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The Effects of a Problem-Solving Strategy on the Long-Term Memory of Algorithms

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UNIVERSITY OF NORTH FLORIDA
College of Education

THE EFFECTS OF A PROBLEM-SOLVING STRATEGY
ON THE LONG-TERM MEMORY OF ALGORITHMS

by

Anne Elcan Mann

A thesis submitted to the Dept. of
Elementary and Secondary Education
in partial fulfillment of require­ments for the degree

MASTERS OF EDUCATION

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Without the help of many people, this thesis would not have been possible. The testing-treatment sequence was a joint project with Dr. Marianne Betkouski of the University of North Florida and James Cortez of The Bolles School.

Special appreciation goes to James Cortez. Without his work compiling and analyzing the statistics, none of the results of the study could have been analyzed and conclusions drawn. For both test years, he and I worked together administering the supervising of testing sessions at The Bolles School.

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Lastly, I would like to express my appreciation to Dr. Elinor Schierer for her encouragement and help in the final writing of this thesis.
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INTRODUCTION

As one goes through life, there are decisions to be made and problems to be solved at every turn. One of the purposes of education is to help prepare individuals for this decision-making. A vital part of the educational process should be related to helping individuals absorb information and concepts, retain the procedures necessary to think logically and analytically, and to be able to apply these processes to problem-solving situations in life.

It can be argued that the curriculum of the school and the methods of teaching should be studied carefully as they relate to the philosophy of education and immediate achievement scores. However, there appears to have been little attention to and testing of retention of concepts by students and their retrieval of data and processes after varying time periods. The methods of instruction used in schools as they promote student retention and application of the processes taught must be studied to give better insight into how education can best prepare the individuals to recall and use their knowledge in the future.

Some research interest has been shown recently in retention, or memory, and attempts have been made to define and measure it. Petriesky in Science 81 (Jan-Feb, 1981) has summarized three hypotheses related to the nature of memory. First, memory and learning can be the result of electrical signals within loops in the brain. These are referred to as the data bank of memory. Second, memory may also be viewed as information stored in large molecules that are broken down into smaller molecules which encode bits of information. These molecules can be compared
to DNA molecules in genetics. A third hypothesis states that memory is the result of strengthening synaptic linkage. At this point, no one knows what definition of memory might be accurate, but Petriesky indicates that a breakthrough is near.

Perhaps, the physiology of memory and recall will, some day, be fully understood. However, whatever memory may be, or whether or not we understand what happens in the human brain when memory takes place, retention of information and recall are critical if students are to be able to use their education as they cope with life.

There are three kinds of memory: iconic, short-term and long-term memory (Petriesky, 1981). Iconic memory is memory that is photographic and is total active recall lasting only a fraction of a second. Short-term memory is, according to William James, immediate awareness or, as Richard Thompson states, "... it is what you have on your mind at the moment (cited in Petriesky, 1981, p. 96)." The final form is long-term memory which involves the mind's choice. This last type is the one which, presumably, must be involved when successful learning is demonstrated.

Because of the importance of long-term memory of concepts and procedures and because of the need for the ability to retrieve data to solve problems, the relation between the method of instruction and retention-retrieval ability of students must be examined. This study was designed to approach an analysis of the nature of this relationship.

Specifically, it was conducted to answer the following question: What is the relationship between retention of algorithms for problem-solving as measured by the Test of Logical Thinking (TOLT) by ninth grade
physical science students at a college preparatory school who have been trained in control of variables, and the ability of students to apply this process to a novel problem-solving situation in Physical Science?

The population was selected from a private college preparatory school in Jacksonville, Florida, which was instructed and tested in laboratory-oriented ninth grade science classes in addition to using the TOLT Form A as an indicator, the retention and retrieval of processes were tested in problem-solving situations in the classroom and observed in the laboratory by the teacher. This teacher observation and assessment, along with the TOLT, are considered essential in attempting to understand the retention of processes by the students for future use in problem-solving.
Very little research seems to have been done in the area of long-term memory as it relates to the retrieval of information which enables a student to problem-solve in a laboratory setting. There have, however, been reports written on the values of memory, that is on the ability to retain facts and retrieve information when needed to solve an immediate problem. While looking at such memory research, though, insight can be obtained regarding the conditions which can affect and improve processes associated with the retrieval of information and the application of this process in novel situations.

An interesting study by Smith and his colleagues (October, 1979) looked at factors which interfere with the retrieval of facts. As in similar studies, subjects were given sentences to learn and were later asked to recall the information. In this way the college-age students in the study were retrieving information after its presentation. Smith (1979) referred to an earlier study (McGoode, 1942) which suggested that when facts are recalled, other facts associated with them are recalled and may interfere with the search for a solution (Smith, 1978). If this were accepted and if the facts learned about a concept can interfere with one another, the implication is that the more information which is learned, the greater the problem of retrieval. This phenomenon has been termed by Smith as the "paradox of interference."

The results of Smith's testing indicated that retrieval interference was more severe in the experiments than in real life memory situations and a possible resolution to the problem may be more frequent re-
trieval of facts. By doing this, facts would be retrieved with less interference and in a shorter period of time because problem-solving schemes would be reinforced and become more familiar.

Based on these findings, the reinforcing of information should be a vital part of the instructional process. Especially in teaching laboratory science, the reinforcing of problem-solving algorithms is necessary if students are to make the processes a part of their long-term memory. Equally as important as controlling interference and reducing retrieval time, is focusing upon student ability to develop a scheme which will enable more information to be retrieved.

The organization of material presented to the students also may have an impact on their ability to retrieve information. The recall of information seems to be made easier and enables retrieval of more facts if there is some form of organization to the random data and if the problems, which Keniston and Flavell (1979) call "targets," are identified and solved. They used subjects in grades one, three, and seven, and subjects at the college level. The individuals were not told that they were being tested for memory. Unorganized material in the form of single words was presented to each group; after a short period of time they were asked to recall the information. In retrieval, first the target had to be identified and established. The recall of information was related to the recognition of the targets, and, if the problem was not solved, it was found that other strategies must be used to recall data. The results showed that many subjects did not start out with a strategy but developed one before the solution was achieved. Both the younger and older subjects possessed the knowledge and cognitive skills
necessary to move from the rote recall of facts to a systematic approach, which in this study was alphabetical organization. There was a correlation between recall abilities and the use of the process of alphabetical organization. Those who used the organizational strategies were able to recall more terms.

A recent finding in this area was reported by Cohen of the University of Texas (cited in Begley & Carey, 1981). He indicates that some information was categorized by individuals even as young as seven months. This generalizing in infants does not seem to require language as was previously thought to be a necessity but instead takes the form of "visual averaging."

Because of the necessity for recall in reasoning, understanding the development of analogical reasoning is important in any study of long-term memory. Lenzer and others (cited in Sternberg and Nigro, 1980) found that individuals above the age of eleven could successfully perform complex analogies. Most of the work in this area of learning has involved use of verbal analogies. In their testing, Sternberg and Nigro (1980) found that analogical reasoning is not absent in elementary age children but is incomplete, with all possible relations not considered and information processed and terminated prematurely. They concluded that as the ability to reason analogically increases with age, the use of association in solving analogy problems decreases. The levels described in this experiment are in complete agreement with Piaget's development periods (Patterson, 1977).

Looking again at the process of developing reasoning and recognizing the importance of memory in the development of logical thinking, the
methods of solving problems must be considered. In processing stored information, the individual must recall related facts and experiences, moving bits of information from former categories to new groupings. This mobility of knowledge is implied by Sternberg and Nigro (1980) as they describe the process of Analogical Reasoning is not shown by their testing. Other tests done by Sternberg (1980) substantiate former results and find that there is no one strategy by which information is processed in problem-solving situations. As age increases, students are more consistent in the use of strategy for recall, but the strategy is best represented by a mixed model rather than by one single model. The mixed model of linear syllogistic reasoning referred (Sternberg, 1980) is composed of: (1) the Spiral Model, using physical arrangement of terms, (2) the Linguistic Model, using relation between terms and (3) the Algorithmic Model using the desired end result as the key to the solution of the problem.

The use of more than strategy in problem-solving is also suggested by Keniston and Flavell (1979). They indicate that a variety of strategies must be considered if a problem is not solved easily.

In considering memory, Neisser (1967) identifies several aspects of higher mental processes. First of all, he considers memory as stored information composed of traces of past mental actions. These traces are stored in the form of "crudely formed ideas" based on association. Deliberate and directed recall, which Neisser calls secondary process, is similar to forming a vision based on immediate stimuli, stored information, and wishes and expectations; the thinking involved is analogous. The secondary processes are arrived at through experience which also includes earlier processes. Lastly Neisser considers failure to recall
as similar to not seeing something in a vision or hearing what is spoken. According to Goleman (1981), it is the result of the inability to establish a frame of reference. What a person remembers depends largely on the purpose for recall, thus his motives and expectations are of the most importance. In a classroom, then, the motive and the expectation should be well established; and in this respect the experimental situations, according to Neisser (1967), are different from the situations faced in daily daily life. Neisser suggests that new situations can be presented which can be solved by the same or similar process as those previously presented.

Memory cannot be considered without briefly looking at forgetfulness. Goleman (1981) writes about the new theory of "childhood amnesia" which results from an adult's inability to think as he did as a child and from the lack of available clues that will trigger recall. This is challenging Freud's theory that forgetting is a result of repression (cited in Goleman, 1981). The average age of first memory is about three-and-a-half years and from that time on, memory increases for each successive year. According to Neisser (cited in Goleman, 1981), the schemata necessary for recall changes as man develops, thereby making retrieval of memories from earlier life difficult.

How much a person can remember depends, according to Pascual-Leone (cited in Goleman, 1981), on the size of his "mental space." The complexity of his thoughts depends on his ability to bring into attention varying numbers of bits of information at one time. According to commonly used psychological tests, the average adult can contain about seven bits.

Two types of recall are advanced by White and Pillemer (cited in
Goleman, 1981 -- that which is spontaneous and without effort and that which is purposefully retrieved differently with purposeful memory resulting from active thought. The later type of recall is more associated with intellectual understanding and wide experience. The memories that seem to "appear" are more sensually or emotionally stimulated and are more associated with the young. The rational information processing associated the maturing individual is the type of recall which was of interest in this study.

The most complete study that has been done to date in the area of retention of processes for problem-solving has been reported by Case (1980). Using the four major developmental stages of Piaget, Case uses executive strategies to explain how working memory helps people to solve problems. Practice and maturation, and general experience have effects on the developing learning process. He proposes that the individual being instructed be observed in his present level of problem-solving. He then should he be exposed to a task slightly above his level of development, being allowed to learn what is right about his strategies or what is wrong. When new strategies for problem-solving are then introduced, the extent of the working memory must be considered. As the child succeeds, more strategies can be introduced as long as they do not go beyond the learner's mental space.

Along with the assessment of the individual's level of learning. Case indicates that the tasks must be analyzed so that the skill level needed to solve the task is enough above the subject's level to permit the upward mobility of learning. He feels strongly that the student must be constantly encouraged to think out consequences.
As advanced by Pascual-Leone and emphasized by Case (1980) complex strategies cannot be developed until the working memory or M-space is developed enough to hold the desired number of strategies efficiently. Though Case's theory of learning and memory is closely related to Piaget, Pascual-Leone, Gagné and Simon, his approach to instruction is unique. His method of teaching problem-solving is based on his "neopiagetian" approach to thinking processes and may involve various problem-solving schemes.

The strategy adopted from Case's work and used in this study focuses on controlling variables in a scientific experiment. While his work looked at short-term memory, the study conducted here looks at the effect of the treatment of controlling variables on long-term memory.

The most recent study, and the one that relates most directly to this project, involved a controlling variable problem-solving situations (Betkouski and Lamb, 1981). Groups of students scored higher on certain tests used to measure retention of formal reasoning processes. As short-term memory can only hold four to six chunks (discrete pieces of information) at any one time, it was important that the experimental procedure used be as efficient as possible (Betkouski and Lamb, 1981). A pre-post retention test design was used as part of a larger study involving the use of neo-piagetian treatment to enhance reasoning ability. The population consisted on ninth grade students in a southeast Georgia private school and eighth grade students from a public school. All were in class-size units in actual class settings and experimental groups were treated, carefully following Case's instructional sequence. Experimental and control groups were administered tests from which sig-
significant differences in favor of the experimental groups over the non-treated control groups was observed on post-test and retention test. Either the Lawson Class Test of Formal Operations or the Tobin-Capie Test of Logical Thinking was used as the testing tool.
PROCEDURE

One of the primary areas of teacher concerns regarding instruction in laboratory sciences is whether or not a student can retain and retrieve a particular procedure for solving certain kinds of future problems. These procedures, or algorithms, are a vital part of any laboratory situation.

This study uses a segment of the population studied by Betkouski, Lamb and Cortez in 1980-81. Further testing was done to determine whether or not the algorithms were stored in long-term memory.

The students were selected from the ninth grade freshman class of a North Florida, urban, private, college preparatory school. Testing was begun two months into the school year. All testing and lessons used were taught in classes in laboratory-oriented physical science class settings. The experimental group consisted of 52 students; the control group was made up of 45 students. In both groups, boys and girls ranged in age from 13 to 15 years. The students were not told the type of testing that was being done and were given only minimal instructions.

As a part of the earlier study (Betkouski and Lamb, 1981), the Test of Logical Thinking (TOLT), Forms A & B (See Appendix B.) designed by Tobin and Capie of the University of Georgia (1979), was administered as a pre-test (Form A) and post-test (Form B) to the entire group of 97 students. The experimental group of 52 students was given a treatment in controlling variables based on the Case instructional sequence (Case, 1980) and modified by Betkouski, Lamb and Cortez (1980). This treatment followed the pre-test. The two tests were administered two weeks apart.
The treatment designed after Case (1980) (See Appendix C.), consisted of three problems, which progressed from two to five variables; each of these variables had to be recognized and controlled. Materials selected were: (1) rods and blocks, (2) bouncing balls, and (3) SCIS Whirly Birds. Students worked together in arbitrarily selected groups, recording information they gained according to a written format (Betkouski, Lamb, Cortez, 1980). After small group work was completed, the experimental subjects in class-size groups discussed and evaluated results. Teacher observations were made during the student discussion to be sure variables were identified.

To test the long-term retention and retrieval of problem-solving techniques, a delayed post-test was given after three-and-a-half months under classroom conditions to all of the 97 subjects. Form A of the Tobin Capie Test, which had been used as the pre-test in the original study, was used as this retention test.

A second testing and treatment procedure was followed in the same school in 1981-82. The same tests and sequence were used; the only changes were in the time schedules. The pre-test (Form A) was administered on the second day of the school year before any teacher instruction was begun; the post-test was given nine weeks after the treatment, and the retention test three months after this. The experimental group consisted of 69 students, with 67 students in the control group. In both of the test years five teachers were involved, using students in their regular class units. Two of the four teachers involved were the same for both years. For both test years, observations were made by the classroom teachers during the treatment sessions. In regular class sessions, the
teacher continued to observe the students to see if problem-solving skills were improved in the subjects treated. These observations were compared with the test data in an attempt to determine similarities and differences in results obtained both quantitatively and qualitatively.
RESULTS

All subjects, experimental and control, were tested using the TOLT as the pre-test, post-test and retention test. The statistical analysis was based on a general linear model which searches for significant group by treatment interaction in pre, post, or retention mean scores for the total test and for the various parts of the TOLT: controlling variables (variations), proportions, probability, correlations, and combinations.

TABLE I

<table>
<thead>
<tr>
<th>Group</th>
<th>Trial</th>
<th>N</th>
<th>Total</th>
<th>Prop</th>
<th>Var</th>
<th>Prob</th>
<th>Corr</th>
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<td>96</td>
<td>3.9896</td>
<td>0.8646</td>
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<td>0.8100</td>
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<tr>
<td>Exp</td>
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<td>34</td>
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TABLE II
TOLT Score Means - 1981-1982

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<th>Var</th>
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<td>Exp</td>
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<td>Exp</td>
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<td>Exp</td>
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<td>1.2424</td>
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Data analysis, using this model, showed little significant difference between groups but did show some interesting trends when data for the three trials were graphed. The results can be seen on Graphs A-F.
GRAPH A
Total Score Means

PRETEST POSTTEST RETENTION

1900

1901

CON EXP

CON EXP
GRAPH B
Controlling Variables Item Means

PRETEST POSTTEST RETENTION

1980

1981

CORRECT RESPONSES

CON
EXP

CON
EXP
GRAPH C
Proportions Item Means
GRAPH D
Probability Item Means

PRETEST POSTTEST RETENTION

1980

1981

CORRECT RESPONSES

CON EXP

PRETEST POSTTEST RETENTION
GRAPH E
Correlations Item Means

PRETEST POSTTEST RETENTION

CORRECT RESPONSES

1980

CON
EXP

1981

CON
EXP
GRAPH F
Combination Items Means

PRETEST POSTTEST RETENTION

PRETEST POSTTEST RETENTION
Further data analyses were conducted. Information for these are displayed in Appendix B.

The number of students for 1980-81 were not well balanced, as the retention test was given to only 97 members of the total test group. The 1981-82 numbers were more balanced and the testing environment controlled.

Because of the time interval between the treatment and the post-test (Form B), this test served as an indicator of immediate response to a treatment. An increase in the mean score in the experimental subtests for both test years was noticed, with the exception of 1981-82 experimental group on the proportions items which stayed the same. The control groups showed the same trend, though in some cases to a lesser degree, indicating a possible testing effect. Perhaps also, normal classroom instruction involving exercises in problem-solving for the groups accounted for the groups showing a mean score increase.

The results of the retention test for long-term memory is of special interest in this study. In most areas for the experimental group there was an increase in the retention mean as compared to the pre-test and post-test means. While the same trend was observed in the control group from pre to post-test, the data indicates lower retention scores for the control group as compared to the treated group.

Since the treatment was designed for controlling variables, this section of data is of particular interest. The 1980-81 results for experimental groups and control groups show an increase in scores when the pre-test results were compared with post-test results, but only the experimental group maintained that increase on the retention test. The
1981-82 groups showed a similar increase when pre-test results and post-test results were compared and when pre-test results and retention test results were compared, but showed a drop when post-test results and retention-test results were compared; however, the experimental group showed less of a decline.

Other areas in the TOLT, showed changes similar to the observed in the controlling variables section. The changes indicate a possibility of information transfer from general problem-solving experiences to particular areas of formal reasoning.

A qualitative evaluation of the results of the testing based on teacher observation, school grade comparison and standardized test give additional meaning to the quantitative analysis of the tests. The general characteristics of the classes were studied indicating that the profile of the 1980-81 group showed higher percentiles and I.Q. means than the one for 1981-82. Science grades for the two groups showed a similar difference between the two classes. Other comparisons were observed by the two teachers who administered the tests both years and they independently arrived at the same conclusion of differences in group characteristics. Of special interest was the difference in observed degree of maturing between the two classes with the 1980-81 group displaying a higher degree of self-discipline. They were more skilled in handling problem-solving strategies in the laboratory than was the 1981-82 group.

Another interesting observation by the teachers was that the "better" students seemed to have more problems in a laboratory setting when they were identifying variables; it also took longer for them to
arrive at a strategy. The studies which suggested interference as a deterrent to recall could account for this phenomenon.
CONCLUSION

The purpose of this study was to determine whether long-term memory could be increased when students were exposed to strategies which taught them to control variables. It appears from both quantitative and qualitative analyses, that the long-term memory was increased, but it must also be understood that the increase was not significant at a level of 0.05 or less. When increases in both experimental and control groups were observed, the problem-solving and practical strategies used by the teachers in their regular instruction were considered, along with the possibility of effects from testing.

Again, teacher observations indicate that sometimes the brighter students as shown by achievement scores and grades, required longer periods of time and had more difficulty in problem-solving. Based on the work of Smith (1978), it is possible to explain this as a result of retrieval interference which could be more severe with these students due to the amount of knowledge that must be processed in order for a scheme to be developed. The higher achievers may have had more trouble controlling variables because their previously acquired reasoning abilities were contaminating the picture. Also, the "high achievers" seemed less able to take risks.

In the near future Educational Records Bureau Comprehensive Testing Program II test scores for the 1981-82 groups will be available. These tests have sections designed to test logical thinking and problem-solving. It is hoped that a statistical analysis can be conducted in order to provide additional long-term memory trends for the experimental
and control subjects which will assist in planning future teaching strategies for improving retention.

The most obvious conclusion reached from this study is that work in this area has just begun. Not only is the testing of long-term memory of algorithms unique, but the approach to the testing of long-term memory here is also unique. By using the teacher in a class setting as the administrator and analyzer of the tests, a new dimension in research is examined. Teaching occurs in real class settings. Even though research in this type of setting is more difficult to control, in the end the results obtained may have greater application to the challenges of teaching problem-solving skills within the context of the regular classroom.
LIST OF REFERENCES


5. The Bolles School Faculty Self Study for SACS, May, 1980.


### TABLE III


**Proportions (Prop)**

<table>
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### TABLE IV


**Controlling Variables (Var)**

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### TABLE V


**Correlations (Cor)**

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</table>
APPENDIX B

TEST OF LOGICAL THINKING

Form A and B
T.O.L.T. - FORM A
Item 1

Orange Juice #1

Four large oranges are squeezed to make 6 glasses of juice. How much juice can be made from 6 oranges?

a. 7 glasses  
b. 8 glasses  
c. 9 glasses  
d. 10 glasses  
e. other

Reasons

1. The number of glasses compared to the number of oranges always be in the ratio of 3 to 2.  
2. With more oranges, the difference will be less.  
3. The difference in the numbers will always be 2.  
4. With 4 oranges the difference was 2. With 6 oranges the difference would be 2 more.  
5. There is no way of predicting.

Item 2

Orange Juice #2

How many oranges are needed to make 13 glasses of juice?

a. 6 ½ oranges  
b. 8 2/3 oranges  
c. 9 oranges  
d. 11 oranges  
e. other

Reasons

1. The number of oranges compared to the number of glasses will always be in the ratio of 2 to 3.  
2. If there are 7 more glasses, then 5 more oranges are needed.  
3. The difference in the numbers will always be 2.  
4. The number of oranges will be half the number of glasses.  
5. There is no way of predicting the number of oranges.
Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4  
b. 2 and 4  
c. 1 and 3  
d. 2 and 5  
e. all

Reasons

1. The longest pendulum should be tested against the shortest pendulum.
2. All pendulums need to be tested against one another.
3. As the length is increased the number of washers should be decreased.
4. The pendulums should be the same length but the number of washers should be different.
5. The pendulums should be different lengths but the number of washers should be the same.
Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4  
b. 2 and 4  
c. 1 and 3  
d. 2 and 5  
e. all

Reasons

1. The heaviest weight should be compared to the lightest weight.  
2. All pendulums need to be tested against one another.  
3. As the number of washers is increased the pendulums should be shortened.  
4. The number of washers should be different but the pendulums should be the same length.  
5. The number of washers should be the same but the pendulums should be different lengths.
A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package, what are the chances that it is a bean seed?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 4
d. 1 out of 6
e. 4 out of 6

Reasons

1. Four selections are needed because the three squash seeds could have been chosen in a row.

2. There are six seeds from which one bean seed must be chosen.

3. One bean seed needs to be selected from a total of 3.

4. One half of the seeds are bean seeds.

5. In addition to a bean seed, three squash seeds could be selected from a total of 6.
A gardener bought a package of 21 mixed seeds. The package contents listed:

3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers

If just one seed is planted, what are the chances that the plant that grows will have red flowers?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 7
d. 1 out of 21
e. other

Reasons

1. One seed has to be chosen from among those that grow red, yellow or orange flowers.

2. \( \frac{4}{9} \) of the short and \( \frac{4}{9} \) of the tall are red.

3. It does not matter whether a tall or a short is picked. One red seed needs to be picked from a total of 7 red seeds.

4. One red seed must be selected from a total of 21 seeds.

5. Seven of the 21 seeds will produce red flowers.
Item 7 The Mice

The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?

a. Yes

b. No

Reasons

1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails.

2. Some of the fat mice have white tails and some of the thin mice have white tails.

3. Eighteen mice out of 30 have black tails and 12 have white tails.

4. Not all of the fat mice have black tails and not all of the thin mice have white tails.

5. 6/12 of the white tailed mice are fat.
Item 8  The Fish

Are fat fish more likely to have broad stripes than thin fish?

a. Yes
b. No

Reason

1. Some fat fish have broad stripes and some have narrow stripes.
2. $3/7$ of the fat fish have broad stripes.
3. $12/28$ are broad striped and $16/28$ are narrow striped.
4. $3/7$ of the fat fish have broad stripes and $9/21$ of the thin fish have broad stripes.
5. Some fish with broad striped are thin and some are fat.
Item 9

The Student Council

Three students from grades 10, 11, 12 were elected to the student council. A three-member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry, and Dan (TJD) and Sally, Anne, and Martha (SAM). List all other possible combinations in the spaces provided.

More spaces are provided on the Answer Sheet than you will need.

STUDENT COUNCIL

<table>
<thead>
<tr>
<th>Grade 10</th>
<th>Grade 11</th>
<th>Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom (T)</td>
<td>Jerry (J)</td>
<td>Dan (D)</td>
</tr>
<tr>
<td>Sally (S)</td>
<td>Anne (A)</td>
<td>Martha (M)</td>
</tr>
<tr>
<td>Bill (B)</td>
<td>Connie (C)</td>
<td>Gwen (G)</td>
</tr>
</tbody>
</table>

Item 10

The Shopping Center

In a new Shopping Center, 4 store locations are going to be opened on the ground level.

A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to move in there. Each one of the stores can choose any of 4 locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations.

More spaces are provided on the Answer Sheet than you will need.
Item 9

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Three students from grades 10, 11, 12 were elected to the student council. A three-member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry, and Dan (TJD) and Sally, Anne, and Martha (SAM). List all other possible combinations in the spaces provided.

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STUDENT COUNCIL

<table>
<thead>
<tr>
<th>Grade 10</th>
<th>Grade 11</th>
<th>Grade 12</th>
</tr>
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<tbody>
<tr>
<td>Tom (T)</td>
<td>Jerry (J)</td>
<td>Dan (D)</td>
</tr>
<tr>
<td>Sally (S)</td>
<td>Anne (A)</td>
<td>Martha (M)</td>
</tr>
<tr>
<td>Bill (B)</td>
<td>Connie (C)</td>
<td>Gwen (G)</td>
</tr>
</tbody>
</table>

Item 10

The Shopping Center

In a new Shopping Center, 4 store locations are going to be opened on the ground level.

A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to move in there. Each one of the stores can choose any of 4 locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations.

More spaces are provided on the Answer Sheet than you will need.
Item 1

House Paint #1

A painter uses 4 cans of paint to paint 6 rooms. How many rooms can be painted with 6 cans of paint?

a. 7 rooms  
b. 8 rooms  
c. 10 rooms  
d. 10 rooms  
e. other

Reasons

1. The number of rooms compared to the number of cans will always be in the ratio of 3 to 2.
2. With more cans of paint, the difference will be less.
3. The difference in the numbers will always be 2.
4. With 4 cans of paint the difference was 2. With 6 cans of paint the difference would be 2 more.
5. There is no way of predicting how much paint is needed.

Item 2

House Paint #2

How many cans of paint are needed to paint 11 rooms?

a. 5 ½ cans  
b. 7 cans  
c. 7 1/3 cans  
d. 9 cans  
e. other

Reasons

1. The number of cans of paint compared to the number of rooms will always be in the ratio of 2 to 3.
2. If there are 5 more rooms, then 3 more cans are needed.
3. The difference in the numbers will always be 2.
4. The number of cans will be half the number of rooms.
5. There is no way of predicting the amount of paint.
Suppose you wanted to do an experiment to find out if changing the height of a ramp changed the distance a ball rolled off the end. Which sets of apparatus would you use?

I. 2 ft.  
II. 4 ft.  
III. 3 ft.  
IV. 2 ft.  
V. 1 ft.  

a. I and IV  
b. II and IV  
c. I and III  
d. II and V  
e. all of them  

Reasons

1. The highest ramp should be tested against the shortest.  
2. All sets need to be tested against each other.  
3. As the height is increased the weight must be decreased.  
4. The heights should be the same but the weights should differ.  
5. The heights should differ but the weights should be the same.
Item 4

Rolling Cylinders #2

Suppose you wanted to do an experiment to find out if changing the weight of the ball changed the distance it rolled off the end of a ramp. Which set of apparatus would you use?

I. 2 ft.
II. 4 ft.
III. 3 ft.
IV. 2 ft.
V. 1 ft.

5 lb.
3 lb.
10 lb.
4 lb.

Reasons

1. The heaviest ball should be compared to the lightest.
2. All sets need to be tested against each other.
3. As the weight is increased, the height should be decreased.
4. The weights should be different but the heights should be the same.
5. The weights should be the same but the heights should be different.

a. I and IV
b. II and IV
c. I and III
d. II and V
e. all of them
An American tourist is sharing a compartment on a Swiss train with six people. Three speak only English and three speak only French. What are the chances of speaking to someone who speaks English on the first try?

a. 1 out of 2  
b. 1 out of 3  
c. 1 out of 4  
d. 1 out of 6  
e. 4 out of 6

Reasons

1. Four selections are needed because the three French speakers could be chosen in a row.

2. There are 6 people from which one English speaking person must be chosen.

3. One English speaking person needs to be selected from a total of 3.

4. One half of the people speak English.

5. In addition to an English speaking person, 3 French speaking people could be selected from a total of 6.
The Coins and Rings

Three gold coins, 4 silver coins, and 5 copper coins are placed in a sack. Four gold rings, 2 silver rings, and 3 copper rings are placed in the same sack.

What are the chances of pulling out a gold object on the first try?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 7
d. 1 out of 21
e. none of the above

Reasons

1. One gold object has to be selected from objects made from gold, silver, and copper.

2. One-fourth of the coins and 4/9 of the rings are made from gold.

3. It does not matter whether a coin or a ring is picked. One gold object needs to be selected from a total of 7 gold objects.

4. One gold object must be selected from a total of 21 objects.

5. Seven of the 21 objects in the sack are made from gold.
A boy has a penny to use in one of 2 gumball machines. The first machine has 30 red and 50 yellow gumballs; the second has 20 red and 30 yellows. He likes only red gumballs.

His chance of getting a red is greatest in the second machine?

a. Yes

b. No

Reasons

1. There are 30 red in the first machine and only 20 in the second.

2. There are 20 more yellows in the first machine and only 10 more yellows in the second.

3. There are 50 yellows in the first machine and only 30 in the second.

4. There is a greater proportion of reds in the second machine.

5. There are more gumballs in the first machine.
Item 8  The Spotted Dogs

Seven large dogs and 21 small dogs are shown in the picture. Some dogs are spotted and others are not spotted.

Are large dogs more likely to have spots than small dogs?

a. Yes
b. No

Reasons

1. Some small dogs have spots and some large dogs have spots.
2. Nine small dogs have spots and only 3 large dogs have spots.
3. Twelve of the 28 dogs are spotted and 16 of the 28 dogs are not spotted.
4. Three-sevenths of the large dogs are spotted and 9/21 of the small dogs are spotted.
5. Twelve of the small dogs have no spots and only 4 of the large dogs have no spots.
Item 9

The Sandwiches

A restaurant allows a choice of three types of bread, three types of meat and three types of spread.

<table>
<thead>
<tr>
<th>Bread</th>
<th>Meat</th>
<th>Spread</th>
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<tr>
<td>wheat (W)</td>
<td>ham (H)</td>
<td>ketchup (K)</td>
</tr>
<tr>
<td>rye (R)</td>
<td>chicken (C)</td>
<td>mayonnaise (M)</td>
</tr>
<tr>
<td>pumpernickle (P)</td>
<td>turkey (T)</td>
<td>butter (B)</td>
</tr>
</tbody>
</table>

Each sandwich must contain bread, meat and spread. How many types of sandwich can be prepared using only one type of bread, one type of meat and one type of spread?

List all of the possible types of sandwiches in the spaces provided on the Answer Sheet. More spaces are provided than you will need. Two examples of different sandwiches are provided for you. (WHK, RCM)

Item 10

The Car Race

In an automobile race there is a Dodge (D), a Chevy (C), a Ford (F), and a Mercury (M). An observer predicts that the order of finish will be DCFM. In the spaces provided on the Answer Sheet, list all other possible orders in which the cars might finish.

More spaces are provided than you will need.
ANSWER SHEET

Name ________________________________

Birthdate ________________________________
  Month ___ Day ___ Year ___

Sex ________________________________

School ________________________________

Grade _____ Date __________

Directions

A series of eight problems is presented. Each problem will lead to a question. Record the answer you have chosen and reason for selecting that answer.

<table>
<thead>
<tr>
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<th>Best Answer</th>
<th>Reason</th>
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<td>7.</td>
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Put your answers to questions 9 and 10 below:

9. TJD SAM  ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
   ____  ____  ____  ____  ____  ____  ____  ____  ____  ____

10. BDGC  ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
    ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
    ____  ____  ____  ____  ____  ____  ____  ____  ____  ____
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    ____  ____  ____  ____  ____  ____  ____  ____  ____  ____


**Test of Logical Thinking**

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<th>Answers: Form B</th>
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<tr>
<td>1. c 1</td>
<td>1. c 1</td>
</tr>
<tr>
<td>2. b 1</td>
<td>2. c 1</td>
</tr>
<tr>
<td>3. c 5</td>
<td>3. c 5</td>
</tr>
<tr>
<td>4. a 4</td>
<td>4. a 4</td>
</tr>
<tr>
<td>5. a 4</td>
<td>5. a 4</td>
</tr>
<tr>
<td>6. b 5</td>
<td>6. b 5</td>
</tr>
<tr>
<td>7. a 1</td>
<td>7. a 4</td>
</tr>
<tr>
<td>8. b 4</td>
<td>8. b 4</td>
</tr>
<tr>
<td>10. Twenty-four combinations.</td>
<td>10. Twenty-four combinations.</td>
</tr>
</tbody>
</table>

For questions 9 and 10 the subject should have the correct combinations and the correct number of combinations. If a combination is repeated the item would usually be scored incorrect. An exception to this procedure occurs if the repeated combination is the one given on the answer form. In this instance a subject could have 25 combinations for item 10, and 28 or 29 combinations for item 9.

In items 1-8 a subject needs to have both the answer and the reason correct to be awarded 1. No part marks should be awarded. Since 1 mark can be obtained for each item, a total test score of 10 is possible.

Raw scores are recommended for use for research and evaluation.

Research is currently underway to provide equating procedures for Form A and Form B. The "transformed" scores will be available early in August 1980 and can be obtained from the authors.
APPENDIX C

TREATMENT WORK SHEET
I. Problem: Determine whether the yellow or white rod is heaviest without removing the rods from the blocks.

Answer: 

<table>
<thead>
<tr>
<th>Method</th>
<th>Conclusion (Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>What does change</th>
<th>What doesn't change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I. Problem: Determine which ball bounces highest and why

Answer: 

<table>
<thead>
<tr>
<th>Method</th>
<th>Conclusion (Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>What does change</th>
<th>What doesn't change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
### III. Problem: What effect does changing the number of turns have on the number of spins?

**Answer:**

<table>
<thead>
<tr>
<th>Method</th>
<th>Conclusion (Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does change</td>
<td>What doesn't change</td>
</tr>
</tbody>
</table>

### IV. Problem: What effect does changing the bolt placement have on the number of spins?

**Answer:**

<table>
<thead>
<tr>
<th>Method</th>
<th>Conclusion (Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does change</td>
<td>What doesn't change</td>
</tr>
</tbody>
</table>
V. Problem: What effect does changing the weight, number of bands, and variations affect the number of spins?

<table>
<thead>
<tr>
<th>Method</th>
<th>Conclusion (Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does change</td>
<td>What doesn't change</td>
</tr>
</tbody>
</table>

Answer: 

- Method
- Conclusion (Application)