THE EFFECTS OF PROBLEM SOLVING TRAINING IN SCIENCE UPON UTILIZATION OF PROBLEM SOLVING SKILLS IN SCIENCE AND SOCIAL STUDIES

By

TERRY JOE SHAW

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1968

Master of Science in Biology
University of California - San Diego
San Diego, California
1971

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF EDUCATION
July, 1977

THE EFFECTS OF PROBLEM SOLVING TRAINING IN SCIENCE UPON UTILIZATION OF PROBLEM SOLVING SKILLS IN SCIENCE AND SOCIAL STUDIES

Thesis Approved:

Thomas D. Johnsten
Thesis Adviser

Terence J. Mills

Franklin R. Leads

Bill F. Elsom

Kenneth E. Wiggins

Norman N. Durham
Dean of the Graduate College

PREFACE

This study is concerned with (1) determining the effect of a process oriented science curriculum on the problem solving ability of sixth grade students, (2) determining if this ability will transfer to social studies, (3) testing models concerning problem solving skills in order to determine if there is evidence for a hierarchy of problem solving skills, and (4) determining if training in the integrated processes increases a student's proficiency in selected basic and intermediate process skills in science and social studies. One of the major tasks of this study was designing science and social studies instruments to test for problem solving ability.

The author would like to express his appreciation to his major adviser, Thomas Johnsten, for his guidance, assistance, and encouragement throughout this study. Appreciation is also expressed to other committee members: Dr. Ted Mills, Dr. Franklin Leach, Dr. Billy Elsom, and Dr. Kenneth Wiggins for their suggestions and assistance throughout the study.

The author would also like to thank the Stillwater Public Schools system for approving the study. Special thanks goes to Joe Payne, the other science teacher involved in the study, for his countless suggestions, cooperation, and assistance in planning and implementing the activities for the control and treatment groups. The author also appreciates the assistance of Mrs. Sue Moore for typing earlier drafts of the manuscript and Mrs. Molly Reid for the typing of the final copy.

Special gratitude is expressed to my wife Thelia for her patience, sense of humor, encouragement and sacrifices and to my infant son, Tarren, for offering instant entertainment and relaxation during any spare minutes I have had while writing this dissertation.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

NATURE OF THE PROBLEM

Introduction

Promoting problem-solving ability has been espoused by curriculum specialists and classroom teachers as a primary goal in education. This goal is a major focus of many of the newly developed science curricula teaching various "process skills" so that the students will be better problem-solvers. Thelen (1) has stated that teaching students to be effective problem-solvers should be the primary purpose of American education. Other authors (2,3&4) agree, stating that "learning how to learn" is more important than "learning what to learn." The education research literature is full of philosophical papers trumpeting the virtues of teaching problem-solving skills in the classroom, while other articles contain material pointing to the absence of acceptable problem-solving behavior among today's students (5). Since the knowledge explosion has made it impossible to learn all of the information in a field, teachers and students are being forced to consider only small portions of any discipline. Today Suchman, Gagne and Bruner (6, 7 & 8) propose that learning the processes of acquiring new information is at least as important as learning new information itself. By learning these processes, individuals should be better prepared to cope with future problems in an aggressive, rational manner, thus enabling them in the future to deal with data and solve problems which were not covered in the classroom. If the student can learn to utilize the kind of intellectual activity which each of these problem-solving processes require, curriculum developers have hypothesized that the student will not only be a better problem-solver in science but also will be a more efficient problem-solver in other areas of his or her life (4).

Several researchers and organizations have identified processes of the scientific enterprise which lead to effective problem-solving and also have identified the kind of intellectual activity which each process requires.

The Commission on Science Education of the American Association for the Advancement of Science (AAAS) for example has identified thirteen processes which are considered to be representative of scientific activity. These processes are broken down into two groups: basic processes and integrated processes. The basic processes include observation, measuring, inferring, predicting, classifying and collecting and recording data while the integrated processes include interpreting data, controlling variables, defining operationally, formulating hypotheses and experimenting (10). According to Gagne (11) these processes form a hierarchy so that effective use of the integrated processes requires prior mastery of the basic processes. Dewey (12) has stated the need for a problem-solving situation to emphasize the self-realization of the student by having him deal with problems in a systematic way. He describes the problem-solving process as the following five linear steps:

1. Felt need
   ↓
2. Identification and definition
   ↓
3. Hypothesis for solution
   ↓
4. Deduction by reasoning
   ↓
5. Verification

Butts and Jones (13), however, disagree with those who see patterns of thought as necessary ingredients of problem-solving behavior. They feel that problem-solving is generally a cyclic, repetitive fluid process rather than a fixed linear process to be plodded through step by step.

One of the goals of this study is to determine if in fact a hierarchy of problem-solving skills does exist.

Definitions of Terms

Problem-Solving Ability--the students' ability to utilize the integrated processes. An operational definition is the students' score on the portion of a test designed to measure competency in the utilization of the integrated processes.

Basic Processes--observing, classifying, using numbers, using space/time relationships, and measuring.

Intermediate Processes--inferring and predicting.

Integrated Processes--controlling and manipulating variables, formulating and testing hypotheses, defining operationally, and interpreting data.

Observing--being aware of several aspects of a phenomena including unusual circumstances, discrepancies, changes taking place, etc. This process is based on the utilization of the five senses.

Classifying--mentally or physically placing objects in groups which have systematic relationships.

Using Numbers--identifying sets and members of sets, ordering, counting, adding, multiplying, dividing, finding averages, using decimals, and powers of ten.

Using Space/Time Relationships--identifying shapes, movement, direction and speed.

Measuring--obtaining the dimensions of an object by comparing the object to a standard unit.

Inferring--an explanation of a particular phenomena based on the observation of that phenomena.

Predicting--foretelling the behavior of an event from the available data which is currently at hand.

Manipulating Variables--changing one factor at a time to determine what effect it will have on the responding variable.

Controlling Variables--holding constant all factors which might influence the behavior of a system.

Interpreting Data--explaining the meaning and implications of information needed to design an experiment as well as explaining the experimental results.

Formulating Hypotheses--designing one or more general models to fit the known data.

Testing Hypotheses--designing and carrying out a test of a model.

Defining Operationally--specifying what must be done and/or what must be observed in order to identify or construct an object, a situation, or an event.

SAPA--"Science...A Process Approach" is a widely implemented K-6 process oriented curriculum developed by the American Association for the Advancement of Science and marketed by Ginn and Co.

SAPA II--"Science...A Process Approach II" is a revision of SAPA. The K-3 portion of SAPA II was first marketed in the spring of 1974 while the 4-6 portion was first marketed in spring 1975.

SAT - Stanford Achievement Test - a popular nationally standardized achievement test.

ESS - Elementary Science Study - a widely implemented K-8 activity oriented science curriculum project.

SCIS - Science Curriculum Improvement Study - a widely implemented K-6 activity oriented science curriculum project.

Need for the Study

Many of the studies involving problem-solving have been implemented using a specially designed unit on problem-solving, often involving individual tutoring, separate from and having no relation to the regular curriculum. In other studies the problem-solving tasks provided in the experiments are so highly artificial that they have little apparent resemblance to the kind of problem-solving task that a child encounters in school. Usually reports of studies contain no information which provides clues as to the degree to which problem-solving ability acquired during the study might be expected to transfer to school-like tasks. If the investigator did attempt to assess transfer to problem-solving ability, the task chosen to check for transfer is generally so similar to the task used to teach the problem-solving skills that it is difficult to determine a notable difference between the two.

Several science curriculum projects developed in the past few years have a strong emphasis on science process skills. Part of the rationale behind this emphasis has been that the student will "develop ability in applying the processes and principles of science to a wide range of problems, social as well as scientific" (14, p. 4). However, upon an extensive literature search, no unequivical study on transfer of training to a different type of problem or to the general school curriculum was found. The time and effort required to teach problem-solving skills, the money spent to develop such process oriented programs, and the expense to the school in purchasing the programs can hardly be justified unless some transfer of training to other subject matter areas and other situations occurs.

Purpose of the Study

The purpose of this study is to (1) determine the effect of a process oriented science curriculum on the problem solving ability of sixth grade students, (2) determine if this ability will transfer to social studies, (3) test models concerning problem solving skills in order to determine if there is evidence for a hierarchy of problem solving skills, and (4) determine if training in the integrated processes increases a student's proficiency in selected basic and intermediate processes in science and social studies.

Statement of the Hypotheses

Stated in the null form the hypotheses are as follows with the capital letters A through G designating groups of hypotheses which consider similar questions:

A. Utilization of problem solving processes in science:

H_1: Training in the integrated processes through the science curriculum will not have an effect on the students' problem solving ability in science.

H_2: Training in interpreting data through the science curriculum will not have an effect on the students' ability to interpret data in science.

H_3: Training in manipulating and controlling variables through the science curriculum will not have an effect on the students' ability to manipulate and control variables in science.

H_4: Training in defining operationally through the science curriculum will not have an effect on the students' ability to define operationally in science.

H_5: Training in formulating and testing hypotheses through the science curriculum will not have an effect on the students' ability to formulate and test hypotheses in science.

B. Utilization of problem solving processes in social studies:

H_6: Training in the integrated processes through the science curriculum will not have an effect on the students' problem solving ability in social studies.

H_7: Training in interpreting data through the science curriculum will not have an effect on the students' ability to interpret data in social studies.

H_8: Training in manipulating and controlling variables through the science curriculum will not have an effect on the students' ability to manipulate and control variables in social studies.

H_9: Training in defining operationally through the science curriculum will not have an effect on the students' ability to operationally define in social studies.

H_{10}: Training in formulating and testing hypotheses through the science curriculum will not have an effect on the students' ability to formulate and test hypotheses in social studies.

C. Utilization of basic processes in science:

H_{11}: Training in the integrated processes in science will not effect the students' ability to utilize the basic processes in science.

H_{12}: Training in the integrated processes in science will not effect the students' ability to observe in science.

H_{13}: Training in the integrated processes in science will not effect the students' ability to classify in science.

H_{14}: Training in the integrated processes in science will not effect the students' ability to measure in science.

H_{15}: Training in the integrated processes in science will not effect the students' ability to use space/time relationships in science.

H_{16}: Training in the integrated processes in science will not effect the students' ability to use numbers in science.

D. Utilization of intermediate processes in science:

H_{17}: Training in the integrated processes in science will not effect the students' ability to utilize the intermediate processes in science.

H_{18}: Training in the integrated processes in science will not effect the students' ability to infer in science.

H_{19}: Training in the integrated processes in science will not effect the students' ability to predict in science.

E. Utilization of basic processes in social studies:

H_{20}: Training in the integrated processes in science will not effect the students' ability to utilize the basic processes in social studies.

H_{21}: Training in the integrated processes in science will not effect the students' ability to observe in social studies.

H_{22}: Training in the integrated processes in science will not effect the students' ability to classify in social studies.

H_{23}: Training in the integrated processes in science will not effect the students' ability to measure in social studies.

H_{24}: Training in the integrated processes in science will not effect the students' ability to use space/time relationships in social studies.

H_{25}: Training in the integrated processes in science will not effect the students' ability to use numbers in social studies.

F. Utilization of intermediate processes in social studies:

H_{26}: Training in the integrated processes in science will not effect the students' ability to utilize the intermediate processes in social studies.

H_{27}: Training in the integrated processes in science will not effect the students' ability to infer in social studies.

H_{28}: Training in the integrated processes in science will not effect the students' ability to predict in social studies.

G. Hierarchy of process skills:

H_{29}: Mastery of the basic processes is not a prerequisite to successful utilization of the integrated processes.

Assumptions

The following conditions are assumed for this study:

1. The selection and randomization process will control for initial differences between groups.
2. Any problem-solving skills which the students in the control groups pick up from students in the treatment group will not significantly affect their problem-solving behavior.
3. The questions on the testing instrument for the three categories of processes (basic, intermediate, and integrated) are of similar difficulty.

Limitations

The following limitations are cited for this study:

1. Inferences will be restricted to the population used in this study.
2. Inferences will be restricted to problem-solving as defined in the study.
3. The reading level of the test may pose a difficulty for the poor readers in the population and this may not accurately measure their problem-solving ability.

Significance of the Study

If the first null hypothesis is rejected, it will indicate that problem-solving skills can indeed be taught through the science curriculum.

If the sixth null hypothesis is rejected, it will indicate that skills are transferred to social studies. If this is true, teaching problem-solving skills in the schools is justifiable on its own merit.

Any effort to shed light on means of effectively approaching new problems will be welcomed by teachers who set as a major goal the improvement of problem-solving ability in their students. This research should lead to a better understanding of how problem solving skills can be taught to students at this level.

CHAPTER II

REVIEW OF THE LITERATURE

Importance of Problem Solving Ability

Since humans have free choice and are continually confronted by varying circumstances, the ability to solve problems is important. As changes come faster and decisions are required which have no parallel in history, society is placing an increasingly greater premium on the ability to effectively find solutions to problems. Parker and Rubin (15) state that process skills are not only important in problem-solving but are also the method by which knowledge is created. These authors go on to say:

> It is through the teaching of process that we can best portray learning as a perpetual endeavor and not something which terminates with the end of school. Through process, we can employ knowledge not merely as a composite of information, but as a system of learning (16, p. 1).

Writers in various academic areas have emphasized the importance of teaching problem-solving skills in their disciplines. In the 1970 National Council of Teachers of Mathematics yearbook Kinsella (17) states that problem-solving should be taught as an end in itself and that the learners attention should be directed to the methods and processes used in solving various problems.

In Effective Thinking in the Social Studies several authors emphasized the need for teaching students the various processes required to intelligently solve problems as they relate to the social sciences (18). In the area of science essentially all of the new curriculum projects have a strong emphasis on "hands-on" experiences which have the stated purpose of teaching problem-solving skills.

Turner (19, p. 339), states, "One of the most publicized objectives in science education has come to be recognized and labeled as problem-solving."

Although there is a tremendous amount of support for teaching problem-solving process skills, the vote is not unanimous. Ausubel (20) questions the assumptions that increasing problem-solving ability should be a primary goal of education. He feels that it is much easier for students to learn facts and content than the processes of problem-solving, and that it takes an exceptional child to be an effective problem solver. He further emphasizes his point by stating that if problem-solving skills are emphasized there will not be adequate time left for the teaching of content. Ausubel (21) goes on to say that it is very inefficient to transmit knowledge by means of hands-on activities and experiments unless the students are still at the concrete stage of cognitive development. However, Lawson and Renner (22) have found that even in high school science classes as many as 75% of the students may still be operating at the concrete stage of development, which leads them to suggest that even in senior level science classes hands-on concrete experiences are necessary in order for the students to comprehend the subject matter.

Andersen and Weigand (23) iterated what is probably the consensus of today's educators when they stated:

> It is of course ridiculous to assume that all knowledge should be gained through problem-solving processes. There are far too many problems. It is equally ridiculous to assume that students saturated with knowledge will automatically begin using this knowledge to solve problems. While it is impossible to teach students all the knowledge they will need...it is not impossible to prepare them as relatively effective problem-solvers, capable of discovering the details for themselves (p. 489).

The Nature of Problem Solving

As one reviews the literature on the subject of problem-solving it becomes apparent that some hard and fast definitions are needed. Some authors equate mastery of problem-solving to the attainment of Piaget's formal operational stage of cognitive development. Others use the term problem-solving interchangeably with inquiry, discovery, productive thinking, creative thinking, or reflective thinking. But even if the relatively narrow definition of problem-solving used in this study is used (i.e., the student's ability to utilize the problem-solving processes of controlling variables, interpreting data, formulating hypotheses and defining operationally) there is still considerable disagreement as to the nature of problem-solving.

The classical scientific method of problem-solving was for years the principal model for teaching problem-solving in science classes. This method which in many respects was similar to Dewey's scheme was typically presented as the five steps outlined below:

1. Defining the problem
2. Constructing hypotheses
3. Experimenting
4. Compiling results
5. Drawing conclusions

Bruner (24), however, disagrees with this linear fashion of thinking. He indicates that many people in a problem-solving situation operate by an implicit perception of the total problem and employ leaps, skip steps, and follow short cuts rather than following rigid formulas or patterns.

Stollberg (25) also opposes a rigid approach to problem-solving. He has stated:

> (Problem-solving) is not a series of fixed steps, described in science texts from three to four or up to ten steps in number...it is an assortment (not a pattern) of skills, attitudes, and habits...the individual who has reasonable command of certain well-selected facts, important principles, and broad generalizations related to his problem can arrive at a better conclusion and do it quicker than a person who is not familiar with the general field of difficulty (p. 226).

In order for the above statement to be meaningful one must be aware of what skills, processes, attitudes, and habits are involved in effective problem-solving.

Loree (26) found that the difficulties students in grades four through nine had in solving problems could be subsumed under four general headings: (a) possession of information, i.e., what the student already knew about the problem situation, (b) retrieval of information, i.e., being able to recall stored information about the problem situation, (c) extracting information, i.e., being able to read and understand a problem and make appropriate observations, and (d) combining operations which include such thinking skills as classifying, comparing, analyzing, synthesizing, hypothesizing, and evaluating. Loree (27) found that before a student could successfully complete the combining operations, he must be able to complete (a), (b), and/or (c) successfully.

Renner, Stafford and Ragan (28) have listed six processes they consider essential to science. Those processes are: observing, measuring, experimenting, interpreting, predicting, and model building. As mentioned in Chapter I, the American Association for the Advancement of Science (AAAS) has identified thirteen processes which are considered to be representative of scientific activity (29). These processes are shown below in the form of a chart representing a hierarchy of processes. This hierarchy is not a flow chart suggesting a progression from one process to another in solving a particular problem. The hierarchy does for example suggest that before a person can effectively use the processes on one level, they must master the processes on the levels below it.

It can be seen that according to this hierarchy, observing is a prerequisite to all other skills. Above observing in the hierarchy is measuring, classifying, using numbers and using space/time relationships. The highest basic processes which interface with the integrated processes are communicating, inferring and predicting. Above this are the four integrated processes, interpreting data, defining operationally, controlling variables, and forming hypotheses. When these four processes are mastered, according to the hierarchy, all the prerequisite requirements have been fulfilled so that the student is equipped to tackle the process of experimenting (30).

Obviously there is a great deal of similarity between the lists of process skills set forth by various groups and researchers doing work in the area of problem solving.

In the author's opinion Butts and Jones (31) have done an outstanding job in summarizing the current concensus of opinion concerning

EXPERIMENTING

↑

MANIPULATING VARIABLES	MAKING OPERATIONAL DEFINITIONS	FORMULATING HYPOTHESES	INTERPRETING DATA	INTEGRATED PROCESS
		↑		
	COMMUNICATION	PREDICTING	INFERRING	
		↑		
CLASSIFYING	MEASURING	USING NUMBERS	USING SPACE-TIME RELATIONSHIPS	BASIC PROCESSES
		↑		

OBSERVING

Figure 1. Hierarchy of Problem Solving Process

Source: R.D. Anderson, et al., Developing Children's Thinking Skills Through Science (Englewood Cliffs, 1970), pp. 216-219.

problem-solving styles and the spirit of the problem-solving endeavor. Although different labels are used, the processes involved are essentially equivalent to those outlined by the American Association for the Advancement of Science described above, but also incorporating assimilation and accommodation. Butts and Jones (32) feel that problem-solving does not involve separate and discrete entities but that each activity is dependent upon preceding activities. They propose the following cyclic model for an inquiry approach to problem solving:

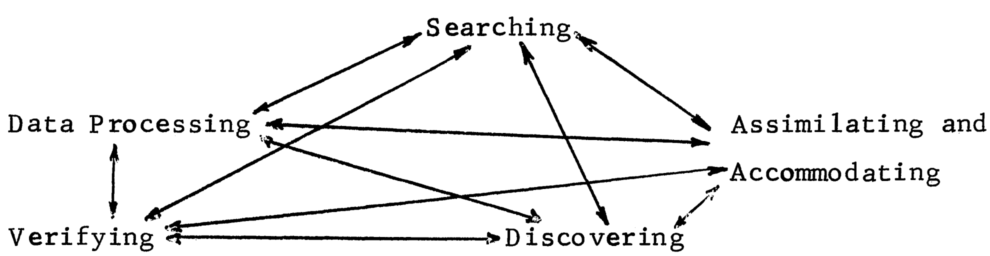


Figure 2. Cyclic Model for an Inquiry Approach to Problem Solving

In describing their model Butts and Jones (33) state:

> A child who finds himself in a problem situation may search for and process data. However, his searching and data processing operatings are dependent on his past searching, data processing, verifying, discovering, assimilating, and accommodating behaviors or strategies. In turn the child's verifying, discovering, assimilating and accommodating processes are also dependent upon his searching and data processing behaviors (p. 44).

Research in Teaching Problem-Solving Skills

The question many researchers have tried to answer is: How can these problem-solving skills be taught more effectively?

Butts and Jones (34) utilized process oriented training in "inquiry" activities with elementary students and found that the students improved significantly in their ability to interpret data, discover relationships between variables, use logic, and recognize causality in a given problem situation.

Olton and Crutchfield (35) have used "productive thinking" instruction to significantly improve the students' abilities in the areas of formulating and evaluating hypotheses, observing, inferring, and predicting. Through individual training sessions Means and Loree (36) have been successful in improving the students' ability in the area of "combining operations." Skills included under the umbrella of "combining operations" are classifying, inferring, predicting, forming hypotheses, and interpreting data. However Parks (37) attempted to teach problem-solving skills through critical analysis of five famous scientific papers but found that this did not improve problem-solving ability of prospective elementary teachers as measured by the Watson Glaser Test of Critical Thinking.

Possien (38) compared the effects of three teaching styles on the development of problem-solving skills in sixth grade children. Method A, an inductive method, required the students to solve a series of map problems through searching and self discovery. In Method B, a deductive method, the teacher presented facts and generalizations. Method C was similar to Method B but also included a detailed explanation of causal relationships underlying the concepts. At the end of the study there was no significant difference between the three teaching methods. By simply discussing with the students the scientific method and its application, Heaney (39) failed to show an increase in problem-solving ability, but when discussion was combined with the use of controlled science experiments being carried out by the students, a significant increase in problem-solving ability was obtained. These results are consistent with the work of Means and Loree (40), Suchman (41) and other researchers who have shown that in order to improve problem-solving ability, the student must be actively engaged in solving problems.

The results of these studies suggest that the development of problem-solving skills is not acquired by discussing the steps of the scientific method or as in indirect result of studying content, but comes by using these skills to solve problems, and by the teacher making a concentrated effort to explain these skills and encourage their use.

Other studies have suggested that there are additional factors besides the thirteen AAAS process skills which affect the students' proficiency in solving problems.

For example, Loree (42) and Gagne (43) agree that possession of information or mastery of content is a necessary prerequisite for problem-solving ability. Loree (44) has divided the requirements for problem-solving into four groups: 1) possession of information, 2) retrieval of information, 3) extraction of information from the problem, and 4) combining operations which include most of the AAAS process skills discussed above. Without the needed background information concerning a problem, it is impossible for the student to understand the problem. In an extensive investigation of problem-solving techniques, Loree (45) also found that some students seemed to possess the proper information, but were not able to retrieve the information without a hint or reminder to get them started. Extraction of information from the problem requires careful observation and being aware of unusual circumstances. Sekyra and Loree (46) have been successful in using taped instruction to improve the students' ability in all four of these areas.

In a study in which Thiel and George (47) investigated factors affecting the use of the process skill of predicting, they suggest that some children have not had the prerequisite concrete experiences required for them to develop the cognitive maturity to effectively make predictions. In a study of formal thinking in children of ages seven to seventeen Case and Collinson (48) found that these children regressed to less mature levels of thought when they were confronted with complex material. These findings and similar results suggest that there is a need for students at the concrete operational stage and even those at the formal stage of cognitive development to be presented with concrete experiences when unfamiliar material is being introduced (49).

Tyler (50) found that previous success in solving problems increased a student's expectations of success in solving future problems and actually improved the student's problem-solving ability.

In a study done with college students Bloom and Broder (51) isolated five major sources of difficulty encountered in a problem solving situation: 1) Lack of direction, i.e., the student did not thoroughly define the problem, 2) Lack of objectivity, i.e., dislike for the subject matter, fear of failure, conflict with personal values, etc., 3) Lack of ability to think logically and systematically, i.e., attempts at solving the problem were dominated by hunches, guesses, etc. 4) Lack of ability to follow a chain of reasoning, i.e., the student was capable of understanding the problem but could not go beyond the first step in a logical sequence, and 5) Lack of knowledge. Inflexibility of mind set has also been identified as a factor interferring with a subject's problem-solving ability. Andersen (52) has suggested that this could be combatted with brainstorming exercises and a hypothetical mode of teaching.

It seems that the best method for those interested in teaching problem-solving would be to design experiences which will strengthen a maximum number of functions known to influence the total process.

Transfer

Teaching for Transfer of Problem Solving Skills

Students need to be able to generalize the principles of knowledge to a variety of situations and be able to discriminate between probable and improbable applicability of hypotheses to new problem situations. These two conditions must be met before training in problem-solving can be beneficial (53). In a study of fourth grade subjects in a classification task, Wittrock and Jones (54) found that focusing on the specific content was very efficient for teaching that specific content but was an ineffective means of teaching for transfer. They also found that students given simple classification rules did not score significantly better in the classification task than the group given specific instruction. However, the group given the classification rules did do significantly better in transferring the skill to another type of classification task.

Other authors have suggested that mechanization in problem-solving can create a strong mind set and actually inhibit problem-solving ability and transferability (55).

Covington and Crutchfield (56) have suggested that brainstorming and other divergent thinking methods be employed to break a mind set and allow the student to become a creative problem solver. They have developed a Creative Problem-Solving Program which they have found to improve observational skills, divergent thinking, and creativity. They also claim that the skills learned from the program should transfer to many school subject matter areas. These claims of transferability were not supported, however, when Treffinger (57) tested fourth, fifth, sixth and seventh grade students who had experienced the Creative Problem-Solving Program. He found no evidence of transfer on the General Problem Solving Test, an Arithmetic Problem Solving Test, the Make up Problems Test or a test for verbal creativity. The treatment group did, however, score significantly higher on the Childhood Attitude Inventory for Problem Solving.

By using a method of hands-on "guided discovery" with sixth grade students, Heaney (58) showed an improvement in the problem solving ability when compared to students exposed to the same subject matter through lecture-demonstration. The students in the "guided discovery" group also scored significantly better in applying their problem solving skills to problems in biology with which they had not had previous experience.

Learning Theory as It Applies to Transfer of Problem-Solving Skills

Current learning theories have interesting implications concerning the topic of transfer of problem solving skills to novel situations.

Gagne (59) poses the following ideas about teaching for transfer:

> What kinds of events support and encourage the transfer of learning? First, it may be noted that transfer requires a suitable design of the learning hierarchy itself, which needs to include the kinds of subordinate capabilities that are relevant to the range of performances for which instruction is designed. As for the conditions of instruction themselves, some evidence suggests the importance of a variety of settings and examples in facilitating transfer of learning to new problems...Perhaps the most dependable factor in the instructional situation for insuring transfer of learning is the thorough learning of the original concept or principle (p. 38).

Bruner (60) suggests that if the student discovers relationships on his own, he is more likely to internalize concepts and to see the application of the concepts to other problems later on.

Bruner (61) goes on to say:

> There is good evidence that too strong an incentive for learning narrows the learning and renders it less generic, in the sense of its being less transferable. When learning is dominated by strong extrinsic rewards and punishments, it becomes specific to the requirements of the particular learning task (p. 136).

Inhelder and Piaget (62) have stated that the pursuit of a generalizing rule distinguished formal thought from concrete thought. A subject at the concrete stage of development can describe and explain observations and other concrete experiences, but does not have the ability to generalize to other situations and construct rules to fit all situations (63). Inhelder and Piaget also state that until a person reaches the advanced formal operational stage (substage III b) he will not experience "the need to find a factor which is not only general but also necessary--i.e., which will serve to express beyond the constant relations the very reason for these relations (64, p. 11). This finding seems to imply that wholesale transfer of training should not be expected unless the student is at the formal operational stage, especially with formulating hypotheses which would require high level hypothetic-deductive thought.

Process Oriented Science Curriculum Projects

The past fifteen years have seen the development of several process oriented science curriculum projects. The most widely implemented elementary science projects have been Science--A Process Approach (SAPA), the Elementary Science Study (ESS), and the Science Curriculum Improvement Study (SCIS).

Although they differ from each other in important ways, all three of these curriculum projects are inquiry oriented with the primary emphasis on concrete objects, events, and/or situations that can be studied in a concrete way. They all lead the children through an investigation of objects which produces data that the learner is lead to interpret (65). The emphasis on hands-on concrete experiences is designed to take into account the cognitive development of the learner (66). In fact Thiel and George (67) have suggested that these hands-on, process-oriented curricula may provide necessary developmental experiences which promote cognitive development. Also Johnson (68) has found evidence that the SAPA and ESS lessons significantly increase the IQ scores of disadvantaged children.

All three programs have an emphasis on content as well as process. The group developing the Science--A Process Approach program commented especially about the importance of content by asking and answering this question:

> What is the Place of the Content (Facts) of Science in This Process-Oriented Program?
>
> Certainly you cannot teach scientific processes without using some content. Much science content is included in Science--A Process Approach, but the emphasis is on the process. In order to attain competence in the processes of science, children deal with such topics as plants,

> animals, energy, light, temperature, heat, solids, liquids, gases, life cycles, electricity, magnetic fields, motion, falling bodies, forces, the sun's motion and many others. The children become very interested in and curious about the topics they are studying even though the primary objective of the instruction is for them to acquire new competencies in the process of science. Many will pursue their aroused interest through additional tests and investigations and through reading (69, p. 11).

Inherent within the Science--A Process Approach curriculum is a strong emphasis on the various skills outlined earlier as being essential for problem solving. While moving through the sequence of modules within the SAPA program, the student progresses up a hierarchy of process skills following the Gagne learning hierarchy model (70). There is also emphasis on continuity in the content, but it is not as tightly structured as is the process continuity (71).

Within each module in the SAPA II program is found at least one generalizing experience, which is designed to give training in the various process skills in a variety of situations. Thus it seems that the new elementary science curricula in general, and SAPA in particular, contain the primary elements cited by the authors above for teaching problem-solving skills and for maximizing transfer of these skills to other problems. In fact the developers of SAPA II have stated the following goals of the SAPA II program as they relate to the learning of problem-solving processes and the transfer of these skills to other areas:

> The program is designed to enable children to acquire competencies in the processes that scientists use--the processes of science. In learning what scientists do, the children become highly involved in using the processes of science.... Scientific knowledge is increasing so rapidly that it is impossible for scientists themselves to keep up-to-date in all sciences. It is likewise impossible for the pupils to learn everything. One strategy is to equip each child with skills he can use to find solutions to

> scientific or other problems he may find in the future.... Instruction provides children an opportunity to practice a way of defining and solving problems (72).

However, the developers of the various programs have received criticism for failing to evaluate their programs in an effective manner for the transfer of problem-solving skills to a different type of problem or to the general school curriculum. Arthur Livermore (73), one of the major contributors to the development and implementation of the "Science--A Process Approach" curriculum, acknowledged that during the development and implementation of the program, transfer of process skills to other areas of the school curriculum had been checked only by an informal teacher survey asking whether the teacher felt that transfer had taken place.

In an ex post facto study Weber (74) compared the science problem-solving skills of fifth grade students in one city who had received four years instruction in SCIS with students in another city who had not received SCIS science instruction. The vocabulary and tasks covered in the process oriented instrument seemed very similar if not identifical to the vocabulary and tasks covered in the SCIS curriculum materials. Thus it was not surprising to the author that the group who had been exposed to the SCIS curriculum for four years scored significantly higher than the group which had not.

In another ex post facto study Linn and Thier (75) attempted to determine the effect of the SCIS unit "Energy Sources" upon the logical thinking abilities of fifth grade students. To test these abilities the assessment task chosen was compensating variables which is based on ideas taught in the Energy Sources unit but is not explicitly covered in the unit. The SCIS group did significantly better on the test than those students who had not received the Energy Sources unit.

In an ex post facto effort to check for transfer of problem solving skills taught in science to other academic areas, Coffia (76) compared the Stanford Achievement Test (SAT) scores of fifth grade students in a university city who had been exposed to SCIS for four years with the scores of students in a non-university city who had not received a process oriented science program. In comparing math skills, math concepts, math application, social studies content, social studies skills, word meaning and paragraph meaning, he found a significant difference at the 0.10 level of confidence between the two groups on the math application and social studies skills portion of the test. This investigator, however, questions whether the difference in the scores of these two groups on a non-process oriented achievement test such as the SAT is valid evidence of transfer of problem solving ability from science to other subject matter areas.

Davis, et al. (77) found no significant difference in SAT scores between students in grades four, five, and six who had used the SAPA science program and students who had used a textbook program. However, the SAPA group did score significantly higher on the Torrance Test of Creative Thinking which is designed to test for verbal fluency and verbal flexibility. The researchers state that both of these components are necessary for divergent thinking and problem solving, however, they did not offer experimental evidence to support this statement.

Thus it seems that some studies suggest that these process oriented curricula may enhance the transferability of problem solving skills, however, an extensive literature search did not reveal a single well controlled study directing itself to that problem.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

This study was undertaken to assess the effectiveness of the teaching of problem solving skills within the science curriculum upon the learner's ability to operationally utilize these skills in science and social studies. This assessment for the science portion of the study was accomplished by comparing the scores of the two groups on a science process instrument; one group had studied science with an emphasis on process, the other group had studied science with an emphasis on content. This assessment for the social studies portion of the study was accomplished by comparing the scores of these same two groups on a social studies process-oriented instrument.

The validity of Gagne's (78) model proposing the necessity of a hierarchy of problem solving skills was also checked. This was done by analyzing test scores to determine if a score signifying mastery of the lower process skills was a requirement for a score signifying mastery of the integrated process skills.

The procedure of this study involved five major steps: (1) selection and assignment of subjects, (2) administering the treatment, (3) designing the science and social studies process-oriented instruments, (4) administering the instrument, and (5) the statistical treatment.

Assignment of Subjects to Groups

The following procedure was used to control for differences between groups, the time of day factor and the teacher variable.

The subjects in this study consisted of four science classes of sixth grade students attending the Stillwater Middle School during the 1975-76 school year. Two of the classes were taught by the investigator and two were taught by a fellow sixth grade science teacher. The investigator and the other teacher shared the same office, had rooms directly across the hall from each other and as a team planned all activities for the sixth grade science program. Both teachers taught sixth grade science exclusively, each having a total of five classes. Of the four classes used in the study each teacher had one control group and one treatment group. The activities for the control and treatment groups were "piloted" in the classes not used in the study a few days before they were presented to the control and treatment groups which were used for the study. Approximately one hour each day was spent in jointly planning activities and discussing means of reducing between teacher variability. Thus the teacher variable was controlled by: 1) having each teacher teach both control and treatment groups, and 2) having both teachers pilot the control and treatment activities.

For the 1975-76 school year the sixth graders attending the school where the study was conducted were randomly assigned by a computer to two teams with approximately one hundred seventy students on a team. Each team of students was instructed by five teachers, one teacher for each of the subject matter areas of science, social studies, language arts, math and reading.

The sixth grade curriculum in social studies, math, language arts, and reading is best described as a traditional, text book oriented curriculum. The sixth grade social studies program covered world history and geography.

The students on each team were then randomly assigned to all classes except that students on team A taking band and orchestra took these instrumental music classes during third period and those on team B took instrumental music second period. Since the students in classes on Team A meeting during the third period and those on Team B meeting during the second period were not drawn from the total population of sixth grade students, data from these two classes were not used in the study. The test scores of any student whose schedule was changed or for any other reason was not randomly assigned to a schedule were not used in the study. Forty-six students met the above criteria in the two treatment classes while the scores of thirty-seven students were used from the two control classes. Table I may help clarify the above discussion.

The time of day factor was controlled as far as possible by assigning teacher A a treatment group at the same time that teacher B was assigned a control group and vice versa. The treatment to group assignment was made by the single flip of a coin since the assignment of the treatment for any of the four classes used in the study automatically determined the assignments for all the other classes.

Administering the Treatment

The Science...A Process Approach II (SAPA II) curriculum was chosen as the program to be administered to the treatment group. The SAPA II

TABLE I

DAILY SCHEDULE FOR TEACHERS INVOLVED IN THE STUDY

	Period	Science Teacher A Team A	Science Teacher B Team B
8:30-8:45	Home Room	Home Room	Home Room
8:45-9:40	1	Control Group[1] Used in Study	Treatment Group[1] Used in Study
9:45-10:40	2	Treatment Group[1] Used in Study	Pilot Treatment Group[2] Not Used in Study
10:45-11:40	3	Pilot Control Group[2] Not Used in Study	Control Group[1] Used in Study
11:45-1:20	4 & Lunch	Pilot Treatment Group[1] Not Used in Study	Pilot Control Group[1] Not Used in Study
1:25-2:20	5	Plan	Pilot Control Group[1] Not Used in Study
2:25-3:20	6	Pilot Treatment Group[1] Not Used in Study	Plan

[1]Students randomly assigned to these classes from total population of sixth grade students.

[2]These classes do not include students taking instrumental music.

program is a K-6 curriculum made up of one hundred five modules dealing with various content topics in mathematics, earth science, physical science, and biological science. The modules are arranged in a hierarchy according to the processes used in the modules. The basic and intermediate processes are covered in modules one through sixty-one. These are normally taught in grades kindergarten through three, while the integrated processes are covered in modules sixty-two through one hundred-five. These integrated processes are normally taught in grades four through six. The philosophy of the program is to use the science content as a vehicle to teach the science processes. This program was chosen for the following reasons:

(1) It has a strong emphasis on the processes defined as problem solving in this study.

(2) The instructions for the teacher are detailed and explicit enough so that between teacher variability could be reduced to a minimum.

(3) Because of the detailed and explicit instructions, the study could be easily duplicated at a future time by other investigators.

The authors of the SAPA II program have identified certain modules as Delayed Entry Back-Up Topics (DEBUT). These are key modules to be used to quickly teach a student the basics of the various processes. The rationale behind the identification of these modules is summarized as follows:

> Frequently individual children or entire schools are introduced to Science...A Process Approach II without the opportunity to acquire the skills developed in the lower levels of the program.... Delayed entry into the program can be accomplished smoothly for groups by backing up for

> remedial instruction in essential areas.... Delayed Entry Back-Up Topics represent key aspects of each of the processes. The simplest most effective modules were designated DEBUT modules (79).

The DEBUT modules appropriate for sixth grade children were included in this investigation to ensure that prerequisite skills and processes were covered before the students were introduced to the integrated processes. These modules are shown in Table II.

Although the primary emphasis in modules 70, 72, 75 and 80 is on the process designated in Table II, all four integrated processes are covered in each of these modules. These eleven modules were covered over a period of twenty-four weeks.

During this same time period the control classes were engaged in units which contained the same content as the SAPA II material, but which had no emphasis on process. The time spent with hands-on activities was the same for both the control and treatment groups. For example, students in the treatment group might be working on Module 64 entitled "Cells, Lamps, Switches-Defining Operationally," in which they write operational definitions and use operational definitions to recognize and construct series, parallel, and short circuits and fuses using dry cells, lights, motors, and switches. The primary emphasis in the activities and discussion was the use of and need for operational definitions. At the same time students in the control group are involved in activities covering the same content (series, parallel, and short circuits and fuses) with the same amount of time spent on hands-on, laboratory activities and also discussion. However, with the control group the primary emphasis was on the various uses of series and parallel circuits, safety factors involved in working with electricity, and why fuses are used in circuits.

TABLE II

SAPA II MODULES USED IN STUDY

Module Number	Title	Process(es) Emphasized
39*	Solids, Liquids, and Cases	Measuring
46*	Observations and Inferences	Observing and Inferring
59*	Metersticks, Money and Decimals	Using Numbers
61*	Circuit Boards	Inferring
62*	Climbing Liquids	Controlling Variables
63*	Maze Behavior	Interpreting Data
64*	Cells, Lamps, and Switches	Defining Operationally
70*	Conductors and Nonconductors	Formulating Hypotheses
72	Heart Rate	Controlling Variables
75*	Graphs and Pendulums	Interpreting Data
80	Inertia and Mass	Defining Operationally

*DEBUT Modules

This format was followed on all modules except the first four which dealt with the basic and intermediate processes of measuring (Module 39-Solids, Liquids and Gases) observing and inferring (Module 46-Observations and Inferences), using numbers (Module 59-Metersticks Money and Decimals), and predicting and inferring (Module 61-Circuit Boards). These four modules were used with both the control and treatment group in order to test hypothesis H_{11}: "Training in the integrated processes in science will not improve the students' ability to utilize the basic or intermediate processes in science," and H_{20}: "Training in the integrated processes in science will not improve the students' ability to utilize the basic or intermediate processes in social studies." Since both the control and treatment groups had the same training in the basic and intermediate processes, a difference in the scores on these processes would have to be due to the students' training in the integrated processes.

The section below summarizes the emphasis in the various modules taught to the control and treatment groups. The SAPA II modules are commercially available from Ginn and Company. The alternate activities were designed by the investigator and are outlined in greater detail in Appendix B.

Module 39, "Solids, Liquids and Gases-Measuring," was used with both the treatment and the control group. This module is designed to teach metric measurement of volume and also the properties of solids, liquids, and gases.

Module 46, "Observations and Inferences-Inferring," was used with both the treatment and control groups. The objectives of this module are to teach the child to (1) distinguish between observations and inferences, (2) construct one or more inferences from an observation or set of observations, and (3) demonstrate that inferences may need to be revised on the basis of additional observations.

Module 59, "Metersticks, Money and Decimals- Using Numbers," was used with both the control and the treatment groups. The objectives of this module are to teach the child to (1) find points on a number line, (2) use decimal notation for tenths and hundredths and (3) identify and name fractional parts of a meter.

Module 61, "Circuit Boards,-Inferring," was also used with both the control and the treatment groups. This module is designed to teach the children to (1) construct a complete electrical circuit, (2) make inferences about hidden circuits, and (3) predict the expected outcome of tests based on inferred connection patterns.

Module 62, "Climbing Liquids-Controlling Variables," was used only with the treatment group. The objectives of this module were to teach the students to (1) identify controlled, manipulated, and responding variables and (2) identify variables which might affect the rate of upward movement of liquids through materials.

The alternate activities used with the control group included observation of a water drop on waxed paper, paper chromotography and capillary action in soil. The objectives of these activities were to teach the student (1) the properties of water (cohesion and adhesion) which make capillary action possible, (2) the importance of capillary action in plant growth, and (3) how capillary action can be used by scientists to separate compounds.

Module 63, "Maze Behavior-Interpreting Data," was the next module used with the treatment group. The objectives of this module were to teach the students to (1) construct a graph showing how an animal's performance depends on the number of trials, (2) use the graph to predict future performance of the animals, (3) identify the data which support and which do not support the statement that time required to perform a task will generally be shortened after a number of trials, (4) operationally define learning in terms of the maze, and identify variables which may affect the rate of learning.

While the treatment group was engaged in Module 63, the control group was participating in various animal behavior activities including running animals through a maze, observing the grooming, cleaning and other on-going behaviors of gerbils, and observing the behavior of a male Siamese Fighting Fish under various conditions. After finishing this unit the students should have been able to (1) construct and read a graph (but not make predictions from, or in other ways interpret, the data contained in the graph), (2) identify repetition as a factor in learning and (3) identify behaviors helpful to an animal's survival.

The next module in the series for the treatment group was Module 64, "Cells, Lamps, and Switches-Defining Operationally." This module is designed to teach the student to (1) identify a simple electric circuit or part of an electric circuit on the basis of an operational definition, and (2) distinguish between an operational and a non-operational definition.

At the same time the control group was engaged in various activities including constructing series, parallel, and short circuits, using dry cells, switches, lights, motors, resistors and fuses. The objectives of this unit for the control group were that the student should be able to (1) construct and identify uses for series and parallel circuits, (2) identify uses for fixed and variable resistors, (3) explain the use of a fuse in a circuit, and (4) identify safety factors which need to be observed when working with electricity.

Module 70, "Conductors and Nonconductors-Formulating Hypotheses," was the next module used by the treatment group. By the end of this module the students should have been able to (1) distinguish between statements that are hypotheses and those which are not, (2) distinguish between statements that support a stated hypothesis and those which do not, (3) construct a hypothesis from a set of observations, and (4) construct a prediction based on a hypothesis.

The alternate activity for Module 70 which was used by the control group included activities concerning the means of heat transfer (radiation, conduction, and convection) and how this could be speeded or slowed by such means as dead air space, insulation, increased surface area, or color. The concepts of molecular motion and thermal expansion were also covered.

The next module for the treatment group was Module 72 entitled "Heart Rate-Controlling Variables." At the end of this module the students should have been able to (1) name variable controlled and variables not controlled in an investigation of human heart rate, (2) construct hypotheses about the effect of one manipulated variable on a responding variable given data in a table or graph, (3) construct a test to show the effect of one manipulated variable on a responding variable in an investigation of heart rate, and (4) identify data about human pulse rate and describe how the data support or do not support the hypothesis.

While the treatment group was working on Module 72, the control group was engaged in activities which included a study of factors affecting the heart rate, location of pressure points and the use of pressure points to control bleeding, the functions of the veins and arteries, and how to recognize a heart attack victim. The objectives of these activities were to acquaint the student with (1) the organs of the circulatory system and the functions of these organs and (2) some knowledge of first aid as it relates to the circulatory system.

The next module the students in the treatment group encountered was Module 75, "Decimals, Graphs and Pendulums-Interpreting Data." The activities for this module included work with pendulums, levels, and balances. After they had finished this module the students should have been able to (1) construct a graph using number pairs expressed in tenths and/or larger numbers, (2) make interpretations of data shown in a graph and (3) identify controlled, manipulated and responding variables in the various activities.

Alternate activities for the control group also included work with pendulums, levers, and incline planes, but the emphasis was on using these mechanisms in machines. When the students finished the unit they should have been able to (1) determine the mechanical advantage of a lever and incline plane, (2) explain why a pendulum would be used in a clock, and (3) state that when using a lever or an incline plane that $force_i \times distance_i = force_2 \times distance_2$.

The last module used in this series for the treatment group was

Module 80, "Inertia and Mass, Defining Operationally." In this module the students used small, four-wheeled carts and weights to establish a relationship between mass and inertia and operationally defined inertia. They also constructed an operational definition of mass by using an equal-arm balance, and then went on to construct an alternative operational definition of mass by using a "mass vibrator," graphing the results and interpreting the graph.

The control group also covered the topics of mass, inertia and speed but did not engage in operationally defining or interpreting data from graphs. When finished with the unit, the students should have been able to (1) determine the speed of a moving object, (2) state that there is a direct relationship between mass and inertia, and (3) state that the force needed to change the motion of an object is proportional to the mass of the object.

The seven modules focusing on the integrated processes were chosen to provide a fairly extensive background of experiences dealing with these various problem solving skills.

Development of an Instrument to Test for Problem Solving Activity

A major task in this study was the development of instruments which adequately tested for the various science process skills and for these same process skills in social studies. It was realized that an individually administered instrument which would actually utilize hands-on activities might be a superior method for testing a student's problem-solving ability in science. However, this means of testing would present problems because of the difficulty of adapting much of the social studies content to hands-on activities in a testing situation, the limited amount of available manpower, and the inability to carefully control a hands-on testing situation. Therefore, the decision was made to use a paper and pencil instrument. Several authors (80, 81, 82, 83) have developed various tests for evaluating the students ability to use the process skills in science. However, none of these tests include all eleven of the process skills and most are not appropriate for sixth grade students. The Westinghouse Learning Corporation in 1975 had developed a School Curriculum Referenced Evaluation (SCORE) designed to test for various science process skills in the fourth, fifth, and sixth grades (84). Twenty-eight of the items in the final science instrument used in this study were obtained from the SCORE tests.

No corresponding process oriented test in the social studies could be located, so the social studies instrument was developed by the investigator especially for this study.

Each of the two tests contained several questions on each of the basic, intermediate, and integrated process skills. Several objectives were written for each process skill then two questions were written to test for each objective, one question containing science content, the other question containing social studies content. The complete science and social studies instruments and a complete list of objectives are included in Appendix A. Examples of these objectives and questions are given below.

Performance Objective 1

The student will choose the hypothesis which is being tested in an experiment.

Performance Objective 2

The student will identify variables which should be held constant in an experiment.

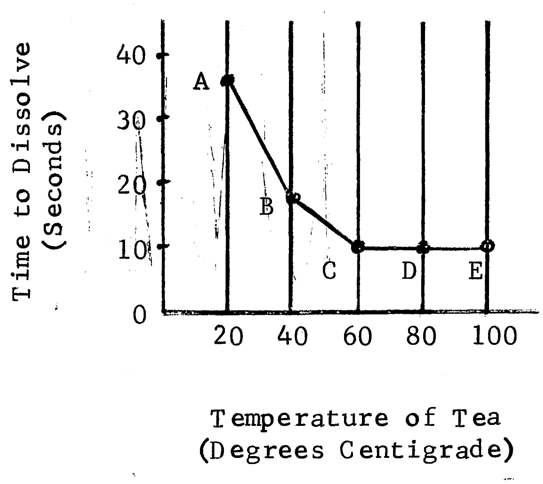
Performance Objective 3

The student will identify data on a line graph that supports a hypothesis.

Sample questions from the science instrument which test for the above objectives:

Read the following story and answer the next three questions.

Sue could not get two teaspoons of sugar to dissolve in her iced tea unless she stirred for a long time. She knew she could easily dissolve the sugar in hot tea. Sue wondered if the temperature made a difference in the amount of time it took for the sugar to dissolve. After trying five different temperatures, She got the results shown on the graph.



Question for Objective 1

The hypothesis Sue was testing was probably

(A) The colder the tea, the quicker the sugar will dissolve.
(B) The sugar will dissolve at the same rate in 60° tea as it does in 100° tea.
(C) The hotter the tea the quicker the sugar will dissolve.
(D) The temperature of the tea does not affect how rapidly the sugar dissolves.

Question for Objective 2

While doing the experiment it would probably be best if Sue would

(A) use iced tea glasses for low temperatures and a tea cup for high temperatures.
(B) stir the tea at the low temperatures to help the sugar dissolve faster.
(C) use the same amount of tea each time.
(D) use tea bags to make the hot tea and use instant tea for the lower temperatures.

Question for Objective 3

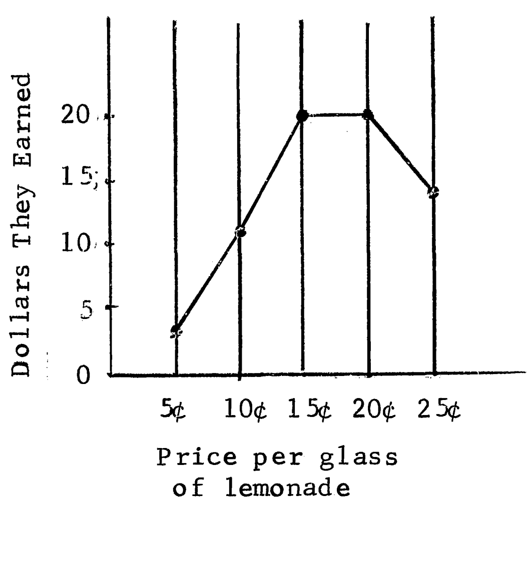
Which part of the graph supports Sue's hypothesis

(A) $\overline{AB}$
(B) $\overline{CD}$
(C) $\overline{DE}$
(D) the whole graph supports the hypothesis.

Sample questions from the social studies instrument which test for the same objectives:

Read the following story and answer the next three questions.

Bob and Betty made money during the summer by selling lemonade in a lemonade stand at the lake. They had been selling the lemonade for 25¢ a glass. They thought that maybe if they lowered their price, more people would buy lemonade and they could make more money. Each weekend for five weekends, they sold lemonade for a different price. They kept careful records of the amount of money they made at each price. This graph shows their results.



Question for Objective 1

The hypothesis for Bob and Betty were testing was probably

(A) the higher the price, the more money they will earn.
(B) the same amount of lemonade will be sold no matter what the price.
(C) the lower the price, the more money they will earn.
(D) they will earn the same amount of money at 15¢ a glass that they do at 20¢ a glass.

Question for Objective 2

When doing this experiment Bob and Betty should

(A) move their stand to a different place each time they change the price.
(B) give away gum when they charge more for the lemonade so the people would not feel cheated.
(C) be sure that the lemonade tasted the same all the time.
(D) lower the price on rainy days to try to sell more lemonade.

Question for Objective 3

Which part of the graph supports their hypothesis

(A) $\overline{DE}$
(B) $\overline{CD}$
(C) $\overline{AB}$
(D) the whole graph supports their hypothesis.

The content chosen for the questions on the science test did not contain material which had been covered in any of the eleven modules. The content of the questions on the social studies instrument was chosen from general material which the investigator felt would be familiar to the students, but not necessarily covered in class and certainly not covered in a process-oriented manner. After being reviewed by a panel of judges, the tests were given to two students not taking part in the study. After some revisions each test item was evaluated by three experts in each of the two subject matter areas on the basis of (1) whether the item tested the stated objective, and (2) whether the item was technically sound. Items in the two tests were either revised or deleted so that any item included in the test was judged by all three experts to meet the two criteria tested above.

The two tests were then piloted with twenty, sixth grade students in another school district in a further effort to identify confusing or ambiguous questions, after which a few minor revisions were made. The end result was two tests, each consisting of sixty-two items, which tested various aspects of the eleven basic, intermediate and integrated processes. Each item in the science instrument had a parallel item in the social studies instrument both of which were written to test for the same performance objective.

The reading level of the two tests was determined using the Dale-Chall readability formula with the following modifications (85).

1. Words in the graph or picture sections were not counted.
2. Numbers were counted as familiar words.
3. Where the question stem and/or distractors were incomplete sentences, they were joined and treated as one complete sentence for each answer, thus the question stem was assumed to be repeated for each distractor.
4. Symbols such as x, =, etc. were counted as familiar words.

Otherwise the complete instructions for using the Dale-Chall Readability Formula were followed. The reading level for the science test was estimated to be 6.0 and the social studies test was 6.2. The investigator feels that these values are somewhat inflated due to the fact that no metric units (gram, centimeter, etc.) are found on the Dale-Chall familiar word list while English units are included. Since the students had used the metric system extensively throughout the

the school year, the investigator feels that the students were familiar with these words. If metric units had been considered as familiar words, the estimated reading level of the tests would have been 5.5 for the science instrument and 5.8 for the social studies instrument. Twenty-three percent of the students taking part in this study had Stanford Achievement Test scores which fell below these estimated reading levels for the two instruments.

A split-half reliability coefficient was determined for both tests (86). The reliability coefficient for the science instrument was 0.924 while the social studies instrument had a realiability coefficient of 0.921.

Administering the Instruments

The students in the four classes used in the study were told that they would be taking more tests in science and social studies like the standardized tests (Stanford Achievement Tests) they had taken earlier. Testing was scheduled for two periods on each of two consecutive days. Half of the students were given the social studies test first while the other half received the science test first in order to control for any variance which might be due to the order of testing. On the second day, the order was reversed.

The science instrument was administered by the science teachers in the regular science classroom. The social studies instrument was administered by the social studies teachers in the regular social studies classroom. Each test was broken down into two fifty minute sessions with a five minute break between the sessions. There were only two students who did not complete all the items within the allotted time.

Statistical Treatments

Two statistical designs were needed to test the hypotheses in this study. For H_1 through H_{28} the t test was used to test the null hypothesis of no significant difference between test scores of the treatment group as compared to the control group.

To determine if mastery of the basic processes is a prerequisite to mastery of the integrated processes, the following table was constructed.

Integrated Processes		Basic Responses: Lack Mastery (0-60% correct responses)	Basic Responses: Mastery (70-100% correct responses)
	Mastery (70-100% Correct Responses		
	Lack Mastery (0-60% Correct Responses)		

Figure 3. Contingency Table to Be Used to Test Hierarchy Model of Problem Solving Processes

A simple Chi-square test will be used to check the relationship between the subjects' scores on the basic processes as compared to their scores on the integrated processes. However, further interpretation of the table will be needed before H_{29} can be accepted or rejected. Scores falling in the lower right box would support the hierarchy model (i.e., a student could master the basic processes and might not yet have mastered the integrated processes). However, scores falling in the upper left box would not support the hierarchy model since that would suggest that a student could master the integrated processes without first mastering the basic processes. The control group had received training in the basic processes but not in the integrated processes, and therefore it would be quite possible that many scores from the control group would occur in the lower right box. Since this would artifically support the hierarchy model, only scores from the treatment group were used in testing H_{29}.

Summary

The experiment sought to determine if sixth grade students instructed in the use of integrated processes in science would be significantly better problem solvers in science and social studies than students who had not received instruction in the integrated processes. One science instrument and one social studies instrument were developed to assess problem solving ability in those two areas. The t test was used to compare the responses on the two instruments. The Chi-square test was used to test the hierarchy model of process skills.

Between group differences were controlled by random assignment of subjects to group. Other variables such as amount of time spent on concrete hands-on experiences, time of day factor, teacher variables, differences between teachers, and testing situation were controlled as carefully as possible through the experimental design and the piloting of the program with students not involved in the study.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Effect of Training on Problem Solving Ability in Science

For this study students were randomly assigned to treatment and control groups. The treatment group received training within the science curriculum in the integrated process skills needed for effective problem solving while science content was the primary emphasis for the students in the control group.

After twenty-four weeks of treatment, a science instrument and a social studies instrument were administered to evaluate the students' ability to utilize problem solving process skills in these two content areas.

To determine if there was a significant difference between the scores of the treatment and control groups on the portion of the science instrument dealing with the integrated problem solving processes a t test was employed. Because the use of the t test assumes homogeneity of variance, an F-maximum test for homogeneity of variances was employed for each t test used in this study. At no time did the F-maximum value even approach the 0.05 level of significance. Therefore it was assumed that both samples were drawn from a population with the same variances.

Stated in the null form, the hypotheses under consideration here are:

H_1 Training in the integrated processes through the science curriculum will not have an effect on the students' problem solving ability in science (all integrated processes combined).

H_2 Training in interpreting data through the science curriculum will not have an effect on the students' ability to interpret data in science.

H_3 Training in manipulating and controlling variables through the science curriculum will not have an effect on the students' ability to manipulate and control variables in science.

H_4 Training in defining operationally through the science curriculum will not have an effect on the students' ability to define operationally in science.

H_5 Training in formulating and testing hypotheses through the science curriculum will not have an effect on the students' ability to formulate and test hypotheses in science.

The following table shows the results of the t tests in regard to the above hypotheses.

TABLE III

t TEST FOR EFFECT OF TRAINING ON PROBLEM SOLVING ABILITY IN SCIENCE

Hypothesis	Mean Scores		t	df	p
	Treatment	Control			
H_1	17.870	13.892	2.765	81	0.007*
H_2	4.565	3.784	2.604	81	0.011*
H_3	6.435	4.405	2.853	81	0.006*
H_4	3.391	2.676	2.057	81	0.043*
H_5	3.478	3.027	1.274	81	0.206

*Significant at 0.05 level of confidence

Thus, the first four null hypotheses can be rejected. These results agree with the findings of other investigators who have also found that training students in these problem solving processes will improve their ability to utilize these processes (87, 88, 80, 90).

H_5, however, was not rejected. Possibly formulating and testing hypotheses requires a higher level of abstract thinking than the other processes or perhaps it was not covered as thoroughly as the other processes were. If formulating and testing hypotheses does in fact require a higher level of abstract thinking than the other processes, in the hierarchy of processes then possibly it should be included in an intermediate step between the other three integrated processes and the process of experimenting (91).

Effect of Training in Science on Problem Solving Ability in Social Studies

To determine if there was a significant difference between the scores of the treatment and control groups on the portion of the social studies instrument dealing with the integrated problem solving processes, the t test was again employed. The F-maximum test was again run on each process in order to check the assumption of equal variances. Again none of the F-maximum values even approached significance.

Stated in the null form, the hypotheses under consideration here are:

H_6 Training in the integrated processes through the science curriculum will not have an effect on the students' problem solving ability in social studies (all integrated processes combined).

H_7 Training in interpreting data through the science curriculum will not have an effect on the students' ability to interpret data in social studies.

H_8 Training in manipulating and controlling variables through the science curriculum will not have an effect on the students' ability to manipulate and control variables in social studies.

H_9 Training in defining operationally through the science curriculum will not have an effect on the students' ability to operationally define in social studies.

H_{10} Training in formulating and testing hypotheses through the science curriculum will not have an effect on the students' ability to formulate and test hypotheses in social studies.

The following table shows the results of the t tests in regard to the above hypotheses.

TABLE IV

t TEST FOR EFFECT OF TRAINING IN SCIENCE ON PROBLEM SOLVING ABILITY IN SOCIAL STUDIES

Hypothesis	Mean Scores		t	df	p
	Treatment	Control			
H_6	16.022	13.270	2.157	81	0.034*
H_7	3.522	3.270	0.903	81	0.369
H_8	6.500	4.703	2.968	81	0.004*
H_9	3.413	2.811	1.700	81	0.093
H_{10}	2.587	2.486	0.316	81	0.753

*Significant at the 0.05 level of confidence

The null hypothesis H_6 was rejected, thus it seems that problem solving processes taught in science will transfer to social studies. Although the treatment group did score higher on all four processes than the control group, only in the case of manipulating and controlling variable, H_8, was the difference large enough to be significant when these processes were considered individually. In the cases of H_7, H_9 and H_{10} the null hypothesis was not rejected.

Effect of Problem Solving Training in Science on Competency in the Basic and Intermediate Processes in Science

Would training in the integrated problem solving processes affect the students' competency in the basic and intermediate processes? Since both the control and the treatment group had received identical training in the basic and intermediate processes, any difference between the scores of these two groups on the portion of the tests covering the basic and intermediate processes would be due to the treatment group receiving training in the integrated processes while the control group did not. The t test was used to determine if these differences were significant.

Stated in the null form, the hypotheses under consideration here are:

H_{11} Training in the integrated processes in science will not affect the students' ability to utilize the basic processes in science.

H_{12} Training in the integrated processes in science will not affect the students' ability to observe in science.

H_{13} Training in the integrated processes in science will not affect the students' ability to classify in science.

H_{14} Training in the integrated processes in science will not affect the students' ability to measure in science.

H_{15} Training in the integrated processes in science will not affect the students' ability to use time/space relationships in science.

H_{16} Training in the integrated processes in science will not affect the students' ability to use numbers in science.

H_{17} Training in the integrated processes in science will not affect the students' ability to utilize the intermediate processes in science.

H_{18} Training in the integrated processes in science will not affect the students' ability to infer in science.

H_{19} Training in the integrated processes in science will not affect the students' ability to predict in science.

Table V shows the results of the t tests in regard to the above hypotheses.

Although the mean score of the treatment group was larger than the mean score of the control group in eight out of the nine hypotheses considered, in no case was the difference great enough to be significant. Therefore, the null hypotheses H_{11} through H_{19} were not rejected.

Effect of Problem Solving Training in Science on Competency in the Basic and Intermediate Processes in Social Studies

The hypotheses considered in this section are similar to those in the previous section except that they deal with the basic and intermediate processes in social studies rather than in science. Since both the control and the treatment group had received identical training in the

TABLE V

t TEST FOR EFFECT OF PROBLEM SOLVING TRAINING ON COMPETENCY IN THE BASIC AND INTERMEDIATE PROCESSES IN SCIENCE

Hypothesis	Mean Scores Treatment	Mean Scores Control	t	81	p
H_{11}	16.07	15.43	0.632	81	0.529
H_{12}	3.13	2.92	0.646	81	0.520
H_{13}	3.52	3.78	1.019	81	0.311
H_{14}	2.52	2.27	1.001	81	0.320
H_{15}	3.48	3.35	0.551	81	0.583
H_{16}	3.41	3.11	0.951	81	0.344
H_{17}	6.20	5.97	0.457	81	0.649
H_{18}	2.93	2.92	0.060	81	0.952
H_{19}	3.26	3.05	0.716	81	0.476

*Significant at the 0.05 level of confidence (none were significant) the basic and intermediate process skills in science and neither group had received training in these process skills in social studies, any difference in the scores of these two groups on the social studies instrument would be due to the treatment group receiving training in the integrated processes while the control group did not receive this training. The t test was employed to determine if these differences were significant.

Stated in the null form, the hypotheses under consideration here are:

H_{20} Training in the integrated processes will not affect the students' ability to utilize basic processes in social studies.

H_{21} Training in the integrated processes will not affect the students' ability to observe in social studies.

H_{22} Training in the integrated processes will not affect the students' ability to classify in social studies.

H_{23} Training in the integrated processes will not affect the students' ability to measure in social studies.

H_{24} Training in the integrated processes will not affect the students' ability to use space/time relationships in social studies.

H_{25} Training in the integrated processes will not affect the students' ability to use numbers in social studies.

H_{26} Training in the integrated processes will not affect the students' ability to utilize the intermediate processes in social studies.

H_{27} Training in the integrated processes will not affect the students' ability to infer in social studies.

H_{28} Training in the integrated processes will not affect the students' ability to predict in social studies.

The following table gives the results of the t test in regard to the above hypotheses.

TABLE VI

t TEST FOR EFFECT OF PROBLEM SOLVING TRAINING IN SCIENCE ON COMPETENCY IN THE BASIC PROCESSES IN SOCIAL STUDIES

Hypothesis	Mean Scores Treatment	Mean Scores Control	t	81	p
H_{20}	16.28	15.59	0.719	81	0.474
H_{21}	3.50	3.14	1.047	81	0.298
H_{22}	3.85	3.22	2.740	81	0.008*
H_{23}	2.55	2.54	0.014	81	0.989
H_{24}	3.34	3.35	0.014	81	0.989
H_{25}	3.04	3.35	1.144	81	0.256
H_{26}	6.09	5.95	0.281	81	0.779
H_{27}	2.85	2.92	0.248	81	0.805
H_{28}	3.24	3.03	0.703	81	0.484

*Significant at the 0.05 level of confidence

In six out of the nine hypotheses tested, the treatment group had a higher mean score than the control group. However, only one of these was significant. H_{22} which dealt with the process of classifying was significant at the 0.008 level of confidence. These results seem inconsistent with the other results of the study. Why would there be a significant difference on the social studies instrument for the process of classifying when there was no significant difference for this process on the science test and the training had taken place in science?

To investigate this further it was decided to examine the percentage of correct responses on each of the questions dealing with classifying on the social studies instrument. A z test for difference between two proportions was employed to determine if the differences on the individual questions were significant.

TABLE VII

z TEST FOR SOCIAL STUDIES QUESTIONS DEALING WITH CLASSIFYING

Question Number	Percent of Correct Responses: Treatment N=46	Percent of Correct Responses: Control N=37	z	P
7	39.1	30.6	0.81	0.481
8	95.7	89.2	1.29	0.197
13	82.6	86.5	0.48	0.631
14	91.3	69.4	2.55	0.010*
15	89.1	48.6	3.99	0.0001*

*Significant at 0.05 level of confidence

After examining these results, it is evident that a large part of the difference between the control group and the treatment group can be accounted for by two of the five questions dealing with the process of classifying, questions 14 and 15 on the social studies instrument. The two questions dealt with classifying primitive tools, weapons and containers.

Perhaps one of the science teachers had inadvertently deviated from the assigned subject matter with one of the treatment groups and had talked about classifying primitive tools and artifacts so that the students in that group had a decided advantage over the other treatment group and the two control groups. Or perhaps during the testing situation one of the teachers administering the social studies instrument had made some comment to students in one of the treatment groups which would give that treatment group an advantage.

A z test was employed to determine if the treatment group of one teacher did in fact score significantly higher on questions 14 and 15 than the treatment group of the other teacher.

TABLE VIII

z TEST COMPARING TEACHER 1 WITH TEACHER 2 ON SELECTED SOCIAL STUDIES QUESTIONS

Question Number	Percent of Control Responses Teacher 1 N=25	 Teacher 2 N=21	z	P
14	88.0	95.2	0.862	0.390
15	80.0	75.4	0.681	0.496

Thus it appears that between teacher variance would not account for the results on these two questions.

The possibility of the social studies teachers covering the material with the treatment group and not the control group was also considered. This was ruled out, however, for the following reasons:

(1) The social studies teachers were not aware of which students were in the control groups in science and which were in treatment groups.

(2) Since the students were randomly assigned to all classes, they did not travel as a classroom unit from one class to the next. Any single class in social studies would have been made up of approximately equal numbers of students from the control groups and from the treatment groups in science. Therefore, if the social studies teachers did happen to cover classification of primitive tools and artifacts with the students, students in the treatment groups would not have an obvious advantage over students in the control groups.

One possible explanation is that when the social studies teachers did discuss the various types of primitive tools, the students who had received training in the integrated processes somehow had an advantage in learning the material in social studies over those students who had not received training.

Testing the Hierarchy Model of Problem Solving Processes

Is mastery of the basic processes a prerequisite to mastery of the integrated processes as Gagne (92) has suggested? If some students in the treatment group score high enough on the integrated processes to indicate mastery but do not score high enough on the basic processes to indicate mastery, then the hierarchy model would not be supported.

However, if all students who master the integrated processes have also mastered the basic processes, the hierarchy model would be supported. The hypothesis under consideration here is:

> H_{29} Mastery of the basic processes is not a prerequisite to successful utilization of the integrated processes.

Scores indicating mastery or lack of mastery were arbitrarily chosen. A Chi-square test was employed to determine significance. The contingency tables for both instruments are Tables IX and X.

The correlation between scores on the basic processes and scores on the integrated processes was also determined. For the science instrument Rho equaled 0.836 and for the social studies instrument Rho equaled 0.826. Both of these correlation coefficients were significant at the 0.0001 level of confidence.

Thus it appears that mastery of the basic processes is a prerequisite for mastery of the integrated processes. Therefore, the null hypothesis was rejected.

Summary

Training in the integrated processes in science did affect the students' problem solving ability in science as well as improving the students' ability to interpret data, control and manipulate variables and define operationally in science. However, this training did not significantly affect the students' ability to formulate and test hypotheses in science.

The training in science also significantly affected the students' problem solving in social studies as well as significantly affecting the students' ability to manipulate and control variables. Thus it

TABLE IX

CONTINGENCY TABLE FOR X^2 TEST ON SCIENCE INSTRUMENT

		Lack Mastery 0 - 60%	Mastery 70 - 100%
Integrated Processes	Mastery 70 - 100%	1	12
	Lack Mastery 0 - 60%	12	1
		Basic Processes	

$X^2 = 18.61$ df = 1 $p = 0.0001$

TABLE X

CONTINGENCY TABLE FOR X^2 TEST ON SOCIAL STUDIES INSTRUMENT

		Lack Mastery 0 - 60%	Mastery 70 - 100%
Integrated Processes	Mastery 70 - 100%	0	10
	Lack Mastery 0 - 60%	13	4
		Basic Processes	

$X^2 = 14.75$ df = 1 $p = 0.0005$

appears that problem solving skills taught in science will also transfer to social studies. Although the mean scores were higher for the treatment group than the control group for the processes of defining operationally, interpreting data, and formulating and testing hypotheses, the differences were not significant at the 0.05 level of confidence.

Training in the integrated processes in science did not significantly affect the students' ability to utilize the basic or intermediate processes in science such as observing, classifying, measuring, using space/time relationships, using numbers, inferring or predicting. Neither did this training in science have a significant affect on the above basic and intermediate processes in social studies with the exception of the process of classifying which was significantly improved in social studies.

The results of this study also support the hierarchy model of problem solving processes by showing that mastery of the integrated processes is extremely unlikely without mastery of the basic processes.

CHAPTER V

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Summary

This study was designed to (1) determine the effect of a process oriented science curriculum on the problem solving ability of sixth grade students, (2) determine if this problem solving ability will transfer to social studies, (3) determine if training in the integrated processes in science increases the students' proficiency in the basic and intermediate processes in science and social studies, and (4) test models concerning problem solving skills in order to determine if there is evidence for a hierarchy of problem solving skills.

The subjects were randomly assigned to the science classes of two teachers. Four classes were selected for the study so that each teacher had one class to serve as a control group and one class to serve as a treatment group. The other classes were used to pilot the activities before they were introduced in the classes being used in the study.

The treatment group was administered a group of modules from the Science...A Process Approach II curriculum which has as a major emphasis the teaching process skills some of which are defined in this study to be problem solving skills. The control group was administered a set of activities which emphasized the same content as the SAPA II modules but had no emphasis on the process skills covered in the SAPA II modules. The amount of time spent with hands-on activities was the same for the control and treatment groups.

At the conclusion of this twenty-four week experiment two process oriented instruments, one for science and one for social studies, which had been designed for this study, were administered to assess the students' ability to utilize eleven basic, intermediate, and integrated process skills.

Training in the integrated processes in science did improve the students's problem solving ability in science. This training also improved the students' ability to control and manipulate variables, interpret data, and define operationally in science, but did not significantly improve their ability to formulate and test hypotheses.

Inhelder and Piaget (93) state that students at the concrete operational stage of cognitive development

> ...stick to dealing with facts whose accuracy is due to serial ordering and correspondence operations, but they do not seek to explain the facts further in terms of the formal operations of implications, etc., which are the conditions of hypothetico-deductive thought (p. 9).

This implies that some of the process skills, possibly formulating hypotheses, may require higher level operations than students who are probably only entering the transition between concrete and formal operational logic are capable of handling. Gagne (94) also presents a similar viewpoint. He feels that an eleventh grader has reached a point where he or she can speculate and formulate and test hypotheses, but that a sixth or seventh grade student is not yet able to deal with such abstractions and requires a concrete laboratory experience before a transition can be made to a more abstract level. This might possibly explain why no significant difference was found for the process of formulating and testing hypotheses.

The training in science also significantly affected the students' problem solving ability in social studies showing that the students did transfer their learning from science content to social studies content. While the students' ability to control and manipulate variables was significantly improved in social studies, there was not a significant increase in their ability to interpret data, define operationally, or formulate and test hypotheses in social studies.

Training in the integrated processes in science did not significantly affect the students' ability to utilize the basic or intermediate processes in science. The basic and intermediate processes assessed in this study were observing, classifying, using numbers, using space/time relationships, measuring, inferring and predicting. Also, training in science did not have a significant effect on the students' ability to utilize these basic and intermediate processes in social studies with the exception of the process of classifying which was significantly improved in social studies.

The results of this study indicated that mastery of the integrated processes was not achieved unless the student had also mastered the basic processes. This finding supports the hierarchy model of problem solving processes.

Conclusions and Implications

The findings of this study which support the hierarchy model of problem solving processes substantiates the importance of mastery of the basic and intermediate processes. Since mastery of the integrated processes was not achieved unless the student had mastered the basic processes, the implications are that it would be fruitless to attempt to teach the integrated problem solving processes to students if their background in the basic and integrated processes is deficient. It seems then that the first task of a teacher wishing to teach problem solving skills would be to determine the level of proficiency of his students in regard to the various process skills and begin instruction which would be most meaningful for that level of proficiency.

The results of this study show that the students who had the process oriented science curriculum score significantly higher on the science problem solving instrument than those students who received the science program emphasizing strictly content. It should be kept in mind that approximately fifty percent of the class time for both the control group and treatment group was spent in hands-on activities. Thus it appears that a laboratory approach to science alone is not sufficient to teach problem-solving skills. These results imply that if a teacher is interested in teaching problem solving processes in science, the teacher should develop or select a curriculum that has a strong and constant emphasis on the processes involved in problem solving.

The results of this study which show that problem solving processes learned in science will transfer to social studies gives merit to the idea that problem solving processes should be taught for their own sake since it has been shown that the student will transfer these problem solving skills to problems dealing with different content than the area in which he first learned the skills. Although it was not tested in this study, these results leave open the possibility that the use of these problem solving skills may actually transfer to non-academic areas and make a person a better problem solver throughout life as some of the curriculum developers claim.

Recommendations for Further Study

Several questions which merit further study are raised below.

(1) Although the null hypothesis was rejected in only one case out of fourteen, the numerical superiority of the treatment group over the control group on the basic and intermediate processes in eleven out of fourteen cases suggests this might be an area for further study. In a larger group or over a more extended period of time would training in the integrated processes significantly affect a students' ability to use the basic and intermediate processes?

(2) Does increased competency in these problem solving processes in science and social studies also increase a person's competency at solving problems in other academic areas as well as everyday problems encountered outside the academic environment?

(3) Is there a hierarchy of skills within the integrated processes?

(4) Are students who are successful in utilizing the various integrated processes (especially formulating hypotheses and interpreting data) able to operate at a higher level of cognitive thought than those who are unsuccessful?

(5) Are students who successfully transfer their learning from science to social studies at a higher level of cognitive development than those who do not.

Lawson and Renner (95) have found that forty to seventy-five percent of the high school students in one study had not yet reached the formal operational stage of cognitive development although they are biologically mature enough to attain this level of thought. One possible explanation is that these students have not received the appropriate experiences which would enable them to mature cognitively.

(6) Does a process-oriented science curriculum provide the appropriate experiences which would enable a person to attain the formal operational level of cognitive development?

A SELECTED BIBLIOGRAPHY

1. Thelen, Herbert. Education and the Human Quest (New York, 1960), pp. 21-28.

2. Bayles, Ernest E. "Thinking: A Pivotal Goal of Secondary Schools," The High School Journal, Vol. 55 (1972), pp. 243-255.

3. Hurd, Paul D. "The Education of Secondary School Biology Teachers," BSCS Newsletter, Vol. 13 (1962), pp. 3-8.

4. Taylor, Calvin W. "Educational Changes Needed to Develop Creative Thinking," Productive Thinking in Education, eds. Mary Jane Aschner and Charles Edward Bish (Washington, D.C., 1968), pp. 245-264.

5. Suchman, J. Richard. "Inquiry Teaching: Building Skills for Autonomous Discovery," Merrill Palmer Quarterly, Vol. 7 (1961), pp. 145-169.

6. _______. "Inquiry Teaching: Building Skills for Autonomous Discovery," Merrill Palmer Quarterly, Vol. 7 (1961), pp. 145-169.

7. Gagne, Robert M. The Conditions of Learning, 2nd ed., New York, 1970, pp. 260-264.

8. Bruner, Jerome. Toward a Theory of Instruction (Cambridge, 1961), p. 72.

9. Science...A Process Approach II, Planning Chart for Modules 1-60, Xerox Corporation (1975).

10. Gagne, Robert M. The Conditions of Learning, 2nd ed., New York, 1970, pp. 260-261.

11. _______. The Conditions of Learning, 2nd ed., New York, 1970, pp. 260-261.

12. Dewey, John. How We Think (Boston, 1938), p. 107.

13. Butts, Davis and Howard Jones. "Inquiry Training and Problem Solving in Elementary School Children," Journal of Research in Science Teaching, Vol. 4 (1966), pp. 21-27.

14. Science...A Process Approach II - The Architecture of a Revision, Xerox Corporation (1975), p. 4.

15. Parker, J. Cecil and Louis J. Rubin. Process as Content: Curriculum Design and the Application of Knowledge (Chicago, 1966), p. 2.

16. ______. Process as Content: Curriculum Design and the Application of Knowledge (Chicago, 1966), p. 1.

17. Kinsella, John J. "Problem Solving," The Teaching of Secondary School Mathematics, Thirty-third Yearbook of the National Council of Teachers of Mathematics (Washington, D.C., 1970), pp. 241-266.

18. Fair, Jean and Fannie R. Shaftel, eds. Effective Thinking in the Social Studies, Thirty-seventh Yearbook of the National Council for the Social Studies (Washington, D.C., 1967).

19. Turner, C. G. "Problem Solving, A Change Concept," The Science Teacher, Vol. 24 (1957), pp. 339-341.

20. Ausubel, David P. "Learning by Discovery: Rationale and Mystique," Bulletin of the National Association of Secondary School Principals, Vol. 45 (1961), pp. 18-58.

21. Ausubel, David P. "Some Psychological and Educational Limitations of Learning by Discovery," The Arithmetic Teacher, Vol. 11 (1964), pp. 290-302.

22. Lawson, Anton E. and John Renner. "Relationships of Science Subject Matter and Developmental Levels of Learners," Journal of Research in Science Teaching, Vol. 12 (1975), pp. 347-358.

23. Andersen, Hans O. and James E. Weigand. "Instructional Theory, Problem Solving and Science Teaching," School Science and Mathematics, Vol. 67 (1967), pp. 483-490.

24. Bruner, Jerome. Toward a Theory of Instruction (Cambridge, 1961).

25. Stollberg, R. J. "Problem Solving, the Precious Gem in Science Teaching," The Science Teacher, Vol. 23 (1956), pp. 225-228.

26. Loree, M. Ray. Problem Solving Techniques of Children in Grades 4-9, Cooperative Research Project #2608 Report to the Office of Education (University of Alabama, 1965).

27. ______. Problem Solving Techniques of Children in Grades 4-9, Cooperative Research Project #2608 Report to the Office of Education (University of Alabama, 1965).

28. Renner, John W., Don G. Stafford, and William B. Ragan. Teaching Science in the Elementary School, 2nd ed., New York, 1973, pp. 136-203.

29. Anderson, Ronald D., et al. Developing Children's Thinking Skills Through Science (Englewood Cliffs, 1970), pp. 216-219.

30. _______. Developing Children's Thinking Skills Through Science (Englewood Cliffs, 1970), pp. 216-219.

31. Butts, David P. and Howard L. Jones. "The Development of the TAB Science Test," Science Education, Vol. 51 (1967), pp. 463-473.

32. _______. "The Development of the TAB Science Test," Science Education, Vol. 51 (1967), p. 465.

33. _______. "The Development of the TAB Science Test," Science Education, Vol. 51 (1967), p. 464.

34. Butts, David P. and Howard L. Jones. "Inquiry Training and Problem Solving in Elementary School Children," Journal of Research in Science Teaching, Vol. 4 (1966), pp. 21-27.

35. Olton, Robert M. and Richard S. Crutchfield. "Developing the Skills of Productive Thinking," Trends and Issues in Developmental Psychology, eds. Paul Mussen, Jonas Langer and Martin Covington (New York, 1969), pp. 68-91.

36. Means, Gladys M. and M. Ray Loree. "The Influence on Problem Solving Ability of Following an Efficiency Model," Journal of Educational Research, Vol. 62 (1968), pp. 135-141.

37. Parks, Marshall E. "An Analysis of a Method for Improving Science Problem Solving Ability Possessed By Prospective Elementary Teachers," (unpub. paper presented to 43rd Annual Meeting of the National Association for Research in Science Training, Minneapolis, Minn., 1970).

38. Possien, Wilma Martens. "A Comparison of the Effects of Three Teaching Methodologies on the Development of Problem Solving Skills of Sixth Grade Children" (unpub. Ph.D. dissertation, University of Alabama, 1964).

39. Heaney, Sally. "The Effect of Three Teaching Methods on the Ability of Young Pupils to Solve Problems in Biology: An Experimental and Quantitative Investigation," Journal of Biology Education, Vol. 5 (1971), pp. 219-228.

40. Means, Gladys M. and M. Ray Loree. "The Influence on Problem Solving Ability of Following an Efficiency Model," Journal of Educational Research, Vol. 62 (1968), pp. 135-141.

41. Suchman, J. Richard. "Inquiry Teaching: Building Skills for Autonomous Discovery," Merrill Palmer Quarterly, Vol. 7 (1961), pp. 145-169.

42. Loree, M. Ray. Problem Solving Techniques of Children in Grades 4-9, Cooperative Research Project #2608 Report to the Office of Education (University of Alabama, 1965), p. 22.

43. Gagne, Robert M. "The Learning Requirements for Enquiry," Journal of Research in Science Teaching, Vol. 1 (1963), pp. 144-153.

44. Loree, M. Ray. Problem Solving Techniques of Children in Grades 4-9, Cooperative Research Project #2608 Report to the Office of Education (University of Alabama, 1965), pp. 22-26.

45. ______. Problem Solving Techniques of Children in Grades 4-9, Cooperative Research Project #2608 Report to the Office of Education (University of Alabama, 1965), pp. 17-18.

46. Sekyra, Francis III and M. Ray Loree. "Taped Instruction Effects on Problem Solving Skills of Seventh Grade Children," Journal of Research in Science Teaching, Vol. 1 (1963), pp. 144-153.

47. Thiel, Robert D. and Kenneth D. George. "Some Factors Affecting the Use of the Science Process Skill of Prediction by Elementary School Children," Journal of Research in Science Teaching, Vol. 13 (1976), pp. 155-166.

48. Case, Duncan and J. M. Collinson. "The Development of Formal Thinking in Verbal Comprehension," British Journal of Educational Psychology, Vol. 32 (1962), pp. 103-111.

49. Lawson, Anton E. and John Renner. "Relationships of Science Subject Matter and Developmental Levels of Learners," Journal of Research in Science Teaching, Vol. 12 (1975), pp. 347-358.

50. Tyler, Bonnie B. "Expectancy for Eventual Success as a Factor in Problem Solving Behavior," Journal of Educational Psychology, Vol. 49 (1958), pp. 166-172.

51. Bloom, Benjamin S. and Lois J. Broder. Problem Solving Processes of College Students (Chicago, 1950), pp. 106-109.

52. Andersen, Hans O. "Problem Solving and Science Teaching," School Science and Mathematics, Vol. 67 (1967), pp. 243-251.

53. Gagne, Robert M. "The Learning Requirements for Enquiry," Journal of Research in Science Training, Vol. 1 (1963), pp. 144-153.

54. Wittrock, M. C. and M. H. Jones, "Transfer of Rules: The Need for Tests of Transfer in the Evaluation of Instruction," ERIC Search, ED 035946 (1969), p. 35.

55. Luchins, Abraham S. and Edith H. Luchins. "New Experimental Attempts at Preventing Mechanization in Problem Solving," Journal of General Psychology, Vol. 42 (1950), pp. 279-297.

56. Covington, Martin V. and Richard S. Crutchfield. "Facilitation of Creative Problem Solving," Programmed Instruction, Vol. 4 (1965), pp. 3-5.

57. Treffinger, Donald J. "The Effect of Programmed Instruction in Productive Thinking on Verbal Creativity and Problem Solving Among Pupils in Grades Four, Five, Six and Seven" (unpub. Ph.D. dissertation, Cornell University, 1969).

58. Heaney, Sally. "The Effect of Three Teaching Methods on the Ability of Young Pupils to Solve Problems in Biology: An Experimental and Quantitative Investigation," Journal of Biology Education, Vol. 5 (1971), pp. 219-228.

59. Gagne, Robert M. The Conditions of Learning, 2nd ed., New York, 1970, p. 318.

60. Bruner, Jerome. Toward a Theory of Instruction (Cambridge, 1961), pp. 57-59.

61. ______. Toward a Theory of Instruction (Cambridge, 1961), p. 136.

62. Inhelder, Barbel and Jean Piaget. The Growth of Logical Thinking from Childhood to Adolescence (Basic Books, Inc., 1958), p. 11.

63. ______. The Growth of Logical Thinking from Childhoor to Adolescence (Basic Books, Inc., 1958), p. 9.

64. ______. The Growth of Logical Thinking from Childhood to Adolescence (Basic Books, Inc., 1958), p. 11.

65. Renner, John W., Don G. Stafford, and William B. Ragan. Teaching Science in the Elementary School, 2nd ed., New York, 1973, p. 283.

66. ______. Teaching Science in the Elementary School, 2nd ed., New York, 1973, p. 283.

67. Thiel, Robert D. and Kenneth D. George. "Some Factors Affecting the Use of the Science Process Skill of Prediction by Elementary School Children, Journal of Research in Science Teaching, Vol. 13 (1976), p. 161.

68. Johnson, Janice K. "Effects of the Process Approach Upon IQ Measures of Disadvantaged Children," Teaching Disadvantaged Children, Vol. 54 (1970), pp. 45-47.

69. Commission on Science Education. Commentary for Teachers of Science--A Process Approach (Washington, D.C., 1970), p. 11.

70. ______. Commentary for Teachers of Science--A Process Approach (Washington, D.C., 1970), pp. 5-7.

71. Renner, John W., Don G. Stafford, and William B. Ragan. Teaching Science in the Elementary School, 2nd ed., New York, 1973, p. 283.

72. Science...A Process Approach II, Planning Chart for Modules 1-60, Xerox Corporation (1975).

73. Livermore, Arthur. Personal communications (January, 1974).

74. Weber, Martin C. "The Influence of the Science Curriculum Improvement Study on the Learner's Operational Utilization of Science Processes" (unpub. Ed.D. dissertation, University of Oklahoma, 1971).

75. Linn, Marcia C. and Herbert D. Thier. "The Effect of Experimental Science on the Development of Logical Thinking in Children," Journal of Research in Science Teaching, Vol. 12 (1975), pp. 49-62.

76. Coffia, William J. "The Effects of an Inquiry-Oriented Curriculum in Science on a Child's Achievement in Selected Academic Areas" (unpub. Ed.D. dissertation, University of Oklahoma, 1971).

77. Davis, Terry, et al. "A Comparison of Achievement and Creativity of Elementary School Students Using Project vs. Textbook Programs," Journal of Research in Science Teaching, Vol. 13 (1976), pp. 205-212.

78. Gagne, Robert M. The Conditions of Learning, 2nd ed., New York, 1970, pp. 260-262.

79. Science...A Process Approach II, Planning Chart for Modules 61-105, Xerox Corporation (1975).

80. Dietz, M. A. and K. D. George. "A Test to Measure Problem-Solving Skills in Science of Children in Grades 1, 2 and 3," Journal of Research in Science Teaching, Vol. 7 (1970), pp. 341-351.

81. McLeod, Richard J., et al. "The Development of Criterion-Validated Test Items for Four Integrated Science Processes," Journal of Research in Science Teaching, Vol. 12 (1975), pp. 415-421.

82. Beard, Jean. "The Development of Group Achievement Tests for Two Basic Processes of SAPA," Journal of Research in Science Teaching, Vol. 8 (1971), pp. 179-183.

83. Jones, Howard L. "The Development of a Test of Scientific Inquiry Using the TAB Format and an Analysis of Its Relationship to Selected Student Behaviors and Abilities" (unpub. Ph.D. dissertation, University of Texas, 1966).

84. School Curriculum Referenced Evaluation in Science for Des Moines Independent Community School District, Des Moines, Iowa, Westinghouse Learning Corporation (Iowa City, Iowa, 1975).

85. Dale, Edgar and Geanne Chall. "Formula for Predicting Readability," Educational Research Bulletin, Vol. 27 (1948), pp. 11-20, 37-54.

86. Bruning, James L. and B. L. Kintz. Computational Handbook of Statistics (Glenview, Illinois, 1968), pp. 187-188.

87. Butts, Davis P. and Howard L. Jones. "Inquiry Teaching and Problem Solving in Elementary School Children," Journal of Research in Science Teaching, Vol. 4 (1966), pp. 21-27.

88. Olton, Robert M. and Richard S. Crutchfield. "Developing the Skills of Productive Thinking," Trends and Issues in Developmental Psychology, eds. Paul Mussen, Jonas Langer and Martin Covington (New York, 1969), pp. 68-91.

89. Means, Gladys M. and M. Ray Loree. "The Influence on Problem Solving Ability of Following an Efficiency Model," Journal of Educational Research, Vol. 62 (1968), pp. 135-141.

90. Suchman, J. Richard. "Inquiry Teaching: Building Skills for Autonomous Discovery," Merrill Palmer Quarterly, Vol. 7 (1961), pp. 145-169.

91. Anderson, Ronald D., et al. Developing Children's Thinking Skills Through Science (Englewood Cliffs, 1970), pp. 216-219.

92. Gagne, Robert M. The Conditions of Learning, 2nd ed., New York, 1970, pp. 260-262.

93. Inhelder, Barbel and Jean Piaget. The Growth of Logical Thinking from Childhood to Adolescence (Basic Books, Inc., 1958), p. 9.

94. Gagne, Robert "The Learning Requirements for Enquiry," Journal of Research in Science Teaching, Vol. 1 (1963), pp. 144-153.

95. Lawson, Anton and John Renner. "Relationships of Science Subject Matter and Developmental Levels of Learners," Journal of Research in Science Teaching, Vol. 12 (1975), pp. 347-358.

APPENDIX A

I. OBJECTIVES FOR SCIENCE AND SOCIAL STUDIES INSTRUMENTS

II. SCIENCE INSTRUMENT

III. SOCIAL STUDIES INSTRUMENT

I. OBJECTIVES FOR SCIENCE AND SOCIAL STUDIES INSTRUMENTS

Below is a list of the objectives corresponding to the various questions on the science and social studies instruments. Following each objective is the number of a question on the science instrument. The "parallel" questions are very similar in format and are both designed to test the same objective, one question dealing with science content and the other dealing with social studies content.

The responses for the questions for objectives 10 and 14 were not included in the final tabulation of the scores because objective 10 dealt with material which was unfamiliar to the students, and the social studies question (number 16) for objective 14 was designed improperly in the final copy of the test so that there was essentially no correct answer. Also, responses from questions 11 and 14 on the science instrument were not included in the tabulations, because there were no corresponding questions on the social studies instrument. Although there were sixty-four items on the social studies instrument and sixty-six items on the science instrument, only the responses from sixty-two of these items were used.

NUMBER	OBJECTIVES	SOCIAL STUDIES QUESTION(S) FOR THIS OBJECTIVE	SCIENCE QUESTION(S) FOR THIS OBJECTIVE
1	Estimate the area of a circle or an irregular figure which is gridded by counting "about how many" square centimeters are contained in the figure.	1	2
2	Make a logical prediction based on data from a bar graph.	2	62
3	Recognize a term which needs to be operationally defined.	3, 31	61, 66
4	Identify a controlled variable in an experiment.	4, 48 56	3, 50, 47
5	Order a set of events in terms of the temporal order in which they happened.	5	6
6	Select an operational definition from a group of statements.	6	7
7	Identify how a set of objects can be divided into a specified number of groups when objects differ in size, with other properties varying.	7	38
8	Identify what property was used to divide a set of objects into groups, when objects differ in two values of one property.	8, 15	20, 9
9	Predict whether two objects could travel at the same speed or whether one would go faster, given information about starting and ending points, times and distances traveled.	9	10
10	Identify the range of a given set of data.	10	19
11	Identify an object or term by using an operational definition and interpreting data from a bar graph.	11, 12	63, 64

NUMBER	OBJECTIVES	SOCIAL STUDIES QUESTION(S) FOR THIS OBJECTIVE	SCIENCE QUESTION(S) FOR THIS OBJECTIVE
12	Identify the group into which a given object should be placed.	13	45
13	Identify what property was used to divide a set of objects into groups, when objects differ in two values of one property.	14	8
14	Choose the type of graph which is most appropriate to represent a given set of data.	16	16
15	Predict the event which would logically occur next in a sequence.	17	18
16	Identify a correct sequence of steps for testing a hypothesis	18	15
17	Calculate and identify the average of a given set of data.	19	21
18	Use cardinal directions when identifying the route between given locations on a simple map.	20	22
19	Locate several points, given the rectangular coordinates.	21	65
20	Distinguish between statements of observation and statements of inference.	22	23
21	Distinguish between observations and predictions in a given example.	23	46
22	Convert a science word problem into an addition problem and give the correct sum.	24	25
23	Identify touching as an appropriate method of observation in a particular instance.	25	26
24	Identify a definition of the term variable.	26	27

NUMBER	OBJECTIVES	SOCIAL STUDIES QUESTION(S) FOR THIS OBJECTIVE	SCIENCE QUESTION(S) FOR THIS OBJECTIVE
25	Identify the decimal fraction which represents a given amount.	27	28
26	Identify human error as an uncontrolled variable in a given experiment.	28	33
27	Read a distance scale on a map and identify the distance from one point to another.	29	39
28	Identify the standard metric units of capacity measurement.	30	40
29	Identify the hypothesis which is being tested in an experiment.	32, 55	53, 4
30	Identify data found on a line graph.	33	54
31	Make a logical prediction based on a line graph.	34	55
32	Identify variables which should be held constant in an experiment.	35	56
33	Identify the manipulated variable in an experiment.	36, 49 57	57, 51 48
34	Identify the responding variable in an experiment.	37, 58	58, 49
35	Identify data on a line graph that supports a hypothesis.	38	59
36	Identify equipment which can be used to measure the volume or space taken up by a liquid.	39	34
37	Write or select a series of decimal fractions which is in correct ascending or descending order.	40	37
38	Distinguish between statements of observation and inference in a paragraph.	41	30

NUMBER	OBJECTIVES	SOCIAL STUDIES QUESTION(S) FOR THIS OBJECTIVE	SCIENCE QUESTION(S) FOR THIS OBJECTIVE
39	Distinguish between statements of observation and inference in a pictured situation.	42	42
40	Solve a word problem using the addition of decimal fractions.	43	52
41	Select a hypothesis from a group of statements.	44	41
42	Locate a specific piece of information on a two-dimensional table.	45	32
43	Make a logical prediction given data in a two-dimensional table.	46	17
44	Identify a prediction which could be made on the basis of a particular set of observations.	47	29
45	Locate a specific piece of information in a bar graph.	50	35
46	Make comparisons between parts of a bar graph.	51	31
47	Select a measurement that is more precise than other measurements.	52	60
48	Identify the sense or senses used for observation in a given story.	53	36
49	Distinguish between statements of observation and statements of opinion.	54	13
50	Identify the best method of testing a hypothesis.	59	43
51	Identify an observation that supports a given hypothesis.	60	44

NUMBER	OBJECTIVES	SOCIAL STUDIES QUESTION(S) FOR THIS OBJECTIVE	SCIENCE QUESTION(S) FOR THIS OBJECTIVE
52	Identify a valid inference based on evidence in a given selection.	61	5
53	Identify an inference from observing a pictured situation.	62	24
54	Identify additional observations needed to test an inference.	63	12
55	Identify one or more inferences which might be drawn from a given set of statistics and reports.	64	1

II. SCIENCE INSTRUMENT

ORES

Objective Referenced Evaluation in Science

ANSWER ALL QUESTIONS ON YOUR ANSWER SHEET. DO NOT MARK IN YOUR BOOKLET.

DIRECTIONS

Each question in this part of the test is followed by a set of answers. Only one answer is correct. After you read each question, decide upon an answer, and then fill in the space on your answer sheet with a heavy black pencil mark.

Notice how the answer to this sample question has been marked.

SAMPLE X

Which of these cities is the capital of the United States?

(A) New York City
(B) Philadelphia
(C) Washington, D.C.
(D) Arlington

"(C)" is the correct response. Therefore, "(C)" on your answer sheet is filled in. Notice that the mark is dark and fills the oval on your answer sheet.

SAMPLE Y

Which of these words means almost the same thing as "choose"?

(A) loose
(B) select
(C) bolt
(D) will

Since "choose" and "select" mean almost the same thing, you should have marked "(B)" on your answer sheet for Sample Y.

SAMPLE Z

Multiply: 6 x 5 = ______

(A) 30
(B) 11
(C) 35
(D) 28

Since 6 x 5 = 30, you should have marked "(A)" on your answer sheet for SAMPLE Z.

Only one response should be darkened for each question. If you change your answer, please erase your first answer completely. Use a pencil, not a ballpoint pen.

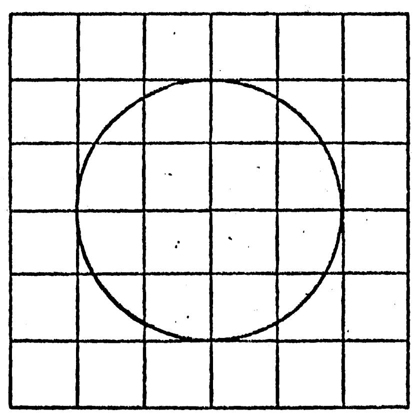
1. Below is a table showing the temperature at different times during a day in Burlington.

TIME	DEGREES CENTIGRADE
4 am	12° C
6 am	11° C
8 am	14° C
10 am	18° C
12 noon	23° C
2 pm	15° C
4 pm	17° C
6 pm	15° C
8 pm	12° C

Which statement below is the best inference about the weather?

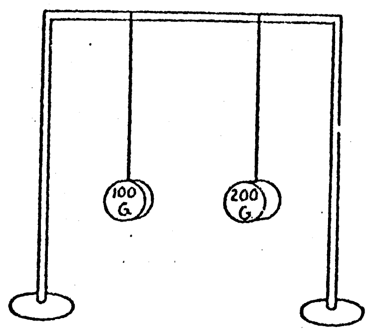
(A) The temperature rose all morning long.
(B) A cold front reached Burlington between 12 and 2 pm.
(C) It is summer in Burlington.
(D) It is the coldest day of the year.

2. In the grid below a circle has been drawn. Each small square equals one square centimeter. The circle has an area of about _____ square centimeters.



(A) 8
(B) 13
(C) 16
(D) 36

3. Clarence did an experiment to find out if weight affects the amount of time it takes a pendulum to swing back and forth. He took 2 strings and tied them onto a bar. Both strings were 2 feet long. On the first string he tied a 100 gram weight, and on the second string he tied a 200 gram weight. His experiment looked like this:



Then he wrote down the number of seconds that it took each pendulum to swing back and forth.

What variable did Clarence control in his experiment?

(A) the length of the strings
(B) the time it took the pendulums to swing back and forth
(C) the weight on the end of the strings
(D) the speed of the pendulums

4. The hypothesis Clarence was testing in the above experiment was

(A) the amount of weight will affect how fast the pendulum will swing.
(B) the 200 gram pendulum will swing faster than the 100 gram pendulum.
(C) the 100 gram pendulum will swing faster than the 200 gram pendulum.
(D) the length of the string will affect how fast the pendulum will swing.

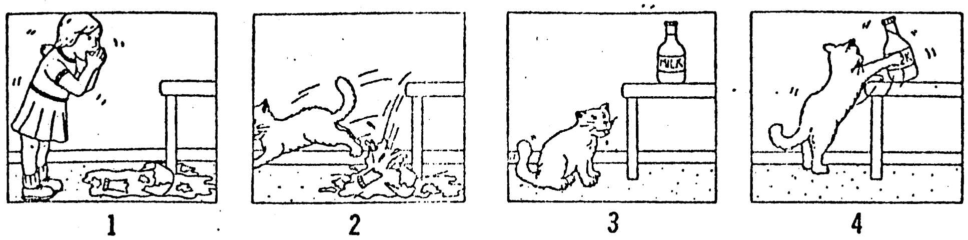
5. England and France have built a very fast, very noisy airplane called the Concorde. Some people are worried that the Concorde might destroy ozone in the atmosphere. If this happened, more people might get skin cancer.

Doctor Wilson is a scientist who is a member of a group named Save Our Environment. What would Dr. Wilson probably think about letting the Concorde land in the United States?

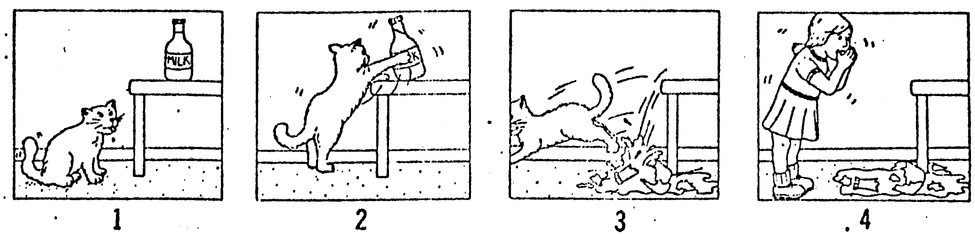
(A) It should land because France and England spent a lot of money to build the plane.
(B) It should land because people in this country need to get to other places quickly.
(C) It should not land because it cost too much to buy a ticket for the Concorde.
(D) It should not land because the noise and destruction of the ozone would harm the environment.

6. Below are four sets of pictures. One set of pictures shows what happened first, second, third, and fourth in the right order. Which set of pictures is in the right order from first to last?

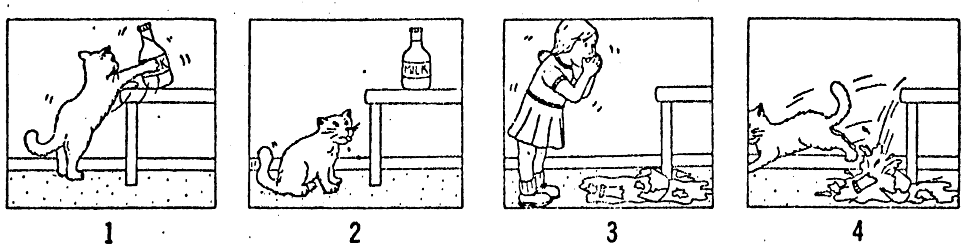
(A)



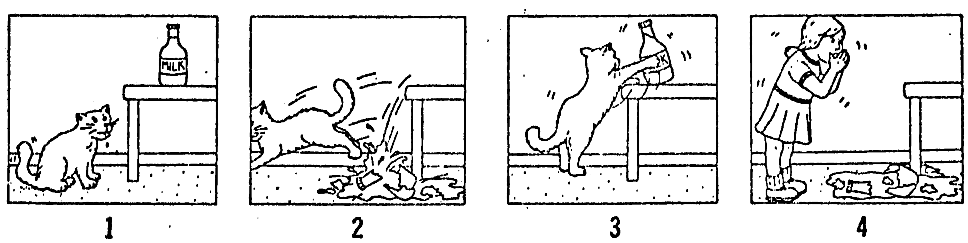
(B)



(C)



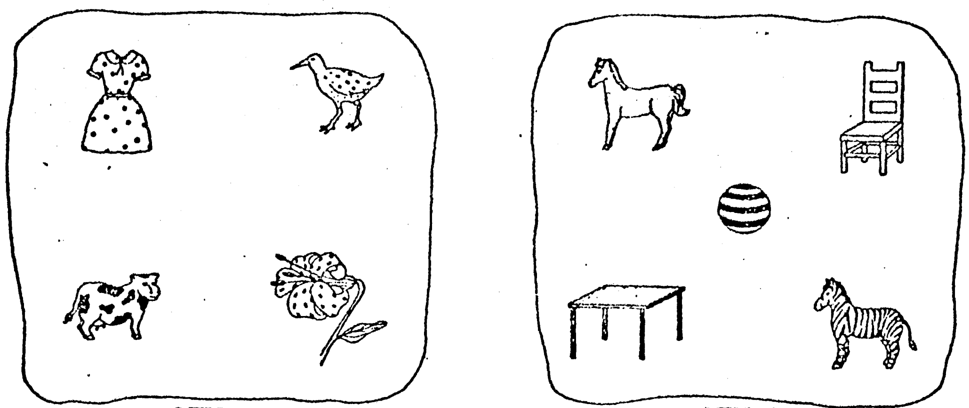
(D)



7. Which one of these statements is an operational definition?

(A) A lever is one kind of a simple machine.
(B) Water is a clear liquid that freezes at 0 degrees Celsius.
(C) A violet is a small type of flowering plant.
(D) Washington D.C. is the capital of the United States.

8. Martin had a group of pictures that he wanted to divide into two sets. He looked at the pictures and saw that there was more than one way that they could be divided. Here is the first way that he grouped the pictures into two sets.

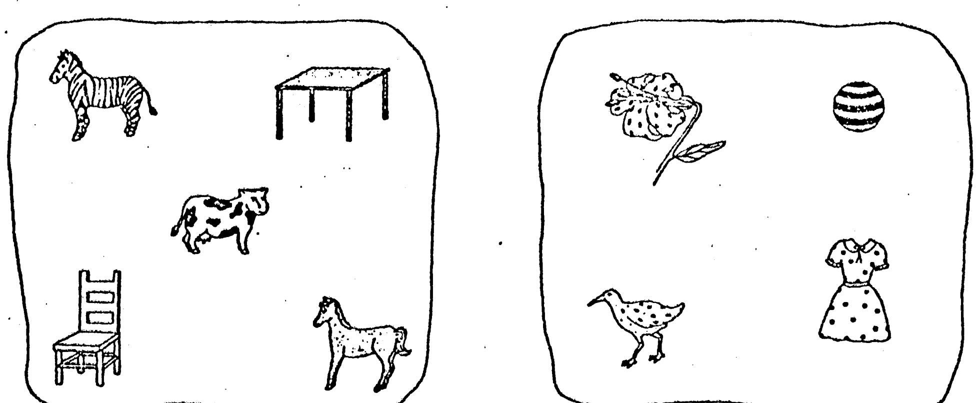


SET 1 SET 2

How did he arrange the pictures into these two sets?

(A) Set 1 has living things, and Set 2 has non-living things.
(B) Set 1 has spotted things, and Set 2 has things without spots.
(C) Set 1 has moving things, and Set 2 has non-moving things.
(D) Set 1 has things with two colors, and Set 2 has things with one color.

9. Then Martin grouped the same pictures into two different sets.

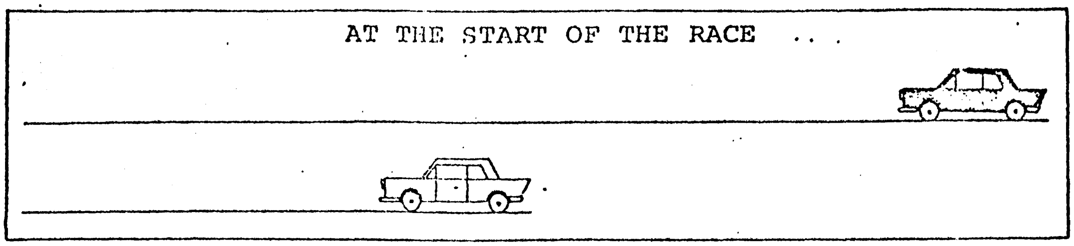


SET 1 SET 2

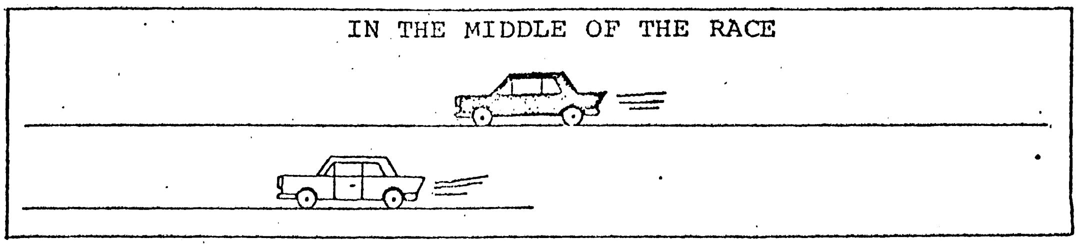
How did he arrange the pictures into the two sets above?

(A) Set 1 has things that are made by people, and Set 2 has things that are not made by people.
(B) Set 1 has moving things, and Set 2 has non-moving things.
(C) Set 1 has things with 4 legs, and Set 2 has things that do not have 4 legs.
(D) Set 1 has animals, and Set 2 does not have animals.

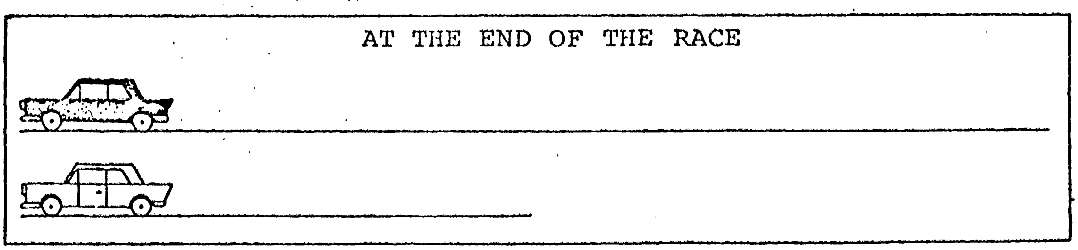
10. It was the day of the big Auto Race. The **black** car and the white car lined up on the race tracks. The race track for the brown car was twice as long as the race track for the white car. The two cars began the race at exactly the same time. Here is how the two cars looked at the start of the race.



Here is how the two cars looked in the middle of the race when exactly half of the time had gone by.



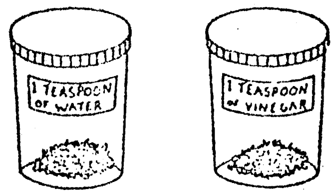
Here is how the two cars looked at the end of the race. They reached the finish line at exactly the same time.



What can be said about the speeds of the **black** car and the white car during the race?

(A) The **black** car traveled at a faster speed than the white car.
(B) The white car traveled at a faster speed than the **black** car.
(C) The **black** car and the white car both traveled at the same speed.
(D) You cannot compare the speeds of the **black** car and the white car.

11. Patty wanted to find out about rusting. She took a ball of steel wool and put it into a jar. She put a teaspoon of water on the steel wool. She put another piece of steel wool into another jar and put a teaspoon of vinegar on it. She put the lids on the jars and put both jars on a shelf. This is how Patty's experiment looked.



The next day Patty looked to see how much the steel wool in each bottle had rusted.

What hypothesis was Patty testing with her experiment?

(A) The amount of rusting depends on the type of metal used.
(B) The amount of rusting depends on the type of liquid used.
(C) The amount of rusting depends on the amount of light in the room.
(D) The amount of rusting depends on the amount of moisture in the jar.

12. One day Janet noticed that her goldfish was swimming around near the top of the tank while she was playing the record player. She inferred that sounds made the fish swim near the top of the water.

Janet did some things and made some observations. Which one of Janet's observations was MOST helpful in testing her inference?

(A) The fish stayed on the bottom when she left the record player turned off and tried to be quiet.

(B) The fish came up to the top when she sprinkled some food on the water.

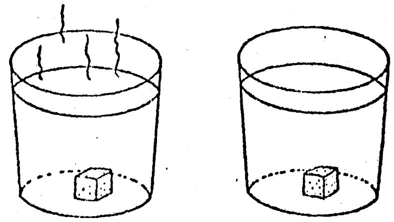
(C) The fish stayed on the bottom when she put her finger in the water.

(D) The fish came up to the top when she rang a bell and went down when she stopped ringing it.

13. Some students were given a cup of vinegar and were asked to observe and describe it. Which student stated an OPINION rather than an observation?

(A) "It is clear and has no color."
(B) "It has an awful taste and smell."
(C) "It feels and looks wet."
(D) "It fizzes when you put baking soda in it."

14. Danny thought that a sugar cube would dissolve faster in cold water than in hot water. He took two 50 milliliter beakers and filled one with cold water and one with hot water. He put one sugar cube into each beaker. His experiment looked like this:



Then he timed the experiment and wrote down the number of minutes it took for each cube to dissolve. He found out that the cube in hot water dissolved faster than the one in cold water. His hypothesis seemed to be false.

Which is the BEST list of the steps in Danny's experiment?

(A) 1. make an hypothesis
2. fill one beaker with cold water
3. fill one beaker with hot water
4. put a sugar cube in each beaker

(B) 1. make an hypothesis
2. put 1 sugar cube in hot water and 1 in cold water
3. write down the minutes it takes each cube to dissolve and compare the times
4. decide if the hypothesis could be true or false

(C) 1. make an hypothesis
2. decide if the hypothesis could be true or false
3. time the experiment to see how long it takes each sugar cube to dissolve
4. compare the results of the experiment

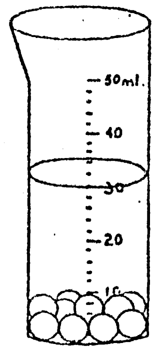
15. Which list below gives the correct order of steps for testing an hypothesis?

(A) 1. perform the test and write down the data
2. identify the variables and design a test
3. decide if the data show that the hypothesis could be true or is false
4. think about the meaning of the data and draw conclusions

(B) 1. identify the variables and design a test
2. perform the test and write down the data
3. think about the meaning of the data and draw conclusions
4. decide if the data show that the hypothesis could be true or is false

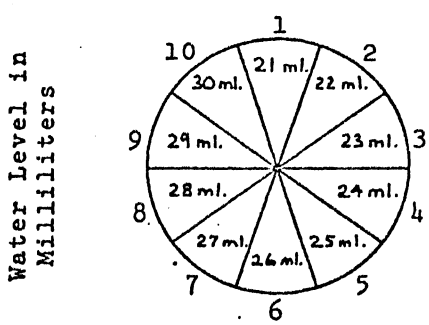
(C) 1. decide if the data show that the hypothesis could be true or is false
2. think about the meaning of the data and draw conclusions
3. identify the variables and design a test
4. perform the test and write down the data

16. Bonnie did an experiment with volume. She took a graduated cylinder and put 20 milliliters of water in it. Then she dropped a marble into the water and wrote down how much the water level went up. She kept adding marbles until there were 10 marbles in the water. Each time she wrote down how much the water level went up. Here is how the cylinder looked.



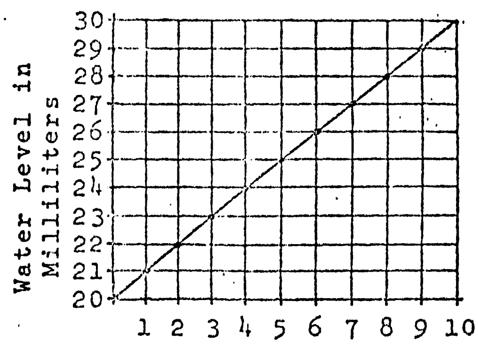
Bonnie wanted to make a graph using her data. Which type of graph would be BEST to show the results of this type of experiment?

HEIGHT OF WATER FOR EACH MARBLE ADDED



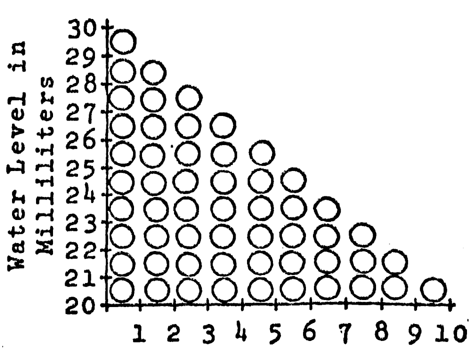
Number of Marbles
(A)

HEIGHT OF WATER FOR EACH MARBLE ADDED



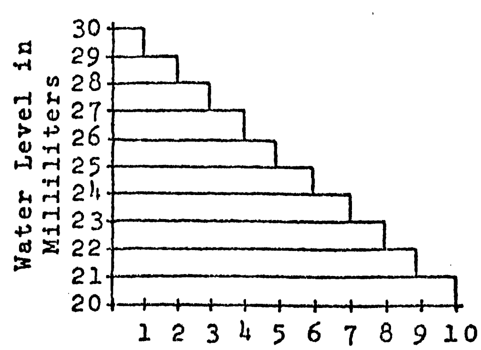
Number of Marbles
(B)

HEIGHT OF WATER FOR EACH MARBLE ADDED



Number of Marbles
(C)

HEIGHT OF WATER FOR EACH MARBLE ADDED



Number of Marbles
(D)

17. Joel filled a can with sand, a can with black dirt, and a can with water. He put the three cans under a bright light bulb and measured their temperatures every ten minutes. If he makes another measurement after 40 minutes, what will MOST LIKELY happen according to the chart below?

TIME	SAND TEMPERATURE	BLACK DIRT TEMPERATURE	WATER TEMPERATURE
0 minutes	20 degrees C.	20 degrees C.	20 degrees C.
10 minutes	22 degrees C.	23 degrees C.	21 degrees C.
20 minutes	24 degrees C.	26 degrees C.	22 degrees C.
30 minutes	26 degrees C.	29 degrees C.	23 degrees C.

(A) The water would be hotter than the sand or black dirt.
(B) The black dirt would be hotter than the sand or water.
(C) The sand would be hotter than the water or black dirt.
(D) The sand, the water, and the black dirt would all be the same temperature.

18. Roberta wanted to know if the moon came up at the same time every night. She decided to keep a record of the time that it rose each evening of the week. On Monday, the moon rose at 4:22 in the afternoon. On Tuesday it came up at 5:25 p.m., and on Wednesday it rose at 6:29 p.m. What time will the moon probably rise on Thursday?

(A) 6:05 p.m.
(B) 7:32 p.m.
(C) 9:19 p.m.
(D) 12:00 p.m.

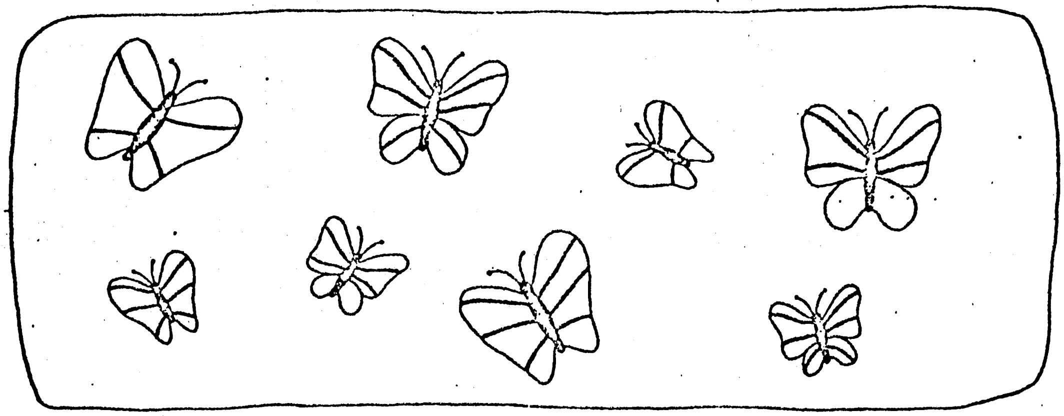
19. Six students tried to guess how many ping pong balls a one-liter jar would hold. Here are their guesses:

20
25
25
30
40
40

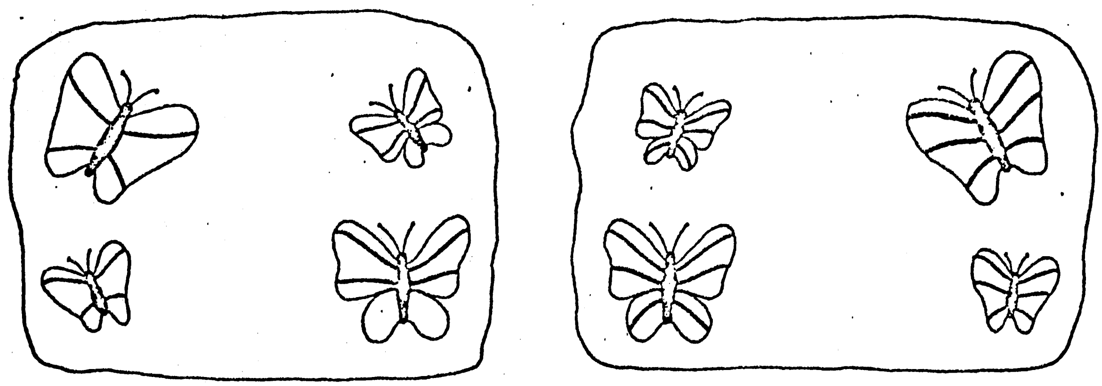
What was the range of their guesses?

(A) 6
(B) 20
(C) 30
(D) 40

20. Here is a set of butterflies.



Now the set of butterflies has been divided into two sets.



SET 1 SET 2

How were the butterflies divided into Sets 1 and 2?

(A) by the number of wings
(B) by size
(C) by shape
(D) by the number of stripes

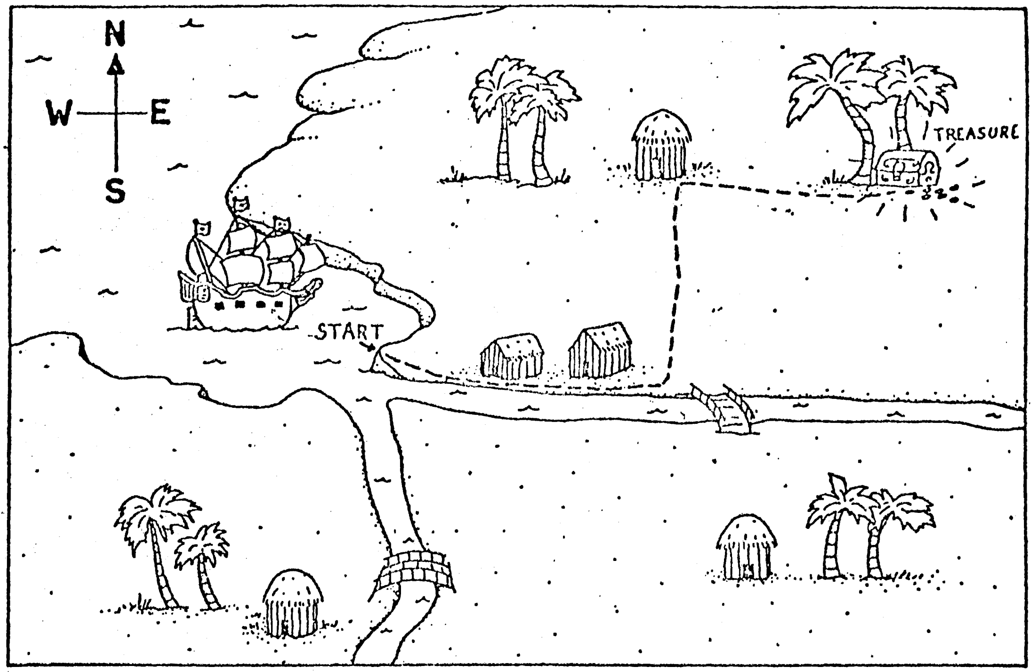
21. Mark, Terry, and Jennifer each ran one time around a track. A friend kept a record of the number of seconds that each one took to run the race. Here are their times:

Terry - 9 seconds
Mark - 5 seconds
Jennifer - 4 seconds

What was the average time for the 3 runners?

(A) 6 seconds
(B) 18 seconds
(C) 5 seconds
(D) 9 seconds

22.



Which one of the following is the correct set of directions for reaching the treasure if you start from the ship?

(A) Follow the river east until you reach the bridge.
Go south to the grass hut.
Turn west and go to the 2 large trees.

(B) Follow the river south until you reach the bridge.
Go north to the grass hut.
Turn west and go to the 2 large trees.

(C) Follow the river south until you reach the bridge.
Go south to the grass hut.
Turn east and go to the 2 large trees.

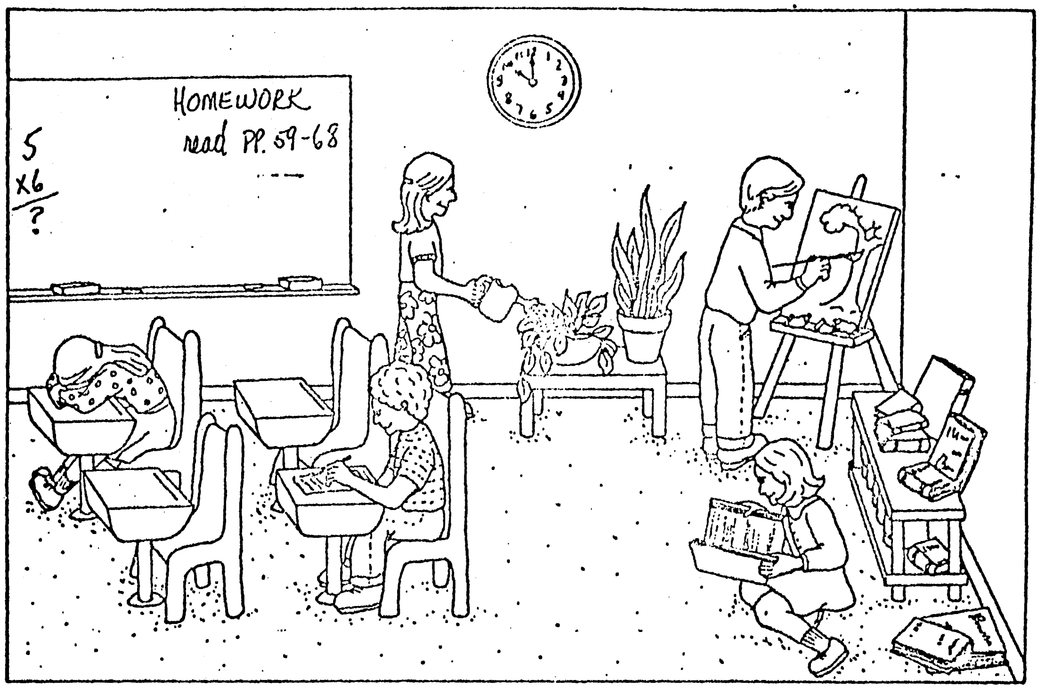
(D) Follow the river east until you reach the bridge.
Go north to the grass hut.
Turn east and go to the 2 large trees.

23. Francis learned that if a drop of iodine is placed on something that has starch in it, the iodine will change the starch to a dark, purplish color. He decided to test a piece of bread by placing a few drops of iodine on it.

Which one of his statements is an inference, instead of an observation?

(A) "The iodine soaked into the bread."
(B) "The bread turned dark."
(C) "The bread had starch in it."
(D) "The bread got wet from the iodine."

24. Observe this classroom scene.



Which statement about the scene is an inference?

(A) One of the girls is asleep.
(B) One of the boys is painting.
(C) One of the girls is sitting on the floor.
(D) One of the girls is watering a plant.

25. Jess poured 64 milliliters of water into an empty beaker. Then he poured in 8 milliliters of oil with the water. What was the total amount of liquid in the beaker?

Which number sentence gives the correct solution?

(A) 64 x 8 = 482 milliliters
(B) 64 + 8 = 72 milliliters
(C) 64 x 8 = 512 milliliters
(D) 64 + 8 = 74 milliliters

26. What is the BEST way to find out if a wooden block is smooth?

(A) Scrape it against a table and listen to the sound it makes.
(B) Hold it up to see how much light it reflects.
(C) Push it across the floor to see how far it will slide.
(D) Rub it with your hands to feel any rough places.

27. A variable in an experiment is defined as

(A) the equipment that is used.
(B) a method that is used.
(C) an outcome of the experiment.
(D) any factor that can change.

28. Choose the number below that is equal to seven tenths.

(A) 0.070
(B) 0.007
(C) 0.07
(D) 0.7

29. Phil found a rubber ball on his way to school. He decided to experiment with it in science class. He wanted to see how high the ball would bounce when it was dropped from different heights.

Phil dropped the ball from a height of 2 feet and it bounced back 1 foot. Then he dropped it from 4 feet and it bounced back 2 feet.

Phil dropped the ball one more time. He stood on a ladder and dropped it from a height of 6 feet. How high did the ball bounce when Phil dropped it from 6 feet?

(A) lower than when he dropped it from 4 feet
(B) higher than when he dropped it from 4 feet
(C) the same height as when he dropped it from 4 feet

30. Read the paragraph below and then answer the question that follows.

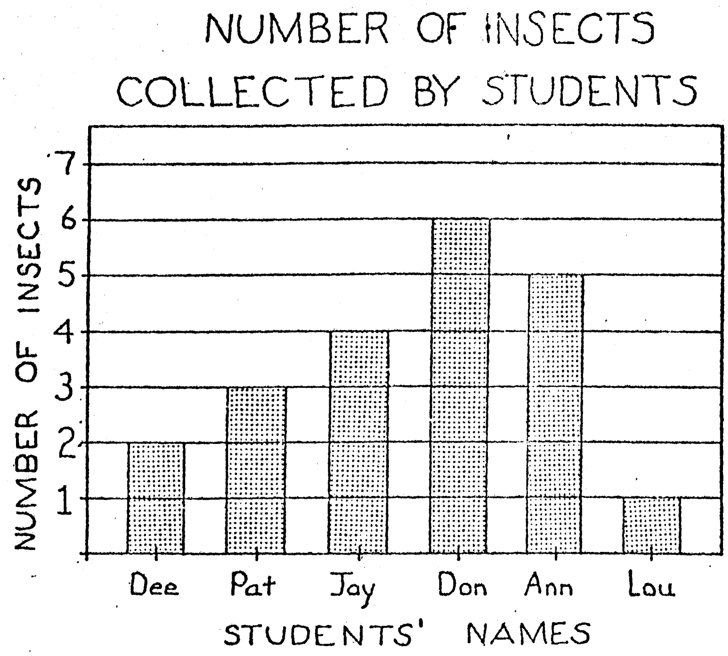
Burt and Grace Noles were building a tree house in their back yard. They were using a rope to lift up the boards that they needed. Suddenly the rope broke and the boards fell to the ground. "Wow!" shouted Grace. "The rope just broke. That stack of lumber must have been too heavy."

"I don't think so," Burt argued. "Maybe the rope wasn't strong enough. It was getting too old and rotten to lift the boards."

Which one of their statements is an observation?

(A) "The rope just broke."
(B) "That stack of lumber must have been too heavy."
(C) "Maybe the rope wasn't strong enough."
(D) "It was getting too old and rotten to lift the boards."

31. A group of students went on an insect hunt. Each student counted the number of insects found in a certain place. They put all of their data together to make a bar graph.



Which one of the following people collected more insects than Jay?

(A) Dee
(B) Pat
(C) Lou
(D) Ann

32. David kept a record of the different kinds of animals in his fish tank. Every week he counted each kind of animal and wrote the number in a table. Look at David's table.

	NUMBER OF ANIMALS EACH WEEK			
KIND OF ANIMAL	Week 1	Week 2	Week 3	Week 4
guppies	10	12	6	10
snails	10	15	18	20
catfish	2	2	5	5
turtles	2	2	2	2

How many catfish did David have during the third week?

(A) 18
(B) 6
(C) 5
(D) 2

STOP !!

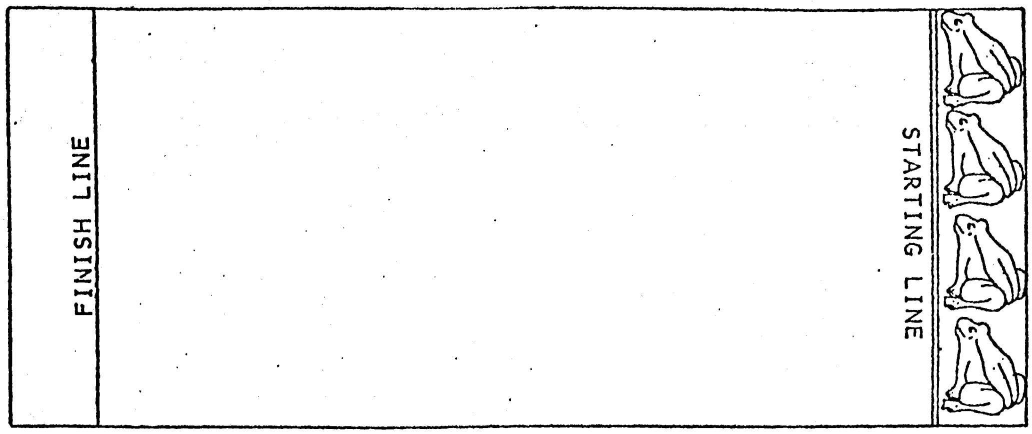
You have just completed Part 1 of the test. Do not work beyond this point until you have further instructions from your teacher.

Part 2

SCORE

After instructions from your teacher, you may begin Part 2 of the test.

33. Some students who had pet frogs did an experiment to see whose frog was the best jumper. They drew a straight line on the floor and put all of the frogs on the line. This is how the race track looked. The frog that crossed the finish line first would be the best jumper.

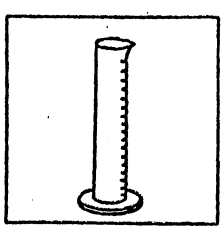


The students all held their frogs down until somebody said, "Go!" Then each student released his or her frog and gave it a push to get it started. The first frog over the finish line was supposed to be the winner.

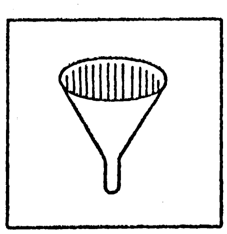
When the race was over, the students began to argue about which frog was really the best jumper. They had forgotten to control an important variable, and something was different for each frog in the race. What variable was not controlled?

(A) the way the frogs were lined up at the start
(B) the time of day that the race was held
(C) the distance each frog had to jump to the finish line
(D) the way the frogs were released and pushed

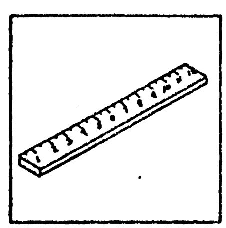
34. Carla's science class was doing an experiment with vinegar and baking soda. To begin their experiment, each student had to pour 25 milliliters of vinegar into a paper cup. Which piece of equipment could be used to measure a volume of vinegar equal to 25 milliliters?



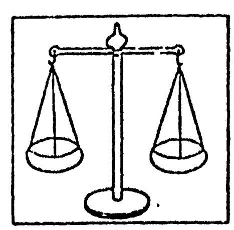
graduated cylinder (A)



funnel (B)

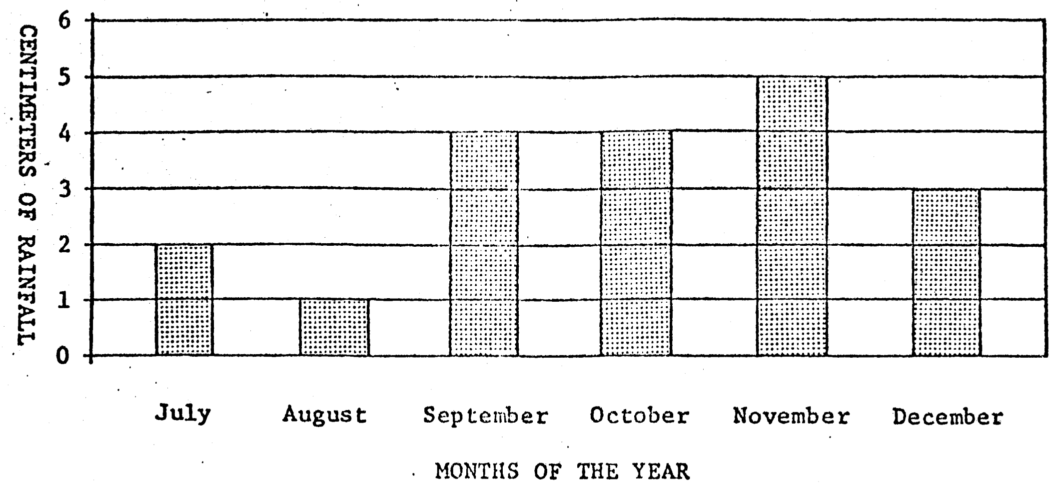


ruler (C)



scale (D)

35. A newspaper printed the following graph that showed the rainfall for the last 6 months of the year.



How many centimeters of rain fell in the month of October?

(A) 1 centimeter
(B) 3 centimeters
(C) 4 centimeters
(D) 5 centimeters

36. Read this story and then answer the question that follows.

Mick was tucked under the covers of his bed, sleepily watching the TV set. All of his friends were in school by now. But Mick had the mumps.

He thought that he might be sick when he drank his milk last night. Every time he swallowed, his ears and throat hurt. This morning he felt his neck and decided that it was swollen. He put a thermometer under his tongue. A few minutes later the thermometer read 101 degrees. When he looked in the mirror, he knew he had the mumps.

Which of his five senses helped Mick observe that he was sick?

(A) hearing and taste
(B) touch and sight
(C) sight and hearing
(D) touch and taste

37. Which list of numbers is in order from smallest to largest?

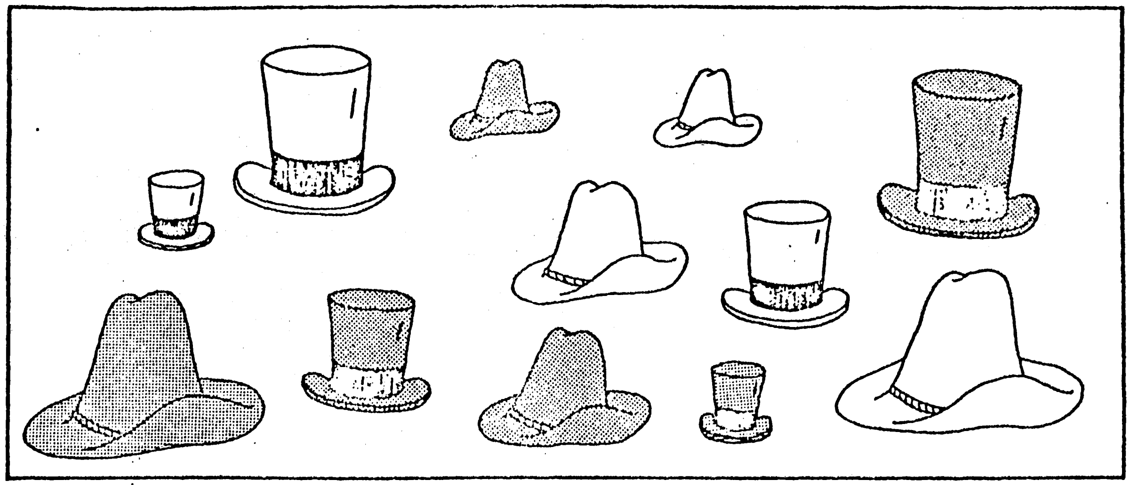
(A) .7 .10 .52

(B) .13 .26 .042

(C) .003 .125 .3

(D) .68 .093 .137

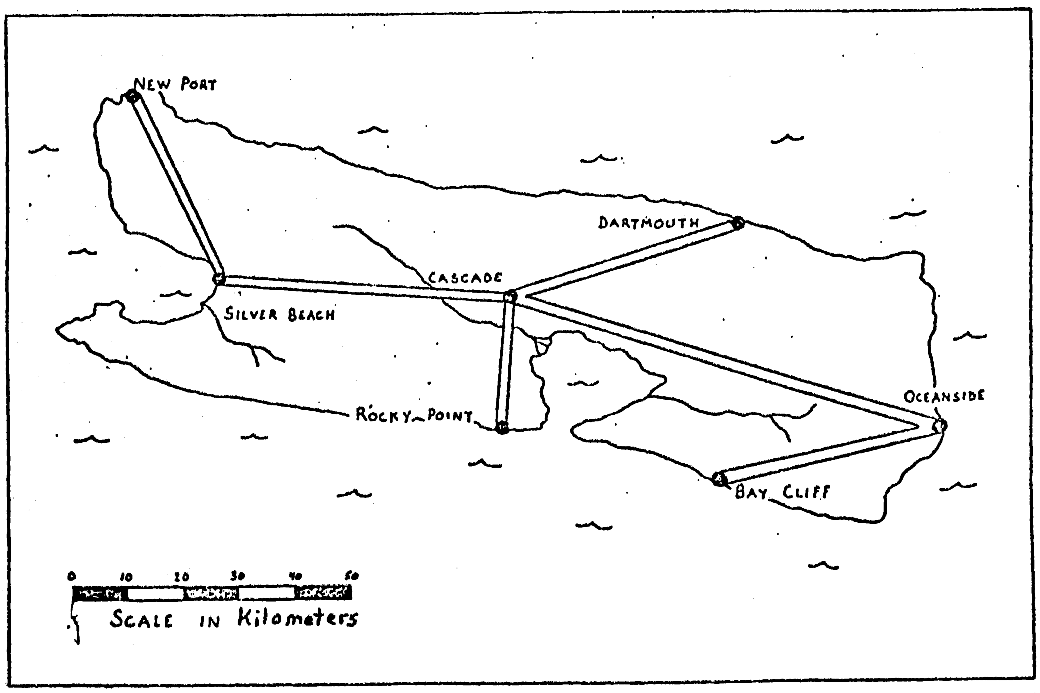
38. Look at this set of hats.



How could you divide this set of hats into THREE groups so that all the hats in a group are alike in some way? Each group of hats would be different from the other groups.

(A) 3 different sizes of hats
(B) 3 different shapes of hats
(C) 3 different colors of hats
(D) 3 different kinds of hats

39.



On the map above, how far is it from Silver Beach to Dartmouth?

(A) 40 kilometers
(B) 50 kilometers
(C) 90 kilometers
(D) 150 kilometers

40. What units should you use if you are talking about the volume of water a fish tank can hold?

(A) meters
(B) kilograms
(C) square centimeters
(D) liters

41. One day in science class, Paula found some seeds sprouting in a dark cupboard. She thought darkness might help seeds to sprout faster, and decided to experiment to find out.

Paula wrapped some peas in a wet paper towel and put them in a dark drawer. She wrapped some more peas in a wet paper towel and put them on a sunny windowsill.

After three days, Paula looked at the peas. The peas from the dark drawer had more sprouts than the ones from the windowsill. Paula decided that peas sprout faster in the dark than in the light.

Which sentence from the story tells Paula's hypothesis?

(A) Paula found some seeds sprouting in a dark cupboard.
(B) She thought darkness might help seeds to sprout faster.
(C) The peas from the dark drawer had more sprouts.
(D) Paula decided that peas sprout faster in the dark.

42.

Which one of the following is an observation about the picture above?

(A) The bird is afraid of the cat.
(B) The cat wants to climb the tree and catch the bird.
(C) The bird is perched on a branch above the cat.
(D) The cat is hungry.

43. Robin and Jill were watching several ants carrying small seeds back to the ant den. All the ants seemed to follow the same tiny path. The girls wondered how the ants found their way to the food and then back to the den. They put a small piece of paper on top of the ant's path. When the ants reached the piece of paper, they seemed confused and began to go in different directions. The girls made a hypothesis that maybe ants feel their way with their feelers. Maybe when the ants came to the paper, it did not feel right, so the ants were confused. The girls decided to make more observations to test their hypothesis.

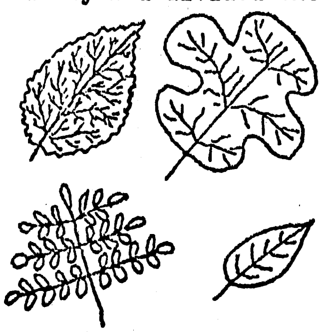
Which of the following observations would be most helpful in testing the hypothesis?

(A) Put perfume at one end of the path to see if it confuses the ants.
(B) Remove their feelers and see if the ants can find their way along the path.
(C) Put sugar at one end of the path to see if the ants travel faster.
(D) Shine a light on the ants to see if the ants follow the light.

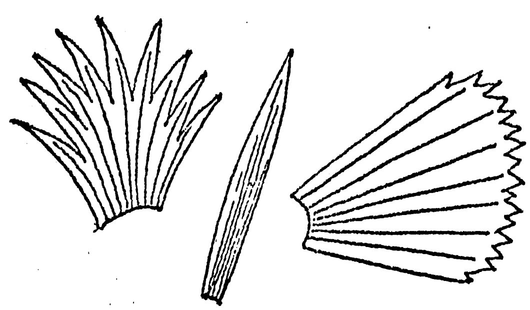
44. Which of the following observations would support Robin and Jill's hypothesis?

(A) Putting dirt over the path also confused the ants.
(B) After a short time, the ants found their way across paper, sandpaper, leaves and other objects which the girls put across the path.
(C) The ants seemed to be touching the ground with their feelers as they went along the path.
(D) After getting the path hot by shining a heat lamp on it, the ants could still find their way.

45. Terry had divided the leaves in his leaf collection into two groups

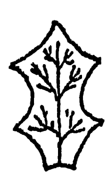
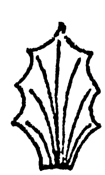


Group A



Group B

Which one of the following leaves should fit into Group B?

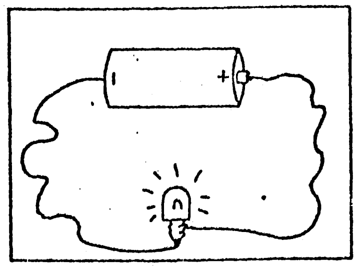
 (A)  (B)  (C)  (D)

46. Four people were discussing the weather one January day. Which one of their statements was a prediction rather than an observation?

(A) "Look at those gray clouds in the sky."
(B) "The temperature is 3 degrees Centigrade."
(C) "If it gets much colder it could snow."
(D) "The wind is starting to blow much harder now."

47. Read about this experiment and then answer the following THREE questions:

Dora thought that a flashlight bulb would shine more brightly if it had more batteries for power. She took a bulb and attached 1 battery to it. She used a dark room and observed the amount of light that the bulb gave off. Her experiment looked like this:



Then she took the same bulb and attached 2 batteries to it. The bulb burned much more brightly. When she attached 3 batteries to the bulb, it was brighter than it had been with 2 batteries.

In the experiment above, what was the controlled variable?

(A) the brightness of the light from the bulb
(B) the flashlight bulb that was used
(C) the length of time that the bulb burned
(D) the number of batteries attached to the bulb

48. In Dora's experiment, what was the manipulated variable?

(A) the brightness of the light from the bulb
(B) the flashlight bulb that was used
(C) the length of time that the bulb burned
(D) the number of batteries attached to the bulb

49. In Dora's experiment, what was the responding variable?

(A) the brightness of the light from the bulb
(B) the flashlight bulb that was used
(C) the length of time that the bulb burned
(D) the number of batteries attached to the bulb

50. Read the story about the experiment and then answer the TWO questions that follow.

Jenny did an experiment to find out how fast liquids will drip out of a bottle. She filled a plastic bottle with water and poked a hole in the bottom of the bottle with a nail. Then she counted the number of minutes it took for all of the water to drip out of the bottle. Next Jenny filled the bottle with syrup. Again she counted the minutes it took for the syrup to drip out of the bottle. Then she rinsed all the syrup out of the bottle and filled it with oil. She counted the number of minutes it took the oil to drip out. When she had finished she made this chart to show her results.

Type of Liquid	Minutes to Drip
Water	10 min.
Syrup	21 min.
Oil	16 min.

Which variables were kept the same in Jenny's experiment?

(A) the type of liquid and the type of bottle
(B) the amount of liquid in the bottle and the type of bottle
(C) the type of liquid and the time it took the liquid to drip out
(D) the amount of liquid in the bottle and the time it took the liquid to drip out

51. What variable did Jenny change in her experiment?

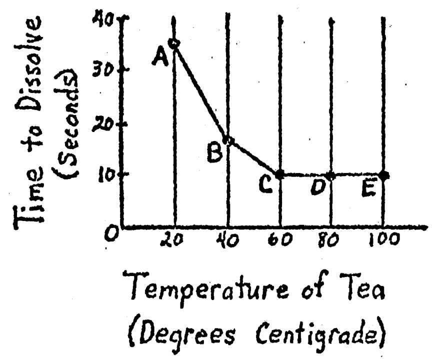
(A) the amount of liquid in the bottle
(B) the type of bottle
(C) the type of liquid in the bottle
(D) the way she timed the dripping

52. Mary needed to buy two pieces of wire for an experiment. One piece needed to be .7 meters long, and the other piece needed to be 1.6 meters long. How much wire should she buy altogether?

(A) 8.6 meters
(B) 1.3 meters
(C) 1.67 meters
(D) 2.3 meters

Read the following story and answer the next seven questions.

Sue could not get two teaspoons of sugar to dissolve in her iced tea unless she stirred for a long time. She knew she could easily dissolve the sugar in hot tea. Sue wondered if the temperature made a difference in the amount of time it took for the sugar to dissolve. After trying five different temperatures Sue got the results shown on the graph.



53. The hypothesis Sue was testing was probably

(A) The colder the tea, the quicker the sugar will dissolve.
(B) The sugar will dissolve at the same rate in 60° tea as it does in 100° tea.
(C) The hotter the tea the quicker the sugar will dissolve.
(D) The temperature of the tea does not affect how rapidly the sugar dissolves.

54. The sugar dissolved slowest when the temperature was

(A) 20°
(B) 40°
(C) 60°
(D) 100°

55. If Sue had lowered the temperature to 10°, the sugar would probably have dissolved in

(A) less time than 40°
(B) more time than 20°
(C) the same amount of time as 20°
(D) None of the sugar would have dissolved since it was getting close to freezing (0°)

56. While doing the experiment it would probably be best if Sue would

(A) use iced tea glasses for low temperatures and a tea cup for high temperatures
(B) stir the tea at the low temperatures to help the sugar dissolve faster
(C) use the same amount of tea each time
(D) use tea bags to make the hot tea and use instant tea for the lower temperatures

57. When doing the experiment Sue would probably be changing the

(A) amount of sugar used at each temperature.
(B) amount of tea used at each temperature.
(C) amount of time it takes for the sugar to dissolve.
(D) temperature of the tea.

58. The results Sue was interested in were

(A) the temperature of the tea
(B) the amount of sugar that would dissolve in 40 seconds
(C) how sweet the tea tasted after the sugar dissolved
(D) the amount of time it took for the sugar to dissolve

59. Which part of the graph supports Sue's hypothesis

(A) $\overline{AB}$
(B) $\overline{CD}$
(C) $\overline{DE}$
(D) the whole graph supports the hypothesis

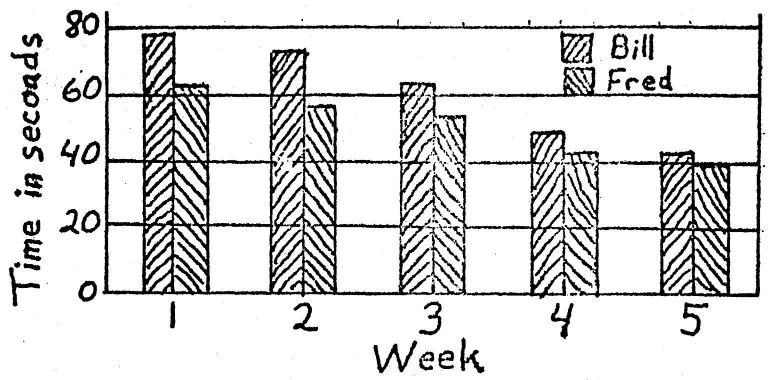
60. Four students measured different things about an ice cube in science class. Which student made the most precise measurement?

(A) Don: "It is colder than 0^oC."
(B) Susan: "It is about 1 cubic centimeter in size."
(C) Bob: "It weighs 30 grams."
(D) Denise: "It melted in less than 1/2 hour."

GO ON TO NEXT PAGE.

Read the following story and answer the next four questions.

Bill and Fred were both going out for track. They kept a record of the time it took them to run the 400 meter dash. As the season passed their time improved. Use the bar graph of their times to answer the following questions.



61. Before we can tell which is the best athlete we will need to know

(A) which boy spent the most time working out.
(B) what their times were at the end of eight weeks.
(C) which boy followed the coach's training rules the best.
(D) what is meant by the term "best athlete."

62. The best prediction of Bill's time during the sixth week would be

(A) 50 seconds
(B) 45 seconds
(C) 40 seconds
(D) 30 seconds

63. If the best athlete is the boy who runs the 400 meters in the shortest time at the end of five weeks, which boy is best?

(A) Bill
(B) Fred
(C) Impossible to tell

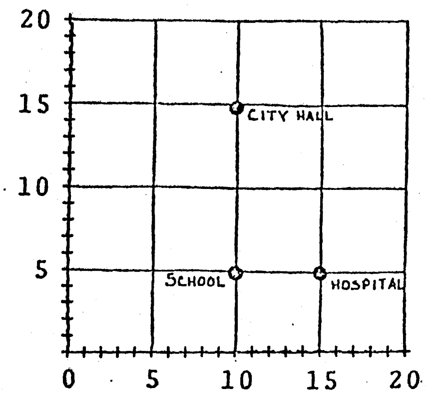
64. If the best athlete is the boy who makes the most improvement from the first week to the fifth week, which boy was best?

(A) Bill
(B) Fred
(C) Impossible to tell

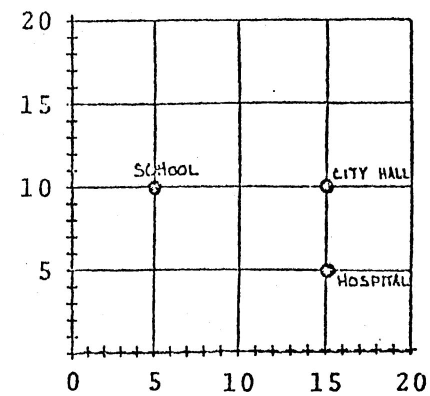
65. Here are the numbers that give the locations for 3 buildings on a grid. These numbers are called rectangular coordinates.

City Hall - (15, 10)
Hospital - (15, 5)
School - (5, 10)

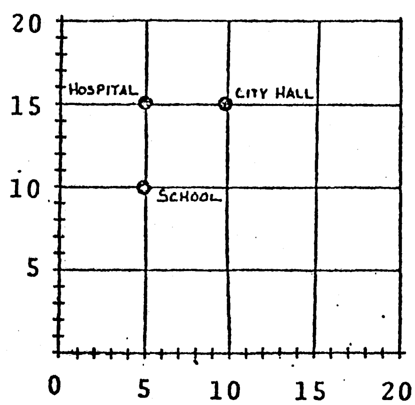
Which grid below shows the correct location for all 3 of these buildings?



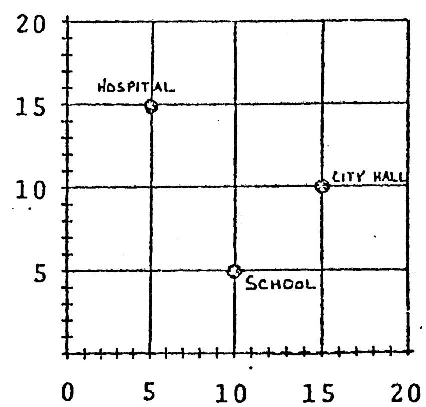
(A)



(B)



(C)



(D)

66. A medical doctor made the statement "Girls are usually biologically stronger than boys."

Before you can agree or disagree with this statement you will need to know

(A) if the doctor is a man or a woman
(B) whether the girls the doctor tested were larger than the boys
(C) whether girls are sick as much as boys
(D) what the doctor meant by "biologically stronger".

III. SOCIAL STUDIES INSTRUMENT

CRESS

Criterion Referenced Evaluation

for the Social Studies

Second Revised Edition

Directions for Marking Your Answers

ANSWER ALL THE QUESTIONS ON THIS TEST ON YOUR ANSWER SHEET. DO NOT MARK IN YOUR BOOKLET.

Each question in this booklet is followed by a set of answers. Only one of the answers is correct. Read each question carefully and choose the answer you think is correct. On your answer sheet, darken the space that matches the answer you choose.

Read the sample question below and notice how the answer has been marked.

SAMPLE X

The country we live in is called

(A) the earth.
(B) North America.
(C) the United States.
(D) Central America.

"(C)" is the correct response. Therefore "(C)" on your answer sheet is filled in. Notice that the mark is dark and fills the center of the space.

Now try Sample Y.

SAMPLE Y

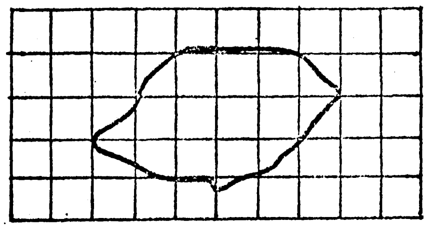
The highest elected official in the nation is
(A) a Senator
(B) the President
(C) a Judge
(D) the Governor

Since the President is the highest elected official in the nation, you should have marked "(B)" on your answer sheet for Sample Y.

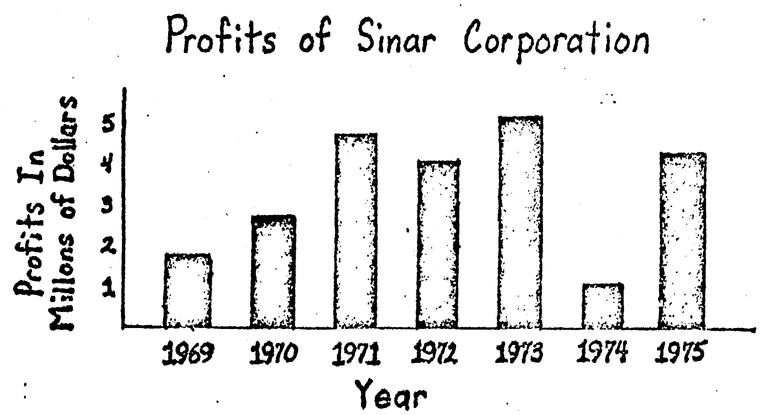
Only one response should be marked for each question. If you change your answer, please erase your first answer completely.

Remember to make a dark mark that fills the space. Use a pencil. Do not use a ballpoint pen.

1. Jim found a small island on a state map. Each block equals one square kilometer. The island has an area of about how many square kilometers?



(A) 9
(B) 11
(C) 13
(D) 15



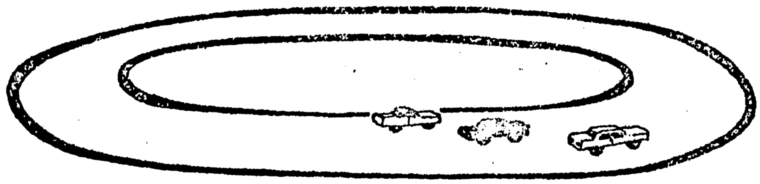
2. From the above graph the BEST prediction would be that in 1976 the Sinar Corporation will make

(A) a larger profit than in 1973
(B) a smaller profit than in 1974
(C) some profit
(D) the same profit as in 1975

3. Some people have stated that "Air pollution lowers the quality of life." Before you can agree or disagree with this statement, you will need to know

(A) if pollution is harmful.
(B) what the people mean by "the quality of life."
(C) how much it will cost to get rid of pollution.
(D) how many people would lose their jobs if factories which pollute the air were closed.

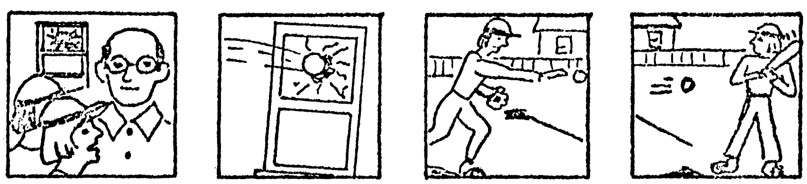
4. Mrs. Thomas was buying a new car. She could not decide whether to buy a small car, a middle-size car, or a big car. She wanted to know which of three different sizes of cars would go the furtherest on four liters of gasoline. She took the three cars to a smooth level test track and put four liters of the same kind of gasoline in each car. Her experiment looked like this

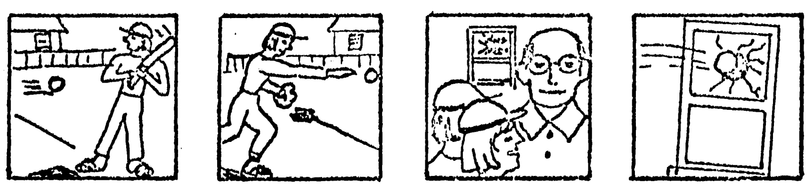


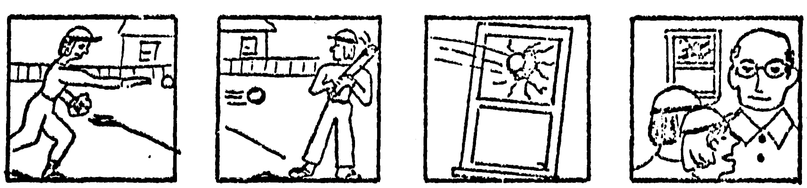
Mrs. Thomas wrote down the distance each car went on four liters of gasoline. What variable did Mrs. Thomas control in her experiment?

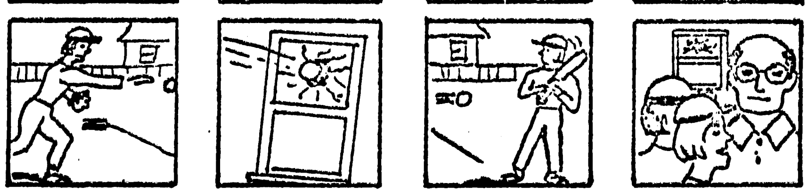
(A) the amount of gasoline
(B) the kind of car
(C) the color of the cars
(D) the distance each car went on the four liters of gasoline

5. Below are four sets of pictures. One set of pictures shows what happened first, second, third and fourth in the right order. Which set of pictures is in the right order from first to last?

(A) 

(B) 

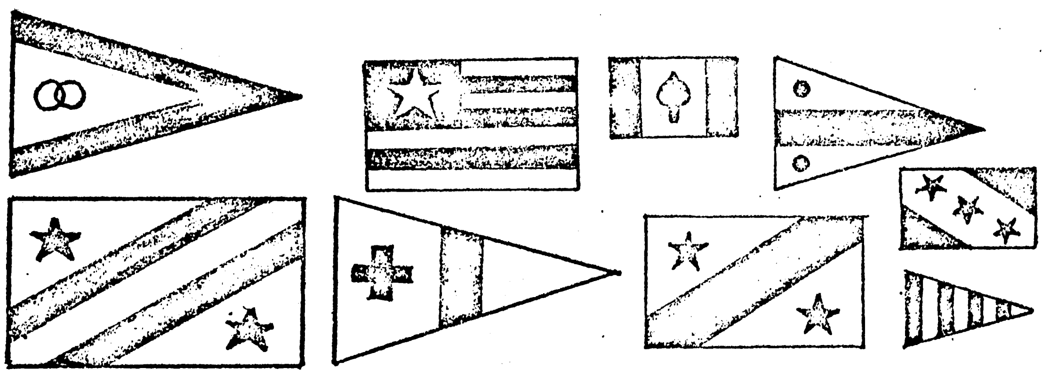
(C) 

(D) 

6. Which one of the following is an operational definition?

(A) bank - one place where people take their money to keep it
(B) savings account - the bank will pay people money if they put their money into the bank's savings account
(C) check - piece of paper which can be used like money
(D) loan - money which is lent

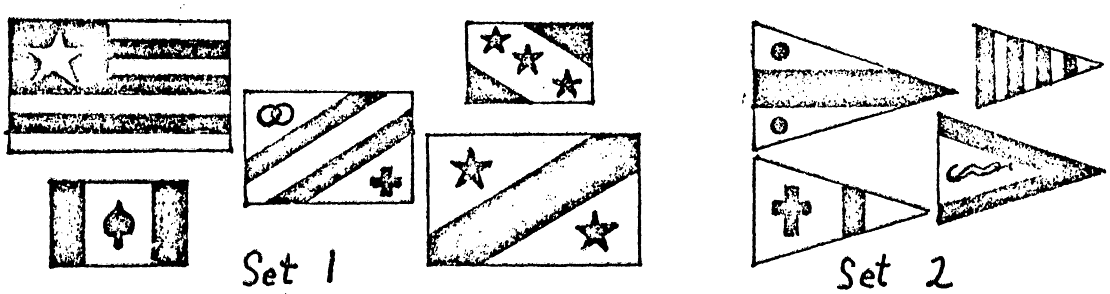
7. Here is a set of flags



How could you divide this set of flags into THREE groups so that all the flags in a group are alike in some way? Each group of flags would be different from the other groups.

(A) 3 different sizes of flags
(B) 3 different shapes of flags
(C) divide them by whether they have a cross or not
(D) divide them by the number of stripes

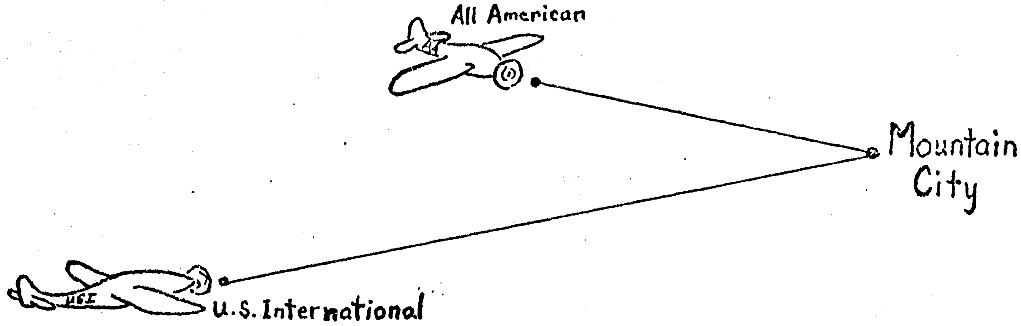
8. The set of flags below has been divided into two sets.



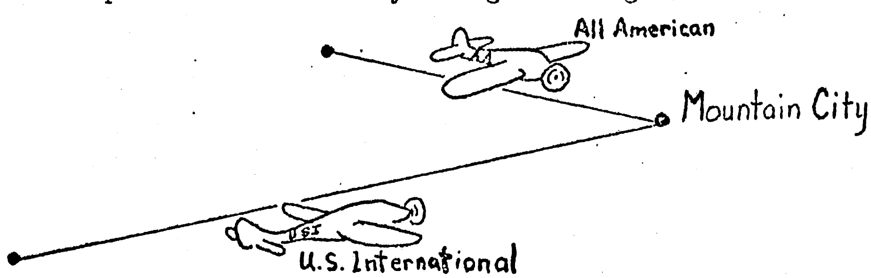
How are the flags divided into 2 sets?

(A) by size
(B) by whether they have a cross or not
(C) by the number of stripes
(D) by shape

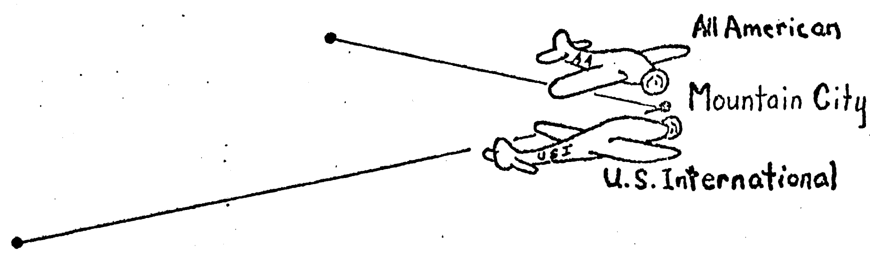
9. Two airplanes had non-stop flights to Mountain City. Both planes left for Mountain City at the same time but the U. S. International plane had twice as far to go as the All American plane. Here is how the planes looked when the flights started.



Here is how the planes looked half way through the flight.



Here is how the two planes looked at the end of the flight. They both reached Mountain City at exactly the same time.



What can be said about the speed of the two planes during the flight?

(A) The U. S. International plane traveled at a faster speed than the All American plane.
(B) The All American plane traveled at a faster speed than the U. S. International plane.
(C) Both planes traveled at the same speed.
(D) One cannot compare the speeds of the two planes.

10. While studying careers, the 6th grade social studies students were looking at how much money people in different jobs earned. Here is what they found

Managers	$12,000
Sales Workers	$10,000
Skilled Workers	$ 9,000
Transportation Workers	$ 6,000
Secretaries	$ 6,000
Laborers	$ 5,000

What is the range of the salaries?

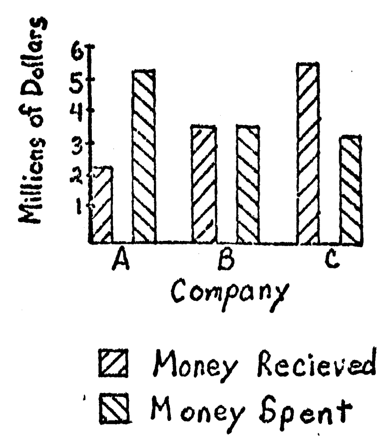
(A) $6,000
(B) $7,000
(C) $8,000
(D) $9,000

11. When a company is making a profit, people say they are "in the black." Look at the amount of money the company receives and the amount of money they spend. A company is "in the black" when they receive more money than they spend.

When a company is not making a profit, people say they are "in the red." Look at the amount of money the company receives and the amount of money they spend. A company is "in the red" when they spend more money than they receive.

By looking at the graph at the right, which company is "in the black"?

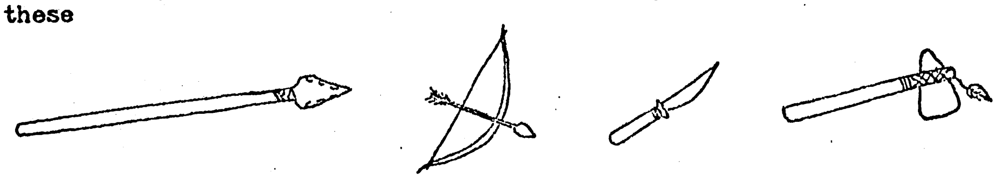
(A) Company A
(B) Company B
(C) Company C
(D) None of the above



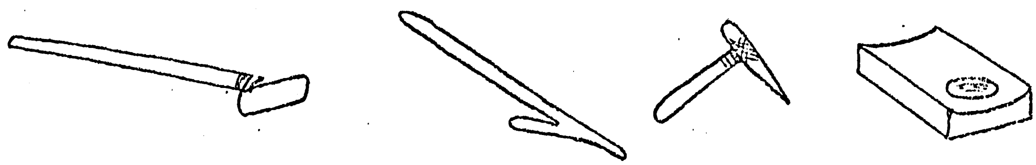
12. By looking at the graph at the right, which company is "in the red"?

(A) Company A
(B) Company B
(C) Company C
(D) None of the above

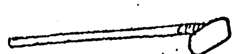
13. Most of the early American Indians were either farmers or hunters. When people study Indian ruins of hunting tribes they usually find tools such as these



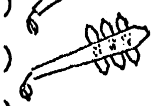
When they dig up ruins of farming tribes, they usually find tools like these

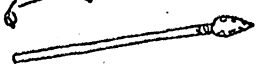


Which of the following tools would most likely be found in the ruins of a farming tribe?

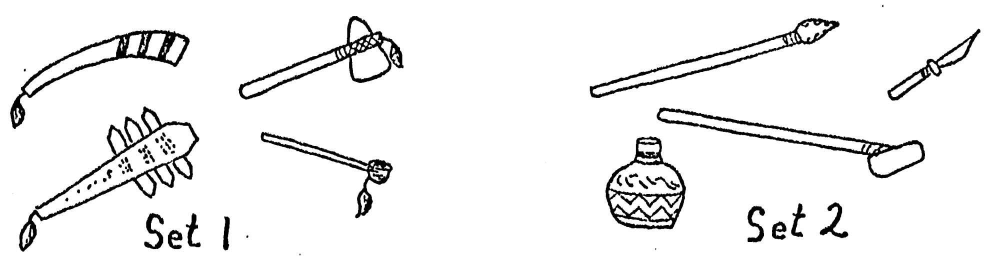
(A) 

(B) 

(C) 

(D) 

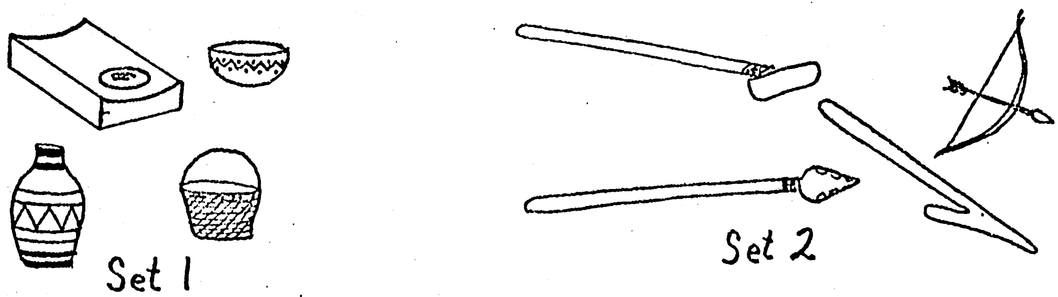
14. An archeologist is a person who studies how people lived in the past. One archeologist divided a group of Indian tools into two groups



How did he arrange the tools into these two sets?

(A) Set 1 was used by hunters and Set 2 was used by farmers.
(B) Set 1 has tools with feathers and Set 2 has tools without feathers.
(C) Set 1 has tools with handles and Set 2 has tools without handles.
(D) Set 1 has tools which are weapons and Set 2 has tools which are not weapons.

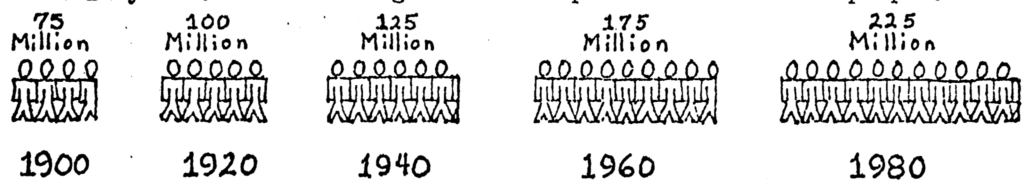
15. The archeologist formed two other groups of tools



How did he arrange the tools into these two sets?

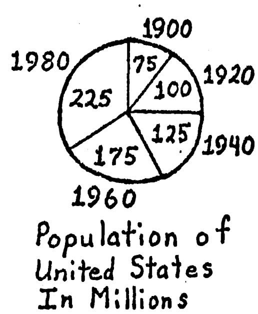
(A) Set 1 was used by farmers and Set 2 was used by hunters.
(B) Set 1 has tools without handles and Set 2 has tools with handles.
(C) Set 1 has tools used to store or grind food and Set 2 has tools which are not used to store or grind food.
(D) Set 1 has tools not used for weapons and Set 2 has only tools used for weapons.

16. Below are figures which represent the population of the United States in certain years. Each drawing of a man represents 20 million people.

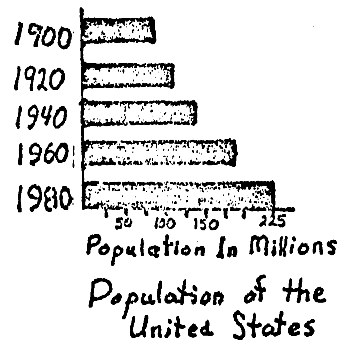


Jim wanted to make a graph for social studies using this data. Which kind of graph would be BEST to show this change in population?

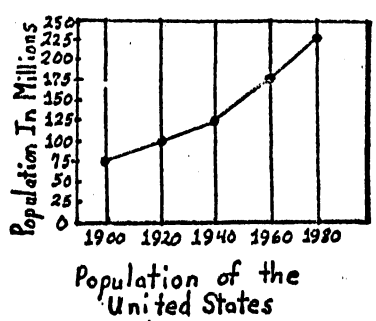
(A)



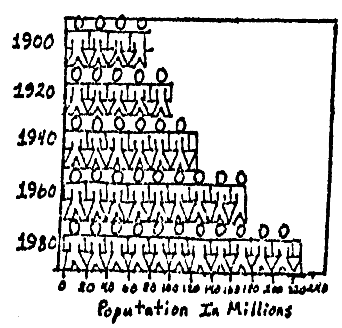
(B)



(C)



(D)



17. The United States government spends more money than it takes in from taxes. It borrows money to make up the difference. The amount of money borrowed is called the national debt. The debt was $291 billion in 1960, $323 billion in 1965 and $383 billion in 1970. What will the debt probably be in 1976?

(A) $350 billion
(B) $470 billion
(C) $580 billion
(D) $640 billion

18. A person is doing an experiment in social studies. Which list below gives the correct order of steps the person should use for testing a hypothesis?

(A) 1. Do the experiment and write down the results.
2. Figure out what the variables are and decide how to do the experiment.
3. Decide if the results supports the hypothesis.
4. Think about what the results mean and draw conclusions.

(B) 1. Figure out what the variables are and decide how to do the experiment.
2. Do the experiment and write down the results.
3. Think about what the results mean and draw conclusions.
4. Decide if the results support the hypothesis.

(C) 1. Decide if the results supports the hypothesis.
2. Think about what the results mean and draw conclusions.
3. Figure out what the variables are and decide how to do the experiment.
4. Do the experiment and write down the results.

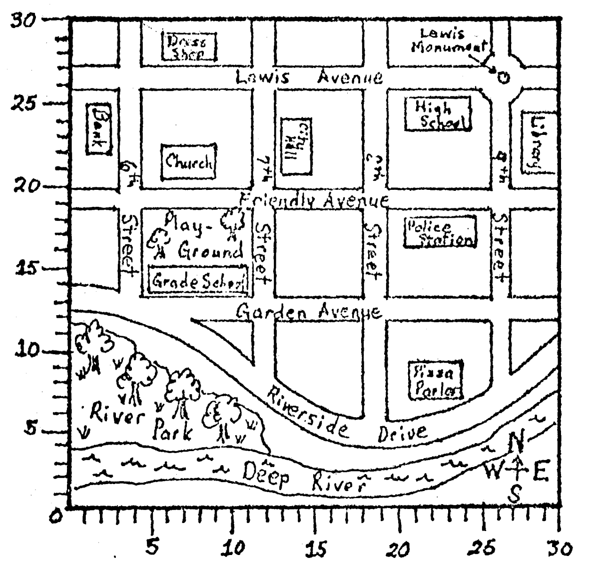
19. While studying the climate of the United States, Tom decided to keep a record of the rainfall in his home town. He did this for three months. Here are his results.

January	17 centimeters
February	14 centimeters
March	8 centimeters

What was the average monthly rainfall during these three months?

(A) 13 centimeters
(B) 14 centimeters
(C) 39 centimeters
(D) 17 centimeters

Use the map below to answer the next two questions.



20. Which of the following is a correct set of directions to get from the grade school to the library?

(A) Go west on Garden Avenue to 9th Street. Go north on 9th Street to Friendly Avenue. The library is north of Friendly Avenue on the west side of 9th Street.

(B) Go south on 7th Street to Lewis Avenue. Go east on Lewis Avenue to 9th Street. The library is east of 9th Street and on the north side of Lewis Avenue.

(C) Go north on 6th Street to Friendly Avenue. Go east on Friendly Avenue to 9th Street. The library is north of Friendly Avenue and east of 9th Street.

(D) Go east on Garden Avenue to 9th Street. Go south on 9th Street to Friendly Avenue. The library is east of 9th Street and south of Friendly Avenue.

21. Look at the map above and find out which set of rectangular coordinates is correct.

	A	B	C	D
Pizza Parlor	(22, 8)	(8,22)	(18,22)	(22,18)
Dress Shop	(7,28)	(7,28)	(28,7)	(28,7)
High School	(22,24)	(24,22)	(24,22)	(22,24)

22. While studying about American Indians, Cheryl attended an Indian pow-wow. Which one of her statements is an inference, instead of an observation?

(A) "The Indians wore brightly colored war paint."
(B) "It takes the Indians hours of practice to learn the dances."
(C) "The chief had a large head-dress with over one hundred feathers."
(D) "Most of the Indian moccasins were decorated with beads."

23. Some voters were talking about an upcoming election. Which one of their statements was a prediction rather than an observation.

(A) "Senator Jones says he wants better schools."
(B) "Brown says he is for law and order."
(C) "Taxes will go up if Jones is re-elected."
(D) "Big government is one thing Brown is against."

24. Mike was making some punch for a friend's birthday party. He mixed 9 liters of pineapple-orange juice and 3 liters of 7-Up. What was the total amount of punch?

(A) $9 + 3 = 12$ liters
(B) $9 \times 3 = 27$ liters
(C) $9 \div 3 = 3$ liters
(D) $9 - 3 = 6$ liters

25. Jim went with his mother and father to buy a new mattress. What is the BEST way to find out if a mattress is hard or soft?

(A) See if it has air vents and handles on the sides.
(B) Measure how thick the mattress is.
(C) Find out what kind of material the mattress is made of
(D) Lie down on the mattress.

26. In social studies a variable in an experiment is

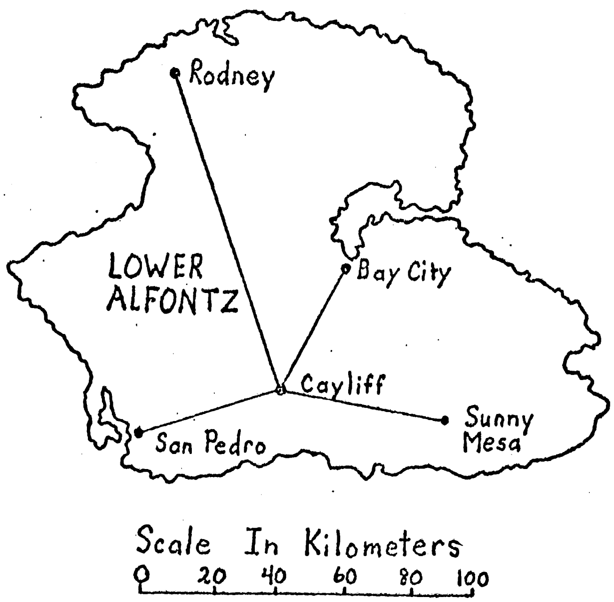
(A) anything in the experiment that can change.
(B) what the experiment is about.
(C) what is learned by doing the experiment.
(D) a method that is used.

27. In a very close election Mrs. Williams won by two and three tenths percent. Which number below is equal to two and three tenths?

(A) .23
(B) .023
(C) 23.0
(D) 2.3

28. A school had four social studies teachers. All four teachers had just finished a unit on China. Mr. Black, one of the teachers, had lived in China and had brought many interesting things to school to show the students. Mr. Black's students did porjects on China. Mrs. Green's students talked about newspaper articles about China. The other teachers had their students answer the questions at the end of the chapter. Since Mr. Black seemed to know more about China than the other teachers, he said he would make out a test to give to all of the students. After giving the test and looking at the results, some of the teachers said the test was not fair for their students. Something was different for the students of each teacher. What variable was not kept the same?

(A) the way the test was written
(B) the school where the test was given
(C) the scores the students made on the test
(D) the way the unit on China was studied in the different classes



29. On the map above, how far is it from Rodney to San Pedro?

(A) 80 km
(B) 100 km
(C) 140 km
(D) 180 km

30. What units should you use to measure the volume of gasoline in the gas tank of a car?

(A) square centimeters
(B) meters
(C) liters
(D) kilograms

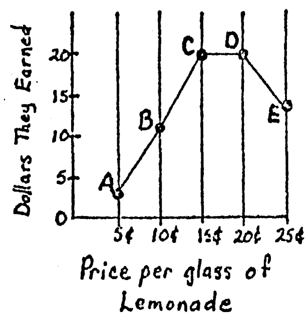
31. People have said, "Living on a farm is living the good life."

Before you can agree or disagree with this statement you will need to know

(A) how much money farmers make.
(B) how far away from your friends you will be.
(C) how much more it will cost to live on a farm.
(D) what the person meant by "the good life."

Read the following story and answer the next seven questions.

Bob and Betty made money during the summer by selling lemonade in a lemonade stand at the lake. They had been selling the lemonade for 25¢ a glass. They thought that maybe if they lowered their price, more people would buy lemonade and they could make more money. Each weekend for five weekends, they sold lemonade for a different price. They kept careful records of the amount of money they made at each price. This graph shows their results.



32. The hypothesis Bob and Betty were testing was probably

(A) the higher the price, the more money they will earn
(B) the same amount of lemonade will be sold no matter what the price
(C) the lower the price, the more money they will earn
(D) they will earn the same amount of money at 15¢ a glass that they do at 20¢ a glass

33. Bob and Betty made the LEAST amount of money when they charged

(A) 5¢
(B) 10¢
(C) 15¢
(D) 25¢

34. If they had raised the price to 30¢, they probably would

(A) earn more money than they did at 25¢
(B) earn less money than they did at 25¢
(C) earn the same amount of money as they did at 25¢
(D) not sell any lemonade since the price was so high

35. When doing this experiment Bob and Betty should

(A) move their stand to a different place each time they change the price
(B) give away gum when they charge more for the lemonade so the people would not feel cheated
(C) be sure that the lemonade tasted the same all the time
(D) lower the price on rainy days to try to sell more lemonade

36. In the experiment Bob and Betty should change

(A) the size of the glass each time they change the price
(B) the number of people buying lemonade
(C) the amount of sugar they put in the lemonade
(D) only the price for a glass of lemonade

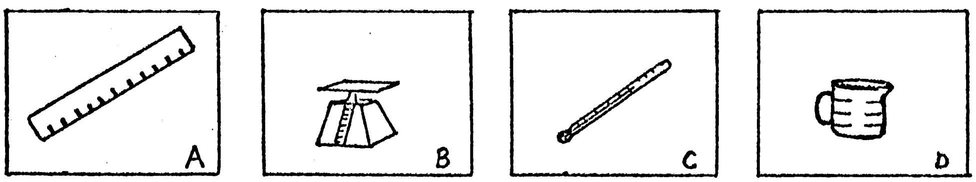
37. The results Bob and Betty were interested in were

(A) the number of glasses of lemonade they sold
(B) how much it cost to make the lemonade
(C) the price of a cup of lemonade
(D) the amount of money they earned

38. Which part of the graph supports their hypothesis

(A) $\overline{DE}$
(B) $\overline{CD}$
(C) $\overline{AB}$
(D) the whole graph supports their hypothesis

39. Jill was making some candy. The recipe called for 500 milliliters of corn syrup. Which piece of equipment could be used to measure a volume of corn syrup equal to 500 milliliters?



(A) Ruler
(B) Food Scale
(C) Thermometer
(D) Measuring Cup

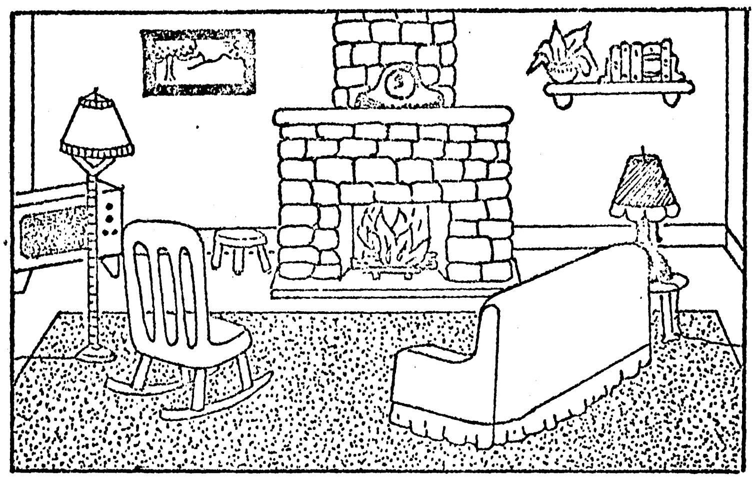
40. Tom and Bill were drawing a map of their neighborhood. They were measuring the distances on the map in meters. Which list of distances is in order from smallest to largest?

(A)	.2m	.12m	.37m
(B)	.15m	.49m	.089m
(C)	.029m	.18m	.6m
(D)	.58m	.62m	.077m

41. Jerry and Carla were talking about a recent student council election. "Richard just barely won the election," Carla said. "He will certainly be a good president." "He will work really hard," Jerry agreed. "And the students will support him."

Which one of their statements is an observation?

(A) "Richard just barely won the election."
(B) "He will certainly be a good president."
(C) "He will work really hard."
(D) "And the students will support him."



42. Which one of the following is an observation about the picture above?

(A) The people who live in this house like to sit around the fire.
(B) The furniture and the house are old.
(C) There are books on the shelf to the right of the fireplace.
(D) This room is where the members of the family spend much of their spare time.

43. Jane needed two pieces of string for a social studies display. One piece needed to be .7 meters long and the other piece needed to be 2.82 meters long. How much string will she need altogether?

(A) 2.52 meters
(B) 2.89 meters
(C) 9.82 meters
(D) 3.52 meters

44. Mr. Black had decided to run for State Representative. Mr. Black noticed that all of the people who won in the last election said they would lower taxes. He thought that campaigning for lower taxes might help a candidate be elected. Mr. Black said he was in favor of lower taxes while the person he was running against campaigned for better schools and roads. Sure enough, Mr. Black was elected.

Which sentence from the story tells Mr. Black's hypothesis?

(A) Mr. Black had decided to run for State Representative.
(B) The people who won in the last election were for lower taxes.
(C) He thought that campaigning for lower taxes might help a candidate be elected.
(D) Mr. Black was elected.

Fourth Class (Parcel Post) Zone Rates

Weight In Pounds	Zones					
	Local	1 & 2	3	4	5	6
	Delivery	up to 150	151-300 mi.	301-600 mi.	601-1000 mi.	1001-1400 mi.
5	.70	.85	1.00	1.15	1.30	1.45
10	.85	1.15	1.45	1.75	2.05	2.35
15	1.00	1.45	1.90	2.35	2.80	3.25
20	1.15	1.75	2.35	2.95	3.55	4.15
25	1.30	2.05	2.80	?	4.30	5.05

45. Use the table above to help you answer this question. How much would you pay to send a 15 pound package 700 miles?

(A) $1.00
(B) $1.30
(C) $2.35
(D) $2.80

46. Use the table above to help you answer this question. Which of the statements below is true? The cost of mailing a 25 pound package 500 miles is

(A) less than mailing a 15 pound package 900 miles.
(B) more than mailing a 15 pound package 900 miles.
(C) the same as mailing a 15 pound package 900 miles.
(D) more than mailing a 20 pound package 1200 miles.

47. People were food gatherers for the first 500,000 years of their life on earth. Then about 10,000 years ago they began to grow food. Cities were first built about 6,000 years ago. The first airplane was built by someone 70 years ago. Only 25 years ago people began to use nuclear power and space vehicles.

Which sentence gives the BEST guess of what will happen based upon what you learned from the story?

(A) Change will take place more rapidly.
(B) People will become tired of change.
(C) Things will stop changing.
(D) People will want to return to "the good old days".

48. Read the story about the experiment and then answer the two questions that follow.

Mr. Marshall was a farmer and he wanted to know which kind of fertilizer would be best for his corn. He divided his field into three equal parts. He planted the same kind of seed in each section. He put two tons of Brand X fertilizer on one part, used two tons of Brand Y fertilizer on another part, and used two tons of Brand Z fertilizer on the third part. When he harvested the corn, he wrote down how much corn he got off of each section. Here are his results.

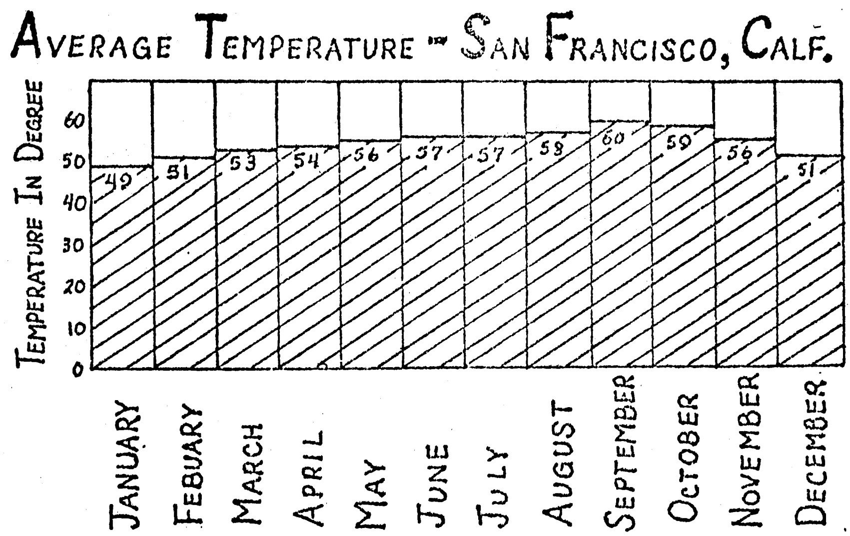
Brand of Fertilizer	Amount of Corn
Fertilizer X	80 bushels per acre
Fertilizer Y	114 bushels per acre
Fertilizer Z	106 bushels per acre

Which variable was kept the same in Mr. Marshall's experiment?

(A) the brand of fertilizer and the field
(B) the amount of fertilizer and the kind of seed
(C) the amount of corn and the kind of seed
(D) the amount of fertilizer and the brand of fertilizer

49. What variable did Mr. Marshall change in his experiment?

(A) the kind of seed
(B) the amount of fertilizer
(C) the brand of fertilizer
(D) the amount of corn



50. The temperature graph above shows that the average temperature for April is

(A) 51
(B) 54
(C) 57
(D) 60

51. By looking at the temperature graph determine which of the following months has a lower average temperature than June

(A) July
(B) August
(C) October
(D) April

52. Four students observed different things about a country shown on a map. Which student made the most precise observation?

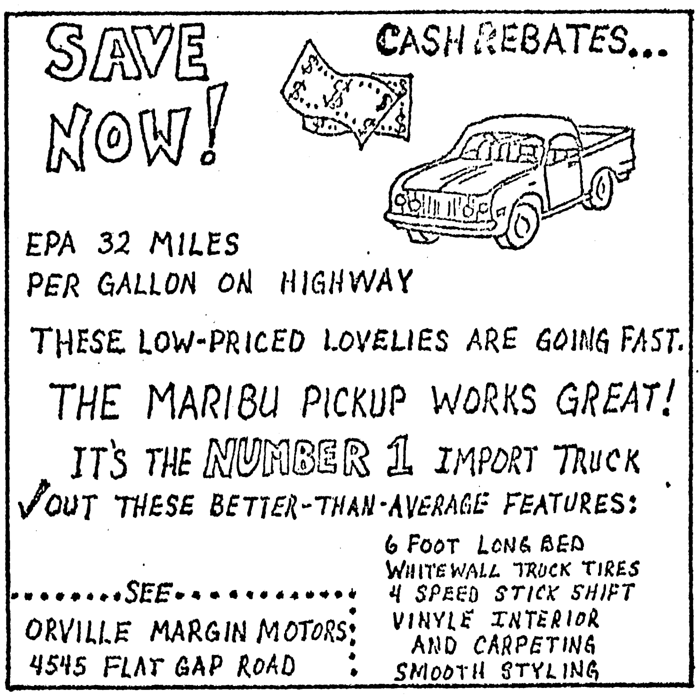
(A) Fred: Mountains cover over half the country.
(B) Linda: The Delta River is 497 kilometers long.
(C) Joe: The population of Capital City is over 1,500,000.
(D) Sue: The rainfall varies from less than 20 centimeters to over 250 centimeters per year.

53. In the family living class at school the students were working on sewing projects. Allen had decided to make a T-shirt. The next Saturday Allen and his parents went to the fabric store where Allen looked through the books and picked out a pattern. After choosing a pattern he liked, Allen chose his material. He found some soft material with bright stripes. During the next two weeks Allen worked hard on his shirt. When Allen wore the shirt he was cool and comfortable.

Which of Allen's senses did he use in the story?

(A) hearing and smell
(B) touch and sight
(C) sight and smell
(D) touch and hearing

54. Read the ad below.



Which statement in the ad is an OPINION rather than an observation?

(A) 32 miles per gallon on highway
(B) It's the Number 1 import truck
(C) 6-foot long bed
(D) Vinyl interior and carpeting

Read the story below and answer the next four questions.

A shopping center manager noticed that stores started selling more as soon as Christmas decorations were put up and Christmas music was being played. The manager wanted to know if the increased sales were caused by the decorations and music. She decided to put up decorations and play Christmas music in half of the stores but not in the other half. After a week she went to ask how much the stores had sold.

55. What hypothesis was the manager testing in her experiment?

(A) The amount of sales is affected by how close it is to Christmas.
(B) The amount of sales is affected by the kinds of things the store sells.
(C) The amount of sales is affected by how early the decorations were put up and the music was played.
(D) The amount of sales is affected by whether the decorations were up and the Christmas music was playing.

56. In the shopping center experiment above, what was the controlled variable?

(A) the shopping center where the stores were located
(B) how much the stores sold
(C) when the decorations were put up
(D) whether Christmas music was playing

57. In the experiment above, what is the manipulated variable?

(A) the shopping center where the stores were located
(B) how much the stores sold
(C) what kinds of things the stores sold
(D) whether the stores had Christmas decorations and music

58. In the experiment above, what was the responding variable?

(A) the shopping center where the stores were located
(B) how much the stores sold
(C) what kinds of things the stores sold
(D) whether the stores had Christmas decorations and music

GO ON TO THE NEXT PAGE.

59. The Davis family owned and ran a small circus. Mr. Davis noticed that on some days many more people came to the circus than on other days. He decided to try to find out why this was. He made the hypothesis that maybe the temperature affected how many people came to the circus. He decided to make more observations to test his hypothesis.

Which of the following observations would be most helpful in testing the hypothesis?

(A) Wait until a rainy day and count how many people come to the circus.
(B) See if more people come on week-ends than during the week.
(C) Get records from the weather bureau and see if more people came on warm days.
(D) See if the animals do their tricks better on warm days.

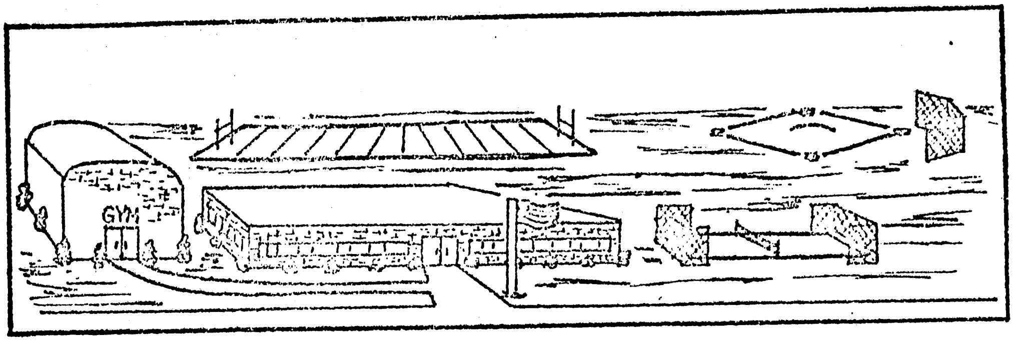
60. Which of the following observations would support Mr. Davis' hypothesis?

(A) When it rained he did not sell as many tickets.
(B) He sold more tickets on days when children were out of school.
(C) On the coldest day of the year very few people came to the circus.
(D) More people came to the circus on the Fourth of July than on any other day.

61. Mr. Jim Baxter is president of the American Tobacco Growers. He has been asked to speak to a group of senators about a bill they are about to pass. The bill would not allow people to smoke in public buildings, on buses, airplanes or trains. This would cut down on the number of cigarettes people smoke.

How will Mr. Baxter probably feel about the bill?

(A) He would be for the bill because smoking is dangerous to your health.
(B) He would be for the bill because many people do not like to be around other people who smoke.
(C) He would be against the bill because he thinks everyone should smoke.
(D) He would be against the bill because he probably grows tobacco and wants to sell all he can.



62. Based on the drawing of the school above, what can you tell about this community?

(A) This is a farming community.
(B) Most students who go to this school will go on to college.
(C) Sports are very important to the people who live here.
(D) This is an all-boy school.

63. A farmer from another country was touring farms in the United States. He noticed that the wheat in this country was much better than the wheat in his country. He thought that maybe the seed the farmers used was better in this country than in his country. The farmer did some experiments and made some observations. Which observation was most helpful in testing his inference?

(A) Irrigated wheat was better than wheat that was not irrigated.
(B) He took some U. S. wheat to his country and found that it produced more wheat than the kind he had been using.
(C) Fertilizing the wheat caused it to grow better.
(D) Planting the wheat deeper did not improve the crop.

64. Jean made money by having a paper route. She kept a record of her income and expenses. Every once in a while she would take money out of her account to buy things for herself. Below is a copy of the records she kept.

DATE	DEPOSIT		WITHDRAWAL		BALANCE	
10/4/75	23	00			70	00
10/10/75			18	00	52	00
11/1/75	25	00			77	00
11/9/75			18	00	59	00
12/3/75	24	00			83	00
12/11/75			18	00	65	00
12/22/75			20	50	44	50
1/4/76	22	00			66	50
1/9/76			18	00	48	50
2/3/76	27	00			75	50
2/12/76			19	00	56	50

Which statement below is the best inference about Jean's account?

(A) Jean spent $20.50 for Christmas presents.
(B) Jean makes mistakes in her records.
(C) Jean is trying to save money to go to college.
(D) Jean deposits the money from her paper route regularly.

APPENDIX B

ALTERNATE ACTIVITIES USED WITH CONTROL GROUP

Alternate Activities for Module 62

Capillary Action

Activity 1

Objectives:

(1) The students will observe an example of capillary action.

(2) The students will be able to define capillary action.

Each student is given one piece of blotter paper measuring 2 cm by 9 cm. The strip of blotter paper is submerged in water to a depth of 5 mm for one minute after which it is removed from the water. The students then write down as many observations as they can about what has just happened to the blotter paper. These observations are discussed and capillary action is defined.

Activity 2

Objectives:

(1) The students will observe examples of cohesion and adhesion.

(2) The students will be able to define cohesion and adhesion.

(3) The students will be able to explain capillary action in terms of cohension and adhesion.

Each pair of students is given a 10 cm square of waxed paper, a dropper, and a 50 ml beaker containing water. They are told to put a drop of water on the waxed paper and make observations of the water drop. During the observation period the teacher should be sure that the students notice that the drop is round, rounded up, will stick to other objects such as a pencil which can be used to pull it around on the waxed paper. After the observation period the properties of water which are responsible for the behavior of water, adhesion and cohesion, are discussed and defined. Also discussed are how these properties are responsible for capillary action.

Activity 3

Objectives:

(1) The students will observe examples of capillary action in various sized tubes.

(2) The students will be able to explain that water will go up higher in a small diameter tube than in a large diameter tube, because the weight of the water is less in relation to the forces pulling the water up.

The students are shown a capillary action apparatus which consists of four glass tubes of various diameters with the lower end of each tube submerged in a reservoir of water. The students will observe that the water goes up higher in the tube with the smaller diameter. This is discussed in terms of cohesion, adhesion and the weight of the water being raised.

Activity 4

Objectives:

(1) The students will observe that the movement of water will become slower as it gets higher above the source of the water.

(2) The students will be able to explain this observation in terms of cohesion, adhesion and the weight of the

water being raised.

(3) The students will learn to graph experimental data.

Each pair of students is given a 2 cm by 9 cm strip of blotter paper, a ruler, and a vial of water. They are told to hold the paper in the water to a depth of 5 mm and to mark the progress of the moving front of the water every 20 seconds for 2 minutes. When this is completed measurements are taken and a graph is constructed. The results of the activity and resulting graph are discussed.

Activity 5

Objectives:

(1) The students will understand that capillary action is necessary in the soil for plants and other organisms to obtain water.

(2) The students will observe that capillary action occurs at different rates in different soil types.

After reading about capillary action in the soil in the textbook (Modern Science, Laidlaw, pp. 55-57), the students were instructed to bring a soil sample to school. The soil was placed in a 30 ml plastic pill vial which had a single 1 mm diameter hole in the bottom. This was placed in a Petri dish containing water and the distance the water had traveled was marked every 30 seconds for five minutes. These results were graphed. Different soil types were compared and plant growth as it relates to soil type and capillary action was discussed.

Activity 6

Objective:

(1) The student will understand that capillary action can be

used to separate various chemicals by means of paper chromotography.

Each pair of students is given a 3 cm by 25 cm strip of white blotter paper, a Petri dish containing water, and their choice of several different colors of ink. A very small drop of ink is placed on the paper 1 cm from the bottom and the lower 5 mm of the strip is submerged in water for 20 minutes, after which the strip is dried. The color separation is again explained in terms of cohesion and adhesion between the dyes, water, and paper.

Alternate Activities for Module 63

Animal Behavior

Activity 1

Objective:

(1) The students will observe that repetition and reward can bring about learning in an animal.

The students were instructed to find out if a gerbil can learn. After discussing the proper procedure for building a maze and conducting the investigation, a cardboard maze was constructed. The students were told that maze-time is an indication of learning, and that the shorter the maze-time the more the animal has learned. The gerbil was run through the maze twice a day for two weeks. Each student kept a data table and at the end of the activity, the teacher told the students what the results on the data table meant. Process skills such as operationally defining learning, controlling variables, interpreting data, forming hypotheses, and making predictions, were not discussed.

Activity 2

Objective:

(1) The students will become familiar with the on-going behavior of gerbils and will learn how these behaviors are valuable for survival.

Each group of five students was given a caged gerbil to quietly observe for 10 minutes. The gerbil was then put into a different cage or another environment unfamiliar to the animal and was observed for another 10 minutes. A drop of syrup was added to the animal's coat so that grooming behavior could be observed. An 8 mm film loop from the "Slow Down" module of the Biological Science Curriculum Study (BSCS) Human Science program was shown. This film loop shows grooming behavior of rats at normal speed and in slow motion. The survival value of the various behaviors was discussed.

Activity 3

Objective:

(1) The students will become familiar with the behavior of Siamese Fighting fish and will learn how these behaviors are valuable for survival.

Each group of four students was given a male Siamese Fighting fish in a four liter plastic tank to quietly observe for 5 minutes. The students then observed the reaction of the fish to movement outside the tank, to a mirror introduced into the tank, to another male fish in an adjacent tank, to another male fish in the same tank, and to a female fish in the same tank. The survival value of the various behaviors was then discussed.

Activity 4

Objective:

(1) The students will "build" an animal which would be well suited for survival in a given environment.

For this activity another module entitled "Animal Crackles" was used from the BSCS Human Science program. It is the goal of this module to show that certain features and characteristics of various animals enable that animal to survive in a given environment. The culminating activity is one in which the students working in groups of about six decide upon an environment and then using pictures of various parts of different animals put together an animal ideally suited to survive within their designated environment.

Alternate Activities for Module 64

Electric Circuits and Their Parts

Activity 1

Objective:

(1) The students will use symbols representing the components of a circuit to draw a schematic diagram of a simple circuit they have constructed.

After reviewing the basic concepts of a circuit covered in module 62, the page entitled "Common Circuit Symbols" from SAPA II, Module 64 is distributed and discussed. Using a dry cell, a switch, wires, and a light bulb and socket, the students construct a simple circuit. By using the symbols for the components of the circuit, the students then will draw a schematic diagram of the circuit they have constructed.

Activity 2

Objectives:

(1) Using schematic diagrams, the students will be able to construct simple series and parallel circuits using two bulbs and sockets, one dry cell, one switch and wires.

(2) The students will be able to list the advantages and disadvantages of using parallel and series circuits.

(3) The students will learn that light bulbs resist the flow of electricity.

The students are given several wires, two bulbs and sockets, a dry cell, and a switch and are instructed to build a circuit so that both bulbs will light. Allow time for trial and error experimentation. After most students have succeeded show them a schematic diagram of a series circuit and have them connect the bulbs in series. After the meaning of the word series is discussed, have the students trace the path of electricity through the circuit. Discuss what happens when one of the light bulbs is unscrewed from the socket or burns out.

Have the students add a third light bulb to their series circuit. Have them notice what happens to the brightness of the bulbs when additional bulbs are added to the circuit. Explain that each bulb resists the flow of electricity so that each bulb added to the series will increase the resistance in the circuit and less electricity can flow through the circuit.

The students are shown a schematic diagram of a parallel circuit which they will then construct. The meaning of the word parallel is discussed, the students trace the electricity through the circuit and discuss what happens when one of the light bulbs is unscrewed. A third bulb is added and resistance in a parallel circuit is discussed.

Activity 3

Objectives:

(1) The students will be able to describe the function of a resistor in an electric circuit.

(2) The students will be able to construct circuits incorporating fixed and variable resistors.

Explain to the students that there are times when it is helpful to reduce the amount of electricity flowing through a circuit or part of a circuit. In these cases a resistor is used. Sometimes it is helpful to be able to change the amount of electricity flowing through a circuit. Give several examples of uses of variable resistors such as volume on a radio, speed setting on a drill or electric mixer, etc.

The students are instructed to build a parallel circuit using two light bulbs, a switch, a dry cell, and a resistor so that one light bulb is dimmer than the other one. The concept of resistance is again discussed using the example of water running through a large hose and then a small hose with the small hose limiting the amount of water that can flow through the large hose.

The students are then instructed to construct a simple series circuit with one bulb, one dry cell and a 5 cm long piece of pencil lead included in the circuit instead of a switch. By connecting one wire to one end of the pencil lead and sliding the other wire along the lead the resistance can be varied so that the light may be bright or dim. The students are then instructed to build a parallel circuit with two bulbs and use the variable resistor to vary the brightness of one bulb without changing the brightness of the other.

Activity 4

Objectives:

(1) The students will be able to connect batteries in series and in parallel.

(2) The students will be able to trace electricity through circuits where the batteries are connected in series and in parallel.

(3) The students will be able to discuss the advantages and disadvantages of having batteries connected in series and in parallel.

The students are instructed to construct a simple series circuit with one bulb, one dry cell, one switch and wires. After noting the brightness of the bulb, another dry cell is added in series. The path of the electricity is traced through the circuit. It is explained that two dry cells connected in series can force more electricity through the circuit than one dry cell alone.

One of the dry cells is reversed so that the two positive (or negative) ends of the dry cells are hooked together. It is explained to the students that the dry cells are now trying to force the electricity to go in opposite directions so that they cancel each other out.

The students are then instructed to connect the dry cells in parallel and to note the brightness of the light. After tracing the path of the electricity through the circuit, it is explained that the electricity coming from either dry cell only has the one dry cell forcing it through the circuit.

Activity 4

Objectives:

(1) The student will be able to identify and construct a short circuit.

(2) The student will be able to construct a circuit containing a fuse.

(3) The student will be able to explain the safety value of a fuse in an electrical circuit.

(4) The student will be able to explain the dangers of a short or overloaded circuit.

The students are instructed to construct a simple series circuit using two dry cells in series, a switch, wires and a bulb and socket. After the students have traced the flow of electricity through the circuit, they connect another wire across the light bulb so that a short circuit will be formed. The students trace the flow of electricity through the short circuit and the causes and dangers of short circuits are discussed. It is pointed out that a fuse is a safety device used to prevent fires when short circuits occur. The students construct a fuse using a strand of #1 steel wool taped to a 3 x 5 index card and insert it into the circuit. After this fuse is used with a normal circuit, the circuit is again shorted out and the fuse creates an open circuit.

Using several small motors and lights, the teacher demonstrates how a circuit can also become overloaded until the fuse burns in two. The following questions are then discussed. If fuses in your home burn out frequently, what does it mean? What should be done to prevent this? How could you tell the difference between a short circuit and an overloaded circuit?

Alternate Activities for Module 70

Heat Transfer: Conduction, Convection, and Radiation

Activity 1

Objectives:

(1) The students will be able to explain thermal expansion by stating that heat causes molecules in any type of material to move faster, and that when they move faster, they take up more space.

(2) The students will state that thermal expansion affects gases more than liquids and liquids more than solids.

(3) The students will be able to state that thermal expansion affects some materials more than other materials.

After using diagrams and examples to explain the first objective, a series of teacher demonstrations are used to reinforce the concept and also to illustrate the second objective. These demonstrations included the use of an air thermometer (flask with a small amount of colored water stoppered with a one hole rubber stopper with a glass tube extending down into the flask just below the level of the water), a liquid thermometer (a flask totally filled with colored water stoppered with a one hole rubber stopper with a glass tube extending about 30 cm above the flask), and a metalic ball and ring.

The third objective is satisfied by a teacher demonstration using a bimetalic strip.

The practical application of these concepts were discussed bringing in their use in thermostats, thermometers, thermal expansion joints, etc.

Activity 2

Objectives:

(1) The students will be able to state that radiant energy is converted to heat when it is absorbed and that heat can be given off in the form of radiant energy.

(2) The students will be able to state that dark colors absorb more radiant energy than light colors and that light colors radiate more radiant energy than dark colors.

Two activities were completed in order to satisfy the above objectives. The first activity dealt with absorption of radiant energy. Two aluminum cuts, one painted black and one unpainted, were filled half full of water. Styrofoam caps with a slot for a thermometer were used to cover the cups. Heat lamps were shined on the cups and temperature readings were taken every minute for fifteen minutes.

The second activity was similar using the same equipment except for the light. Boiling water was added to both cups and temperature readings were taken to determine which color cup cooled the quickest.

Application of these concepts to the color of clothing worn during different times of the year, the color of the roof on a house, the color of radiators, etc., was made in the following discussion.

Activity 3

Objectives:

(1) The student will be able to state that when a material is heated the molecules begin to move faster. If those molecules collide with other molecules around them, this will cause other molecules to move faster. This reaction will travel along a material and is the method by

which heat is conducted from one place to another.

(2) The student will be able to identify materials that conduct heat well and those which do not (non-conductors).

Two activities and a teacher demonstration were used to satisfy the above objectives. The first activity involved the use of two styrofoam cups, an aluminum "horse shoe" and a styrofoam cap for each cup which had a slot for one end of the horse shoe and another slot for a thermometer. Tap water was put in one cup and boiling water was placed in the second cup. The styrofoam caps were put in place and the horse shoe was situated so that both ends extended well into the water. Temperature readings were taken on both cups every two minutes for twenty minutes as heat was conducted through the horse shoe from the hot water to the cold water.

A second activity was essentially the same as SAPA II, Module 70, Activity 2, except that the students did not formulate hypotheses, define operationally, interpret data, or draw generalizations. This activity involves sticking straight pins onto various objects (chalk, fork, etc.) by using wax. Heating one end of the object and recording the amount of time required for the heat to be conducted through the material so that the wax melts and the pin falls. At the conclusion of the exercise it was simply stated that some materials conduct heat well while others do not.

The teacher demonstration used with this group of activities involved packing rock wool attic insulation around an ice cube, placing it directly over a Bunsen burner and heating it strongly for 10 minutes after which time the intact ice cube was removed.

The application of these concepts to everyday activities was made by discussing insulation in homes. thermal underwear, blankets, material used in manufacturing cooking utensils, etc.

Activity 4

Objectives:

(1) The students will be able to state that heat can travel by convection currents in any fluid.

(2) The students will be able to explain that when fluids are heated molecules move faster and take up more space so that there are fewer molecules in a given volume. Therefore the heated fluid is lighter and will rise because it is displaced by denser cooler fluid.

One activity and one teacher demonstration were used to teach the above concepts. In the activity the students used a 250 ml beaker, containing 200 ml of water, a support stand, and an alcohol lamp to observe convection currents in heated water. The alcohol lamp was placed under the beaker but off center. A drop of food coloring and tiny pieces of water-soaked paper were added so that the convection currents could be observed.

The teacher demonstration involved a convection current box with transparent sides and two chimneys. A burning candle is placed inside the box under one chimney and smoke is used to make the convection currents more apparent.

Applying the concepts to every day events involved a discussion about radiator heaters, winds, ocean currents, weather, etc.

Alternate Activity for Module 72

Heart and Circulation

Activity 1

Objective

(1) The students will be able to state the functions of the various parts of the circulatory system.

This activity was essentially the same as the introduction to SAPA II Module 72 involving a brief discussion of the circulatory system including the functions of the heart, arteries, veins and capillaries.

Activity 2

Objectives:

(1) The students will be able to determine their pulse rate.

(2) The students will be able to locate several pressure points and demonstrate how pressure points are used in to stop bleeding in the arms and legs.

The students were shown a method of taking their pulse on their wrist. It was explained that the point where the pulse could be found were places where an artery was just under the skin. Arteries are generally deep under the muscle close to the bone and veins are generally closer to the skin. The students were instructed to find other places where they could feel their pulse (temple, arm pit, ankle, groin, neck, etc.). The use of pressure points in first aid was discussed.

Activity 3

Objective:

(1) The students will be able to explain why pulse rate speeds up during exercise.

The students were told that they were going to determine what effect exercise would have on pulse rate. The pulse rate before and after was determined. A discussion involving four of the functions of the blood (take oxygen and food to the cells, take carbon dioxide and waste away from the cells) was held followed by a discussion centering on why the pulse rate speeds up during exercise.

Activity 4

Objectives:

(1) The students will be able to trace the blood through a diagram of the circulatory system.

(2) The students will be able to explain what causes the heart valves to open and close.

Each group of four students were given a pork heart which had been previously dissected to show the four chambers, valves, veins, arteries, and the thickness of the walls of the four chambers. The students were also given lab sheets asking questions about the above parts of the heart which could be answered by careful observation. With the help of an American Heart Association diagram of the heart and circulatory system, the students were instructed to trace the path of the blood through the pork heart on which they were working.

Alternate Activity for Module 75

Pendulums and Simple Machines

Activity 1

Objective:

(1) The students will determine which of three predetermined

factors will affect the period of a pendulum.

The students were given a lab sheet which instructed them to construct a pendulum using string, fishing weights and a support stand. They were instructed to vary the number of weights on the pendulum, the distance to one side which the weights were pulled to start the motion of the pendulum and the length of the pendulum in order to determine which factor would affect the period of the pendulum.

Activity 2 - Levers

Objectives

(1) The students will be able to label the parts of a lever.

(2) The students will be able to construct and give examples of situations where levers are used to increase speed or decrease effort.

(3) The students will be able to state that $force_1$ x $distance_1$ = $force_2$ x $distance_2$.

The students were given a lab sheet which instructed them to construct levers using metersticks or rulers, a fulcrum and various objects as loads. Using weights or spring scales they then determined the effort required to move the load.

Activity 3 - Incline Planes

Objectives:

(1) The students will be able to state that $force_1$ x $distance_1$ = $force_2$ x $distance_2$.

(2) The students will be able to state that incline planes decrease effort.

(3) The students will be able to state that friction is a force which resists motion. They will also be able to list methods of reducing friction.

The students were given a lab sheet which instructed them to build an incline plane. Using spring scales they determined how much force was required to lift a cart and how much was required to pull the cart up the incline plane. The same procedure was repeated using a 500 g mass. The above objectives were then met through a discussion of the results.

Activity 4 - Pulleys

Objectives:

(1) The students will be able to state that $force_1$ x $distance_1 = force_2$ x $distance_2$.

(2) The students will be able to state that a moveable pulley decreases effort while a fixed pulley changes direction.

The students were given a lab sheet which instructed them to build several systems of fixed, moveable and combination of fixed and moveable pulleys. Using spring scales and rulers they determined the effort and distance required to move a given weight through a prescribed distance.

Alternate Activities for Module 80

Inertia and Mass

Activity 1

Objectives:

(1) The students will be able to state that inertia is the resistance of a stationary object to being moved.

(2) The students will be able to state that the more mass an object has, the more inertia it will have.

The students use a spring scale to determine the initial force required to move several objects such as a 500 g mass, a fishing weight, their science book, etc., across the dish top. This information is used to estimate which objects have the most and the least inertia.

The students also did an activity using the carts and large rubber bands similar to the activity in SAPA II Module 80 except that process skills were not discussed. In this activity the rubber bands were used to propel the carts with and without a 500 g mass added to show that the greater the mass, the greater the resistance to motion.

Activity 2

Objectives:

(1) The students will be able to state that inertia is the resistance of a moving object to being stopped.

(2) The students will be able to show that the more mass an object has the more it will resist stopping.

In the first part of this activity the students used a ruler to propel two carts at the same speed. One cart was loaded with a 500 g mass while the other cart was empty. The distance the two carts traveled after being released was then measured.

Another activity which was used to reinforce the above objectives involved the students' rolling steel and glass marbles down an inclined track onto a horizontal track. While rolling along the horizontal track, the marble would collide with washers suspended just barely above the track by a string. The students determined how many washers were required to stop the marble at the point where it collided with the washers. They then measured the mass of the two marbles in order to determine the relationship between mass and resistance to stopping.

VITA

Terry Joe Shaw

Candidate for Degree of

Doctor of Education

Thesis: THE EFFECTS OF PROBLEM SOLVING TRAINING IN SCIENCE UPON UTILIZATION OF PROBLEM SOLVING SKILLS IN SCIENCE AND SOCIAL STUDIES

Major Field: Higher Education

Biographical:

Personal Data: Born in Cherokee, Oklahoma, January 20, 1947; married, one child.

Education: Graduated from Burlington High School, Burlington, Oklahoma in 1964; received Bachelor of Science in Biochemistry from Oklahoma State University in 1968; received Master of Science in Biology from University of California at San Diego in 1971; completed requirements for teacher certification in secondary science and mathematics at Arizona State University in 1971; completed requirements for the Doctor of Education degree at Oklahoma State University in July, 1977.

Professional Experience: Undergraduate research assistant, Biochemistry Department, Oklahoma State University, 1966-1968; Graduate research and teaching assistant, Salk Institute, University of California at San Diego, 1968-1971; Eighth grade science teacher, Litchfield Public Schools, Litchfield Park, Arizona, 1971-1973; Research Assistant, Biochemistry Department, Oklahoma State University, 1973-1974; Stillwater Middle School Interdisciplinary Outdoor Education Program, 1975-present; Involved in designing and implementing environment awareness as pilot project in Quichita National Forest through Oklahoma State University Extension, summer, 1977. Member of National Science Teachers Association and National Education Association.