topics for CSE like that in Figure 3 may seem overly simple at first glance. However, they can provoke a variety of questions when individuals are allowed to use them freely. The following questions are examples of those that have been asked and investigated by students who have selected the topic dealing with maze learning by rodents:

1. Are rats smarter than hamsters?
2. Do individual animals of one kind vary in their maze learning?
3. Which of the four animals is most curious?
4. Do rats ever reach a point at which they don’t learn more?
5. Do rodents forget?
6. Is learning inversely proportional to the complexity of the maze?
7. Is there a correlation between the number of errors an animal makes and the time required to run the maze?

Variants of these questions and others have also been stated as hypotheses and accepted or rejected on the basis of evidence collected from simulated experiments. The very wide range of sophistication in the questions is obvious. At this stage, there is some tentative evidence that students increase their levels of sophistication as a natural consequence of doing several investigations using CSE.

Any situation in which one or more independent variables can be considered controllable by an experimenter can lend itself to development of a computer program for CSE. A small constraint occurs in that the output of the program (i.e., experimental results) must be expressible in numbers or in a relatively small number of words. Pictures represent a possible output [14] but require expensive ancillary equipment.

Since November 1968, I have devised and tried with students of a wide age range several CSE programs. Among the situations or topics have been:

1. Maze learning by rodents.
2. Paramecium population in a closed system.
3. Rate of photosynthesis.
4. Physical characteristics of water in the Atlantic Ocean.
5. Reaction rate of magnesium in hydrochloric acid.
7. Sliding friction.

The titles do not imply the range of complexity in the situations. One of the topics contains only one controllable variable, another has eight. Any one could be modified to contain any number of controllable variables. On the basis of limited experience, it appears that many levels of complexity should be available to students working with CSE. This wide range of complexity could be within given topics as well as among many topics. There seem to be other criteria for good CSE topics:

1. Data obtained by the student really should be realistic (i.e., they should correspond to real experimental results).
2. Not all controllable variables should have a systematic effect on the data obtained (i.e., the student investigator should have the chance of pursuing what ultimately will be immutable in the general phenomenon being studied).
3. There should be an unlimited range for permitted values for each controllable variable.
4. Topics should correspond to a real incident in the investigator's experience. He should feel that he is investigating a real phenomenon.
5. Topics should go beyond that which can be done readily in the real laboratory. That is, the topics, and CSE in general, should extend, not replace, real laboratory experiences.
6. Topics should be programmed so that the investigator makes a choice of dependent variables (i.e., output) produced by the experiment as well as of values for independent variables in designing the experiment.

As with all educational innovations, CSE should not be regarded as a panacea for science education. The amount and kind of benefits to be derived from CSE depend greatly on how the technique is used and for what purposes or objectives. Many of the potential benefits of CSE are founded on the same psychological bases as are simulation games in which the learner experiences a commitment to some activity in which his personal decisions are important [2].

The potential benefits are really hypothetical at this early stage of development of CSE. The listing here is not intended to be in order of importance or probability.

1. CSE gives students and teachers access to many natural phenomena that are otherwise impossible to study directly in science classes. These phenomena may be too dangerous, too small, too large, too expensive, or too extensive in time to be feasible for ordinary school procedures.
2. CSE provides a unique vehicle for students to develop skills and strategies of inquiry. Working with a computer terminal produces a printed record of everything that is done in the exact
order in which it was done. This record provides a base for teacher-student interaction focused on the process of an investigation as well as on its results.

3. CSE offers a unique medium for educational research into the problems associated with how individuals learn to inquire and how their strategies of inquiry develop and change. The medium provides its own evaluation device and instrument.

4. CSE provides an ideal framework for individualization of science learning. Not only may students progress at their own rate, but they are subject to increased motivation.

5. CSE extends the portion of the investigation beyond that of conventional teaching and learning to inquiry and how their strategies of inquiry develop and change. The medium provides its own evaluation device and instrument.

6. CSE extends the portion of the school day available for learning beyond the time of a given class. There is a distinct possibility that lightweight portable terminals will be developed which will make any telephone an access to the computer.

7. CSE requires a minimum of software compared to other modes of CAT. This simplicity results from greatly reduced length (thus requiring smaller storage capacity) and from ease of expression in BASIC, which is easily learned (thus enabling all science teachers to construct programs).

8. CSE should enable students to develop creativity in science and to develop an interest in science beyond that of conventional techniques. CSE imposes fewer restrictions on the individual than do most laboratories in which the equipment available limits the investigation.

9. Doing CSE should provide a basis for student interest in applying computer programming and simulation to other situations.

10. CSE offers a possibility of reduced instructional costs when compared to other forms of CAT and even to "normal" instructional procedures. A fair price for a computer terminal is now about $550 per month. Assuming that 5 minutes is needed "on-line" by a student for an hour's work and there are 6 hours to the school day of which there are 31 in a month, the cost of instruction is $0.36 per student hour. It costs about $0.50 per student hour for a lecturer, assuming 24 students per class and 4 lecture hours per day at a salary for the lecturer of $1,000 per month.

11. CSE offers unlimited potential for further development and application.

- References


20. Sorps, P. "Computers in the Classroom," Ohio Schools 46:18-20; April 1967, Retracted from RF A Distance Apt. 1


