AN ABSTRACT OF THE THESIS OF

John Stuart Hutchinson for the Ph. D. in General Science
(Name) (Degree) (Major)

Date thesis is presented April 11, 1966

Title AUTOMATED SCIENCE CURRICULUM: AN EXPERIMENTAL SCIENCE PROGRAM

Abstract approved [redacted]
(Major professor)


Purpose

The purpose of this study was to determine statistically the effects of an automated science curriculum on the science learnings of eighth grade students. This curriculum involved the use of Keysort cards as a flexible handbook for teachers and included in the directions for use a teaching method which required the direct involvement of students in the scientific behaviors of inquiry. The aspects of science learnings measured included the students' knowledge of the products of science and their understanding of and ability to use the processes of science.

Study Materials

The Science Teachers' Adaptable Curriculum (abbreviated STAC) consists of a broad spectrum of science curriculum projects

and suggestions printed on Keysort punch cards. They offer a flexibility which allows the individual teacher to develop a scope and sequence consistent with his own strengths and interests and with the abilities and interests of his students. The learning pattern designed for use with the STAC materials is one in which the behavioral processes of inquiry are used as the vehicle for discovering the structure of science. This is accomplished through first-hand experiences with laboratory investigation.

The instrument used for evaluating the science process and product learnings of students is titled the Portland Science Test. The test was developed locally by a group of educators which included the author. Reliability and validity were found to be adequate for the present study.

## Population

The results of a questionnaire revealed that eleven eighth grade teachers were using the STAC material in a manner appropriate to its design. The population of the control group was formed from the 261 students who were in the classes of the eleven teachers the year before the STAC program was available. The experimental group consisted of the 254 students who were with the same eleven teachers during the first year they used the STAC program. The use of a true experimental design of the post-test only, control-group type was based on the assumption that the students in the control and experimental groups were similar samples from the same population.

## Results

Differences between the control and experimental process, product, and total group means were subjected to the critical ratio as a test of the identified null hypotheses. As a result of these analyses, and within the limitations of the study, the following results can be reported:

1. The use of the automated science curriculum did not make a measurable difference in the science process learnings of eighth grade students.
2. The use of the automated science curriculum did not make a measurable difference in the science product learnings of eighth grade students.
3. The use of the automated science curriculum did not make a measurable difference in the total science learnings of eighth grade students.

## Conclusions

Those resisting new programs state that educators have no right to experiment with the future of the children. The results indicate that the automated curriculum can be initiated without impairing the educational growth of students. This action places the curriculum on an evolutionary base which has potential for the immediate revision so necessary in a modern, dynamic society. Revision of the automated curriculum is already underway and includes its adaptation to computerized techniques.

Improved results should be expected by providing individual help, sufficient implementation time, and improved science supply accessibility.

# AUTOMATED SCIENCE CURRICULUM: AN EXPERIMENTAL SCIENCE PROGRAM

by

JOHN STUART HUTCHINSON

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

DOCTOR OF PHILOSOPHY

June 1966

APPROVED:

[redacted]

Chairman of Department of Science Education

In Charge of Major

[redacted]

Chairman of Department of General Science

[redacted]

Dean of Graduate School

Date thesis is presented April 11, 1966

Typed by Kay Smith

## ACKNOWLEDGMENTS

The achievement of a goal depends in large measure on the cooperative efforts of many persons. The author wishes to express his sincere appreciation to his graduate committee and others who have helped to make this investigation possible.

Special thanks are due to those who have made major contribution of their time and talent as follows:

- to Dr. Stanley E. Williamson who provided inspiration during the entire doctoral program.

- to Dr. Donald W. Stotler whose counsel helped to mold the philosophical framework of the study.

- to Dr. Norman K. Hamilton for permission to conduct the study in the Portland Public Schools.

- to Dr. George S. Ingebo for his guidance in establishing the statistical design of the study.

- to Mr. Peter F. Wolmut for his suggestions and assistance with the analyses of the data.

- to the students, teachers, and administrators in whose schools the study materials were used.

Others have felt the pressures of the author during the course of this investigation. Special appreciation is due:

- to my wife, LaDonna, whose understanding and encouragement have pulled me through many moments of frustration and disappointment.

- to my children, Linda, Richard, and Kent, whose patience with my absence and awareness of the importance of the project have been beyond their years.

- to my father, Carl A. Hutchinson, who provided a rich cultural environment and a scholarly example during my formative years.

J. S. H.

TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

# AUTOMATED SCIENCE CURRICULUM: AN EXPERIMENTAL SCIENCE PROGRAM

## INTRODUCTION

### Science and Society

The prime function of an educational system in any society is to pass on to the younger generation the skills and customs of that society. The skills are necessary to be a productive member and the customs are vital so that the individual can live in relative harmony with his neighbors. The specific nature of the skills and customs has fluctuated throughout mans' history. However, decades of time often passed with little recognizable change. This pattern of slow evolution prevailed until the eighteenth century. Prior to this time, a person could live and die in the same kind of world into which he was born.

The eighteenth century, often referred to as the Age of Reason, brought a rebirth of intellectual activity. This activity initiated a pattern of scientific thought which was destined to produce a rate of change previously unknown. The essence of this pattern is a dependence on empirical evidence as a basis for judgments rather than pure logic. Theories were subjected to carefully controlled experiments and the results of the experiments were available for extensive scrutiny by the scientific community.

The scientific methods, hewing essentially to this general pattern, have produced more useful information in the past century than earlier thought patterns had yielded in all previous history.

The technology which has sprung up around this information has brought a new kind of life. Civilization is changing so rapidly that many time-honored customs and traditions are being shaken to their very foundations. Man is being faced with such problems as population and knowledge explosions, nuclear annihilation, space exploration, and those related to automation. Change is coming so rapidly that half the jobs of ten years hence are not even conceived today. With this thought in mind, educators must design an educational program which can evolve with the changes and prepare youngsters to live effectively in the culture in which they will be living. A discussion of this design must be preceded by a re-examination of the goals of science education.

## Goals of Science Education

The primary goal of science education is to produce scientifically literate citizens. This goal is consistent with that stated for society, ie., the preparation of citizens to live productively in a free society. Scientific literacy is essential for full participation in a culture which is highly science-oriented.

The basic goal of science education can be described more fully by subdivision into four parts. These four parts are the goals of the science program of the Portland Public Schools (21, p. 2-3) and are stated as follows:

1. Cultivate those inherent but raw qualities of natural curiosity, initiative, and love of exploration.

2. Develop self-learning skills.

3. Provide insights into the nature of life and environment.

4. Develop worthy social values such as integrity, cooperation, humaneness, and idea sharing.

The casual reader will probably comment that science has no corner on the goals as stated above. Of course he is absolutely correct. The four goals as stated are equally valid for all areas of the curriculum. However, the science laboratory is particularly well-suited for making a contribution to these goals.

## Curiosity, Initiative, and Exploration

All normal human beings are programmed at birth with the qualities of curiosity, initiative, and love of exploration. One only needs to watch a young child at play for evidence that these qualities are inherent. However, the assumption is incorrectly made that, possessing these qualities, the child's only need is to have the ideas poured into his head. More accurately, the assumption might be that the three inherent qualities must be in constant use in acquiring the facts of life. The child must be afforded the opportunity to refine those raw qualities into a set of learning skills so essential even to the consumer of science.

## Self-learning Skills

The rapidly changing world in which we live today demands a facility for adjusting to new ideas and for learning new skills which was undreamed of only a quarter of a century ago. The responsibility for the development of this facility must be recognized and shared by all social organizations. The contribution which the schools can make concerns the development of self-learning skills.

These self-learning skills will be variously referred to in the present study as science process learnings, scientific behaviors of inquiry or investigation, and problem-solving or heuristic behaviors. An in-depth discussion of these skills is provided on pages 30-36.

The continuous production of new information requires the individual to be capable of gathering data pertinent to the social and individual problems which will confront him. Some of the self-learning skills with which he must be armed to meet such challenges are as follows:

1. Ability to recognize when a problem exists.

2. Ability to gather pertinent data.

3. Ability to withhold judgments until all possible data have been evaluated.

4. Ability to use appropriate resource materials and persons.

5. Ability to draw tentative conclusions in terms of the data.

The schools will be influential in the development of skills such as those above to the extent that the student is given the opportunity to practice them. Telling the student he should use these skills is not enough. His learning environment must be programmed in such a way that he is placed in situations which call on the use of the self-learning skills. Science subject matter can form a major portion of the environmental program.

## Nature of Life and Environment

Scientific inquiry has produced a vast amount of information about the nature of life and environment. In the present study, these results of scientific inquiry will be referred to as the "science product learnings."

The phase of the educational program of youth which has received the greatest emphasis is the dissemination of facts, concepts, and principles. Often, in the past and in many classrooms today, this preoccupation with science product represents the extent of the offering. Insights into the nature of life and environment cannot be realized without inclusion of subject matter. However, the subject matter of the various fields should be the vehicles for attaining not only goal number three (page 3), but also goals number one, two, and four. Memorization of bare facts is possible without attention to the methods for acquiring knowledge. However, information acquisition is an important concomitance when the emphasis is directed toward sharpening the skills of inquiry.

## Social Values

A goal in science education which can be found in much of the literature today is that students should develop worthy habits and attitudes. Actually the scientific enterprise and science education have both been criticized for verbalizing habits and attitudes but not causing these to become a part of the individual's value system. For that reason certain values should be stated which are in fact very similar to the habits and attitudes formerly listed. Values which have been stated in one of the goals in an earlier part of this section include those such as integrity, cooperation, and humaneness. A value such as integrity is really an outgrowth of the scientific procedures. A scientist is required to be absolutely honest in reporting his work because he knows it will be carefully checked and often repeated by his colleagues. This kind of check against one's work requires absolute integrity. Such integrity is as important to being a productive and useful citizen as it is to working in the scientific community.

Cooperation is a value which should be placed in high esteem by all of the citizens of a democratic society. In doing the work which is of scientific nature, one is often required to work in small groups. This requires a respect for the other person's ideas and cooperation in reaching the goals of the small group. One must also recognize when working alone will yield better results. Social situations often require work in small groups in the development of community projects. Adopting cooperation as a value is extremely important.

Humaneness is another value which should be practiced continuously in science courses. Experimentation with animals should bring out the fact that it is accomplished only for the purpose of extending man's knowledge. No experimental act should be performed on an animal unless it will yield valuable information and only then with humane techniques. The science classroom is an excellent place to develop a respect for and a humane attitude toward animals and fellow human beings.

A value which is most important to the advancement of knowledge is that of idea-sharing. When one makes a discovery he often wants to share this idea with someone else. In science the opportunity is made available through reporting these discoveries in journals. Students in science classes can be given practice in idea-sharing through the reporting of results of various projects. Many people are reluctant to share ideas on a subject with another person or a group of people. Science classes as well as other subjects in the curriculum should place greater emphasis on this value.

The development of such social values for science will keep science in the mainstream of life. Other values can certainly be added to the list which is developed here. The values which are used as examples in this instance illustrate the idea that the scientific enterprise and the science education enterprise must incorporate into their statements of goals a set of mutually-accepted values.

Science education is more than an introduction to such specialized areas of knowledge as biology, chemistry, or physics. It is an important system of training for the kind of American citizen needed in this age of science under a democratic way of life. It develops those values, skills, appreciations, and interests which are necessary not only to the scientist but to every intelligent citizen. The purpose of science education, then, is to develop competent citizenship through insight into the content now regarded as fundamental while developing lasting interests and skills in using the processes of science.

## A Learning Pattern for Science

The major emphasis in the learning of science should be placed on productive patterns for acquiring information. The objectives which were set down in the preceding section were stated as being applicable to any area of the curriculum. This being the assumption, science then becomes but one vehicle for helping students to attain the goals which if achieved will help them to learn and think productively.

### Scope and Sequence

The first step which educators often take in establishing the curriculum for science is to design a scope and sequence. The scope of a course designates the content to be presented to students and the sequence is the order in which that content is offered. A fresh approach to this problem is to open up the entire scope of science each year and to establish something more lasting than content as a sequence. The investigative patterns used by scientists for nearly four centuries apparently have more lasting usefulness as a basis for sequence than do the products thus acquired.

Primary Grades. The formulation of a process sequence can logically begin at the point that children begin their formal education, ie., kindergarten. During this period, extending through the third grade (primary grades), the emphasis can be placed on making observations. All the senses are involved in a variety of ways. However, sorting of the observations can be initiated along with simple experimentation. Contacts with scientists would be very limited during the primary years. Thus the following process sequence emerges:

| K-3 | 4-6 | 7-9 | 10-12 |
|---|---|---|---|

Observation--Classification--Experimentation--Participation

Intermediate Grades. The intermediate years, 4-5-6, can be devoted to the refinement of the similarities and differences observed which in turn lead into systems of classification. The student-invented systems (including qualitative and quantitative relationships) direct the learner toward an understanding of scientific classification and the reasons for which systems of classification were adopted by scientists. Observational skills would be further enhanced by these activities. More opportunities would be available for simple experimentation and to get acquainted with scientists as people and the science enterprise as a human pursuit.

Upper Grades. Grades seven, eight, and nine, often referred to as the junior high school years, represent a crucial period for most children. At a time when they should be given opportunity for increased participation in the planning and conduct of learning activities, they are forced to be passive observers. Large blocks of time must be made available to students at this age in order for them to experiment. An experiment has often been described as a contrived situation which permits optimum observation. The subtleties of the situation are explored persistently with long and short term investigations. Observation and classification continue to open up new insights. The 'Participation' aspect of this sequence receives more attention as the students have more contacts with scientists and the science enterprise.

Secondary Grades. The curriculum of the high school, grades 10-11-12, must maintain a "liberal arts" approach. This requires attention to the needs for successful citizenship. Thus prepared, these "candidates for society" can proceed to their individually-selected occupational choices. The findings of science and the scientific behaviors are social tools in their final utility. Therefore, a science process sequence should not only be a valuable aid to future scientists but it should also aspire to produce graduates who are literate in science.

"Participation" during the 10-11-12 period designates a time when students have direct experience with the scientific enterprise. This experience can take the form of visitations with scientists both in the school and in their laboratories. Observation, classification, and experimentation continue as important parts of the sequence during this period. For the prospective non-scientists, visitations would probably be the extent of their involvement in "Participation". The science-oriented students would have the additional opportunity of working with the scientists in their laboratories. These sorts of involvements can provide the learner with an understanding of the revisionary nature of the science enterprise and allow him to participate in its further revision.

## Classroom Pattern

Once the overview of curriculum emphases is established, the matter of specific learning patterns for classrooms can be considered. These patterns should include programming the environment of the student so that he can learn most effectively. So in reality we must first consider the tone of the environment and then examine a possible learning pattern which can be used in this climate.

Principles. There are several principles which the teacher must keep in mind when setting the tone for a productive learning environment. The first of these is that communication is a two-way effort. It is never complete and it is more than verbal. The students will communicate with those persons they trust and with those who encourage freedom to differ and freedom to interpret. The second is that anxiety may decrease learning. This has some bearing on the attitude which the teacher establishes in the classroom. Attempts to persuade and control and the establishment of a rigid social structure may decrease the understanding of the students. The third is that learning is occurring all the time the students are in that environment and that different kinds of learning occur simultaneously. Each person is motivated to learn by what is important to him. People are controlled by the norms or groups which have prestige for them. Leadership in any group is chosen by the group; the teacher in the classroom cannot keep it all for himself.

Research Approach. Since the scope of study is all of science and the sequence is in terms of clusters of processes by primary, intermediate, etc., pupils must be given the opportunity to work and learn in a scientific, problem-seeking manner. This implies that children learn most effectively by direct, first-hand involvement. It also implies that the classroom be organized in a manner similar to that employed in a modern research laboratory.

A research laboratory has a director and is supported by an administrative organization. The laboratory is equipped by the administration with basic materials necessary to carry out the intended research. In addition to the director, personnel in the research laboratory includes scientists, engineers, and technicians. In the well-organized laboratory, scientists do only what others cannot do. Furthermore, the engineers and technicians also have designated responsibilities and tasks. All function as parts of a close-knit team. The general area of work to be pursued is normally defined by the administration; the director and personnel of the laboratory then hold planning sessions to determine what specific areas will be examined and how the members of the various teams will be organized. Frequently individuals work alone on problems of their own interest. In other situations scientists, engineers, and technicians group together to solve the various problems on which they have decided to work.

In addition to the necessary equipment and supplies, a laboratory is equipped with reference books that are pertinent to the problems being studied. When information beyond what is contained in the research library is required, the researchers consult outside sources, order films that deal with the subject, or visit another laboratory in which related problems are being investigated. The progress made in the studies proposed by the laboratory staff is determined by the limitations, interests, and abilities of the personnel involved in the project. Thus an environment is created in which there is a great deal of freedom for individuals to learn.

A classroom can be organized in a similar fashion in which the teacher acts as the director of learning activities and the pupils in the classroom fill roles of scientists, engineers, and technicians. The teacher initially defines the broad area in which the learning will be pursued. Through various brainstorming sessions the students and teacher determine the most productive avenues to follow. Thus a free-wheeling environment is established in which the only limitations to learning are the limitations of the students themselves.

## Materials of This Study

The materials employed in this investigation are unique in their design. The philosophy on which the materials rest is not unique but has been slow in implementation. The intent of this study is to determine the effectiveness of these materials in the implementation of this philosophy.

Automated Materials

The science curriculum under study in this investigation is the original and only automated teacher guide program known. The materials are automated in the sense that they offer a system of rapid organization and retrieval of curriculum content. One can develop a sequence consistent with his own abilities and with the needs and interests of the students in his class. The Keysort process provides this flexibility by offering immediate sorting possibilities to the user.

The use of these materials was initiated in the Portland Public Schools in the fall of 1962. These beginnings were made in the ninth grade classes of several of the high schools. Interest in the materials spread and in the spring of 1963 an in-service class was offered to interested teachers from the elementary schools of the city which placed heavy emphasis on the use of the Keysort cards for instructional purposes. Additional in-service offerings were made available to elementary teachers during the 1963-64 school year which provided experiences in the use of the Keysort curriculum. Teachers at all levels of instruction K-8 began using the Keysort cards as their primary source of science curriculum ideas. Evidence of in-service experience was a requirement for those wishing to use the materials above the third grade.

## Heuristic Discovery

The National Science Foundation has funded extensive science curriculum revision during the past eight years. This revision has emphasized inductive and deductive reasoning processes as a significant means for acquiring knowledge of science. These processes of science form the basis of heuristic methods of investigation. Students are called on to use the processes of science to discover the products of science. The results of such a procedure are twofold. The students gain an understanding of and an appreciation for the ways in which the scientists work. They also learn the principles which underlie the structure, often referred to as the products of science.

The automated science curriculum using the Keysort cards was designed in such a way that the emphasis is directed toward heuristic methods as the means for learning the products of science. The need for an evaluation of this intent was recognized at the start of the program as a critical necessity to the continued progressive evolution of the material. It was also recognized that such an evaluation would demand a measuring instrument which not only determines students' facility with the products of science but also reveals the effectiveness with which students use the processes of science.

Portland Science Test

In the fall of 1959 a committee was organized for the purpose of brainstorming a fresh approach to the testing of learnings in science. It was recognized at that time that both processes and the products of science education should be measured. It was also recognized that too many tests require a reading skill which places undue limitations on some of the students being tested. Thus after long and arduous developmental sessions a test resulted which employed the use of pictures and a minimal amount of reading. The members of the committee attempted to devise items which revealed understanding of processes and products of science. The initial trials with the test were performed in 1960-61. Revision of the material was then based on feedback from these trials and revised and additional items were again tested in 1961-62. The revision process was repeated and a third trial was accomplished in 1962-63. Preliminary validations were carried on by the members of the committee in terms of the trial testing and reliability was determined through an item analysis. The first city-wide use of the test was made in the fall of 1963. The test was named Portland Science Test, Fall Edition 1963. Validation has been accomplished by correlating the scores made by students on the test with the judgment which science teachers have regarding the same students.

Only those students which the teachers placed at the extremes of the rating scales were used.

The Portland Science Test has been developed with the objectives of the Portland Science program as the overriding consideration. The automated science curriculum has also been developed with the same objectives in mind. Thus the Portland Science Test emerged as the overwhelming and obvious choice as the instrument which could most effectively measure the impact of the automated science curriculum.

## Computers in Education

The significance of the study should be explored in another direction. The use of computers in the field of education is currently being extended. A few schools are experimenting with programming students for classes in a flexible scheduling arrangement using computers. Marshall High School of Portland is using computers for this purpose. Many high schools are using computer techniques for storing and processing student data, such as test scores and student attendance. However, there appears to be little effort being directed toward computerizing curriculum.

The automated science curriculum under consideration for this study marks the initial attempt to streamline the curriculum in preparation for computerizing. Evaluation of the program at this point in its development will provide an important baseline for continued comparisons as the curriculum evolves toward computerized systems.

The debate over whether or not the curriculum should be computerized appears irrelevant. The question which must be faced is whether the educators will adapt the techniques of computers to the curriculum in productive ways or allow a computerized society to thrust the computer into the field of education with great speed and little thought. The evaluation of the Portland automated science curriculum contains historical ramifications since it represents the beginnings of a curriculum design which surely will have an impact of national significance on science education and in fact all facets of the educational enterprise.

## Baseline for Revision

One of the most important features of the automated curriculum is its revisionary nature. It offers an evolutionary base for an educational program which shows promise for catching up and keeping pace with the changing needs of a dynamic society. The flexibility of the materials being evaluated in this study makes possible immediate revision in terms of the latest available information.

The base for most curricula in use today is static to the extent that the course of study is adopted along with the desired text for a period of several years. Although some schools provide additional materials during the adoption period, most classrooms are saddled with the same material for the entire time span. The static base is also represented in many school systems by the absence of a planned curriculum design. Little, if any, change takes place in the educational program from year to year while society continues to advance at an ever-increasing rate. The real issue on which the automated curriculum rests, then, is whether the educational systems across the land retain their static bases of operation allowing imperceptible change or incorporate into their programs an evolutionary base which has a chance for meeting the educational demands of the future.

The chief criticism of those resisting experimentation with new programs is aimed at their effects on students. These critics say that educators have no right to experiment with the future of the children. Their argument is immediately invalidated by recognizing that educators can ill-afford to maintain the status-quo with curriculum programs. Continuous revision is a critical necessity.

## Problem of This Study

Ideas for class and individual projects in science have been placed on Keysort cards for use by teachers in the Portland Public Schools. It is the problem of this investigation to learn the effects, if any, of this type of curriculum on science learnings of eighth grade students. An attempt will be made to measure not only the knowledge students have of the products of science but also their understanding of and ability to use the processes of science.

### Hypotheses to be Tested

A self-renewing curriculum which is continuously subject to critical analysis has been mentioned and will be more fully described (pages 57-73). It is generally agreed that such a design is preferred to a long-range static program used with uncritical acceptance if implementation can be accomplished without impairing the educational growth of children. On this basis, the following null hypotheses were identified and tested:

1. The use of the automated science curriculum will have no effect on the science process learnings of eighth grade students.

2. The use of the automated science curriculum will have no effect on the science product learnings of eighth grade students.

3. The use of the automated science curriculum will have no effect on the total science learnings of eighth grade students.

## Assumptions

The study is based on four prime assumptions. These assumptions are stated as follows:

1. The Portland Science Test is a valid and reliable testing instrument for measuring students' abilities to use the processes and learn the products of science.

2. No element other than that built into the experimental design will significantly affect the results of this study.

3. The classroom teachers involved in the study used the automated materials in a manner appropriate to the design.

4. The students in the control and experimental groups are similar samples from the same population.

## Limitations

Two limitations appear as significant to the present study. They are described as follows:

1. The study is limited to groups of eighth grade students from the Portland Public Schools during the school years 1962-63 and 1963-64.

2. Since the teachers involved were using the experimental materials for the first time, the "Hawthorne effect" may have been operative.

Procedures to be Used

The design of the study has been described by Campbell and Stanley (8, p. 195) as a true experimental design of the "Post-test Only, Control Group" type. Its form is as follows:

$$\begin{array}{ccc} R & & 0_1 \\ R & X & 0_2 \end{array}$$

It is based on the law of the single variable. The same teachers are involved during both the control and experimental years. The entire population, not just a sample of students, is involved. The only significant variable is the use of an experimental program in a natural setting in which neither the teachers nor the students were aware of their involvement in the study.

Eleven different classes ($R_1$, $R_2$, $R_3$, ... $R_{11}$) were post-tested ($0_1$) after having experienced a normal curriculum program. This testing was performed in November, 1963 with 261 students following their 1962-63 eighth grade experience. Eleven new classes were post-tested ($0_2$) after having experienced the experimental (X) curriculum program with the same teachers. The second post-testing ($0_2$) was accomplished in November, 1964 with 254 students following their 1963-64 eighth grade experience.

The raw means and standard deviations of the control and experimental groups will be determined and converted to standard scores. The significance of the difference between the means of the two groups will be determined by application of the critical ratio.

The summary and conclusions of this study will consider which of the null hypotheses may be rejected at the one per cent level of confidence. In terms of these data the limitations of the study will also be considered. Finally, suggested routes for the improvement of the automated curriculum will be made in terms of the results of the study.

The problem of this study is to learn the effects, if any, of an automated science curriculum on the science learnings of eighth grade students. The Portland Science Test is used to measure both the knowledge students have of the products of science and their understanding of and ability to use the processes of science.

# REVIEW OF THE LITERATURE

## Introduction

The literature reveals little activity concerned with automating the school curriculum. However, punch cards have been widely applied to other aspects of the educational scene and to many problems of business and industry. Also a good deal of the science education research which has been conducted in the last decade can be related directly to the present study. This research has been categorized into the following topics for treatment in this review: (a) patterns of curriculum organization and (b) patterns of classroom organization. The final section of the review (c) will be concerned with the development of punched card methods.

## Patterns of Curriculum Organization

A treatment of curriculum organization can be considered logically in terms of scope and sequence. Blough (6, p. 142) provides the following definition:

> Scope refers to content, methods, activities--both horizontal and vertical experiences within the school program. It is sometimes referred to as the "what" of the curriculum. Sequence refers to the arrangement of experiences--the continuum, which is provided throughout a child's life. It is sometimes referred to as the "when" of the curriculum.

The content of a curriculum is also designated as the subject matter, ie., concepts, principles, facts, theories. The methods and activities make up the ways in which the content is presented to the learner. For a consideration of these two aspects of scope, one must be concerned with the structure of the content and the nature of learning.

Structure of the Content

A great deal has been written in the past ten years (5, p. 128) about the values of structured versus unstructured curricula. The debate today is swinging away from "whether or not" and toward consideration of who does the structuring and how it is accomplished. In this context, Bruner (7, p. 7) states that structuring is a matter of learning how things are related. Thus structuring becomes a property of learning and must necessarily be accomplished by the learner.

The problem of providing the setting for the learner to discover the structure of a discipline has also received much attention in the past decade. Justification for this attention is found in the work of Jean Piaget on cognitive development in children. Eleanor Duckworth, who has studied with Piaget, states (14, p. 172) that "His findings lead him to conclude that an individual's intellectual development is a process of equilibration, where the individual himself is the active motor and coordinator of his own development". On the matter of teaching the structure of a subject matter area, Duckworth (14, p. 174) attributes the following statement to Jean Piaget:

> Teaching means creating situations where structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than a verbal level. . . A ready-made truth is only a half-made truth. . . A teacher would do better not to correct a child's schemas, but to provide situations so he will correct them himself.

The matter of how to provide these situations will be delayed until some characteristics of learning have been examined.

## Nature of Learning

Discussions concerned with learning eventually focus on motivation. A definition of this term has been provided recently by Waetjen (51, p. 22). He states that motivation is "the process of arousing action, sustaining the activity in progress, and regulating the pattern of activity." Another way of expressing motivation is to relate it to those students who are knowledge-seeking or curious. Studies by Maw and Maw (35, p. 201) show that children with high curiosity perform differently (either more learning or greater retention) in the learning situation. Thus motivation appears to assume a basic role in learning.

Waetjen (51, p. 24) describes a situation which encourages motivation and has high probability for introducing information into the cognitive structure of the learner. This situation is one in which

> . . . there is, for the most part, a match between the curriculum content (including the instructional procedures) and the cognitive structure of the learners. Since there is a generous portion of match between these two elements, it means that the youngster is familiar with the material or the situation because it fits into his predictions. On the other hand, there is also some degree of "mismatch," meaning there are some elements of either the content or the instructional procedure which the learner does not know and did not predict. This is a dissonant situation which results in arousal of conflict with a consequent need for the learner to assimilate or articulate the unknown, incongruous, or unfamiliar material into his cognitive structure. To do this, he engages in exploratory behavior . . . In this condition the learner is a <u>seeker</u> of knowledge. It would be improper to believe that all youngsters who are in the motivated condition engage in similar exploratory behaviors. We must recognize that the modes or strategies by which youngsters seek information and by which they process it into the cognitive structure are unique.
>
> We emphasize that this is an individual difference in learning.

The process of assimilation into the cognitive structure is consistent with the learning theories of Piaget. The "mismatch" described by Waetjen puts the individual out of balance with his environment and induces what Piaget (42, p. 181) calls "equilibration" which consists of "processes with feedback and with feedforward, of processes which regulate themselves by a progressive compensation of systems." More simply, equilibration is referred to by

Piaget as "a process of self-regulation".

Further consistency is found between the theories of Waetjen and Piaget in the matter of assimilation. Waetjen (51, p. 24) speaks of a "need for the learner to assimilate." Piaget (42, p. 185) reaches the conclusion from his studies that assimilation is "the fundamental relation involved in all development and all learning" and defines it as "the integration of any sort of reality into a structure." He further states that "Learning is possible only when there is active assimilation."

From these findings of Piaget and Waetjen, it appears clear that the major factors which influence behavioral changes are motivation, assimilation, equilibration, and individual differences. Other factors have received attention in a publication edited by Waetjen (50, 96 p.) which also appear to have an influence on learning. The present discussion will be limited to the four mentioned above because they appear to have most direct bearing on the present study. The automated science curriculum is so designed that these learning factors are emphasized.

## Methods for Acquiring Process Skills

With the position that the learner structures his own knowledge and a familiarity with some of the important factors of learning, attention can now be focused on ways of attacking the provision for discovery situations. Numerous studies have been conducted both on the local level and on a national scale. The results of these studies are detailed on the following pages.

The program under investigation in the present study is designed to be most effecitve when the techniques of heuristic investigation are used. Henderson (23, p. 1014) defines heuristic methods as those which include both inductive and deductive reasoning processes. He further states that. . .

> Characteristic of the heuristic methods is the feedback from the student's behavior to the teacher. The teacher's responses are determined in part by the inferences he draws from the student's behavior, both verbal and non-verbal, which he observes. It is this feedback which so dramatically distinguishes these methods from the tell-and-do methods. In fact, the role of the teacher who employs heuristic methods is closely similar to the role of a student in the teacher's class. Both entertain hypotheses from the data available to them--the student from the data which the teacher brings to his attention, the teacher from what the student does and says. Both test these hypotheses, rejecting or accepting them in terms of new data which become available.

These methods employ Piaget's process of equilibration on the part of both the student and the teacher, thus relating the learning theory directly to the learning method.

These comments also imply a need for first-hand contact on the part of the student with the content and methods of the discipline. The recognition of this need is current in the thinking of educators but not newly conceived. Craig (10, p. 153) stated over thirty years ago that "it is evident that the work in the study of science in the early years should be concerned with the observation, manipulation, and explanation of natural phenomena, always in truthful, even if elementary, fashion." In the same publication Curtis (11, p. 86) reports various research findings which support a "project method". This method defines a situation in which the student selects the project, plans the work and maintains a complete record of his progress toward completion. Implied in this approach is an emphasis on heuristic investigation but these methods were not specified.

Attempts at specificity have been made in more recent studies. By making the assumption that the "project method" and the "problem-solving method" are similar activities, specific description has been located in the literature. Atkin (1, p. 415) suggests that the dynamics of problem-solving include the following behaviors:

1. Sensing a problem and deciding to find an answer to it.
2. Defining the problem.
3. Studying the situation for all factors bearing on the problem.
4. Making the best tentative hypothesis as to the solution of the problem.
5. Selecting the most likely hypothesis.
6. Testing the hypothesis.
7. Drawing a conclusion.
8. Making inferences based on this conclusion when facing new situations in which the same factors are operating.

Atkin (1, p. 421) studied these behaviors in children in grades 1, 3, and 6 and found that all the aspects of problem-solving behavior were recognizable except one. He describes that exception as the ability to recognize assumptions. Based on this study, Atkin (1, p. 422) concludes his report with the observation that. . .

> If empirical techniques for testing hypotheses, in contrast to authority, are considered desirable for children, it should be noted that elementary school children use these techniques significantly more when they solve problems in classroom settings in which they participate in selecting the problems they work on.

The idea of student selection of projects relates problem solving directly to the project method.

Until recently, the organization of the behaviors described by Atkin could be found in all science textbooks for grades K-12 as a set pattern of investigation. This created a stereotype of science thinking which has not yet been eliminated in the minds of many persons. Hurd (27, p. 35) strikes a blow at this stereotype in his description of problem solving.

> Methods for solving problems in science are numerous. There is no one scientific method; in fact, there are almost as many methods as there are scientists and problems to be solved. Inevitably the details of scientific investigation are seldom the same for any two problems. What is done is highly flexible and quite personal. Incentive, intuition, the play of imagination, fertility of ideas, and creativeness in testing hypotheses are important parts of the process. The methods of science are something more than measurement, laboratory techniques, and data processing

> followed by logical deductions. Sometimes they are not very logical, but the search for truth is always present. Presenting problem-solving as a series of logically ordered steps is simply a technique to isolate the critical skills and abilities and to give them special attention in teaching.

Another term which appears in current literature in relation to problem solving is "process". Often the term is used in a vague sort of way without alluding to its specific properties. Smith (47, p. 212) suggests that "It relates to science as a mode of inquiry, as method (s), as a self-correcting procedure for the seeking of knowledge, and as a critical, continuing probing for the truth". Once again the concept of equilibration is encountered in relation to learning method. In providing this clarification, Smith also used the term "inquiry", a term which has always been synonymous with "investigation".

One of the most comprehensive studies relative to patterns of scientific investigation was conducted by Suchman (49, 150 p.) at the University of Illinois. He used the term "scientific inquiry" and provided (49, p. 4) the following limitations for the concept:

> Inquiry can be divided into four main types of action: searching, data processing, discovery, and verification. While none of these actions is unique to inquiry, they are all essential to it and, in combination, form a cycle of operations that characterize the inquiry process.

The Illinois study was carried out over a period of five years and consisted of four parts. The first part was the development of materials and methods; the second was the preparation of teachers; the third was composed of providing the training to fifth and sixth grade students; and the fourth part consisted of the measurement and comparison of the experimental and control groups.

The results of the study prompted the following statement by Suchman (49, p. 81):

> Our main conclusion from the test results and from our experience with Inquiry Training in many classrooms is that the technique in its present form has a marked effect on the motivation, autonomy and question-asking fluency of children. They clearly enjoy having their quest for assimilation. Because they are not generally accustomed to having and exercising this freedom under ordinary circumstances in most classrooms, they have some initial difficulty making full use of it in the beginning of the training period. But, as the results clearly show, after twenty-four weeks their fluency and autonomy are far in advance of children who have not had Inquiry Training.

A distillation of the many research studies reveals two overriding impressions. The first is that a great deal of investigation must continue in science education before any definitive instructional methods can emerge. Research into the nature of the learner has barely scratched the surface of what needs to be done. The problems presented by the variables of individual differences in students <u>and</u> teachers needs more attention. The speed and accuracy of the computer offers the instrumentation for greater yields of useful information to these problems. As computerized techniques evolve, elimination of time lapse variables and technique variables becomes a definite probability.

A second impression is that using the heuristic methods of investigation to permit students to discover the structure of scientific knowledge is realistic. At least in the light of present understanding of learning, this approach appears to offer the greatest return on the investment. Situations which appear to offer the greatest opportunity for students to exercise heuristic discovery must have certain critical elements. These elements have been stated by Suchman (49, p. 81-82) as follows:

1. Concrete problems that are immediately intelligible to the learner.
2. Freedom to perform data-gathering operations.
3. A responsive environment.
4. Elimination of extrinsic rewards.

When these elements have been incorporated adequately into an instructional program, the volume of useful information for continued evolution and improvement of that program will increase greatly.

## Designs for Science Sequence

The material considered thus far in this chapter has been concerned with the scope of the curriculum. The attention will now shift to a discussion of the literature as it relates to the "sequence" of the science curriculum. Recall that sequence was described on page 26 as the arrangement of experiences which is designed to give students meaningful contact with the discipline.

Attempts have been made to locate definite content for study at specified grade levels in the elementary school. Studies have also been carried out to determine if a consistent pattern of grade placement exists among various courses of study designed by curriculum personnel in different school systems. Dunfee and Greenlee (15, p. 17) report that the studies reveal little agreement as to what is a desirable sequence for elementary science.

Mallinson (34, p. 258) suggests that attempts to grade-place subject matter in the elementary curriculum are futile and supports this contention with the following rationale:

1. Rapid accumulation of science information and increasing sophistication of modern children render ephemeral many topics.
2. Almost any topic or concept can be taught at any grade level.
3. No topic can be fully developed at a specific grade level.
4. Cannot deny the study of a topic because it is "scheduled later".

It is possible that these difficulties can be surmounted by the construction of a sequence based on something other than content. The discussion of scope led to the hypothesis that heuristic methods offer productive ways to discover the structure of science. A consistent pattern might emphasize these same investigatory processes in the development of a sequence for elementary school science.

The comparison of the life span of the content of science with the heuristic processes is revealing. Kessen (28, p. 6) offers this comparison in his statement that . . .

> The procedures of science. . . in the context of early science education are recognizably the procedures of science at all levels of sophistication. Scientific enquiry is a seamless fabric. The content will change, the demand for precision will vary, the generality of conclusion will be different, the interrelation of studies will be understood in different ways, but the procedures and attitudes of scientific study remain remarkably the same from the time the kindergarten child wonders about color to the time the graduate physicist wonders about particle emission.

The significance of this approach to the present study lies in the fact that heuristic processes of inquiry form the basis of the sequence used by teachers in the study. No experimental evidence could be located in the literature which would indicate a preference for a process sequence over a content sequence. However, numerous process schemes have been proposed. Heathers (22, p. 202) suggests that there are three types of processes in elementary science. These are: process of inquiry, involving the behaviors of the scientific methods; processes in nature, which include all the observable cause-effect relations; and process of applying knowledge in which the experimenter manipulates cause to obtain the desired effect. Other interesting patterns are reported in the literature by Hoffmaster (25, p. 15-17) and by Lundstrom and Lowery (33, p. 16-19).

One of the most significant developments with a process sequence is being accomplished by the Commission on Science Education of the American Association for the Advancement of Science. The primary objective of the program is to develop the child's skills in using the science processes. Livermore (30, p. 272) writes that. . .

> Skills cannot be developed by reading about science. For this reason, the exercises were written as instructions for teachers, not as reading material for children. Each exercise described a variety of activities which the children would do, either individually or in small groups. Demonstrations by the teacher were avoided as much as possible.

The similarity of this approach to the methods of the present study is striking. The content on each of the Keysort cards is in the nature of instructions to the teacher. It then becomes the teacher's responsiblity to offer this content to the student in such a way that he becomes involved in meaningful activity.

The processes adopted by the AAAS Commission on Science Education have been identified. Livermore (30, p. 273) describes them as follows:

> . . . the processes are the warp on which the woof of content is woven. In the primary grades eight processes have been identified. They are:
>
> Observing
> Classifying
> Measuring
> Communicating
> Inferring

Predicting
Recognizing Space/Time Relations
Recognizing Number Relations

At the level of grades 4 and 5, integrated processes are used. These are rooted in the simple processes and seem more appropriate to the aim of acquiring a scientific approach to knowledge at the intermediate grade levels. The integrated processes are:

Formulating Hypotheses
Making Operational Definitions
Controlling and Manipulating Variables
Experimenting
Interpreting Data
Formulating Models

Future plans for the project include continued curriculum development through grade 16 and increased attention to teacher preparation (31, p. 48). Support for the project is being financed by the National Science Foundation.

The references cited in regard to a sequence of science in the elementary schools offer theoretical support for the process sequence being used in the present investigation. Such a sequence appears most consistent with a scope which emphasizes heuristic discovery of the structure of science.

## Patterns of Classroom Organization

The pattern of classroom organization employed in the present study is one generally referred to as "self-contained." This type of organization places the responsiblity for all except a few specialized areas of the curriculum (viz. music, shop, home economics) in the hands of one teacher. In addition to the self-contained classroom, the teachers in this study used a variety of reference materials as a classroom library instead of a single basic textbook. Also the students were placed in the classrooms randomly, creating heterogeneous grouping. Consequently, this section will reveal literature which bears relation to these aspects of classroom organization.

## Grouping Patterns

In the context of the present discussion, "homogeneous or heterogeneous" groupings of students appears irrelevant. Blough (5, p. 117) has stated that "Science experiences must not be reserved for any special group. Every child, as he comes to assume adult responsibilities in a democracy, must participate wisely in making many decisions which require knowledge of science--its contents and its methods".

In terms of learning theory, the individual should discover the structure of science in an environment which has elements both common to the group and unique to the individual. Does this imply a different curriculum for each person? Foshay (16, p. 51) says it does.

> . . . we can organize the school to permit a separate curriculum for each child. Not the same curriculum, with children going through it at individual rates. That is not individuality; that is merely a more detailed control. No; we can, if we have the nerve, organize a special curriculum for every one of the millions of children in school. These curricula would have many common elements, of course--especially in the fundamental skills. But the kind of attack to be made on these learnings, even the learning of the skills, can vary enormously from one child to another, as (for example) the programs of individualized reading have shown.

This approach is consistent with the learning theories considered earlier. It can also fulfill Suchman's important elements of heuristic discovery described earlier and outlined on page 36. Preston (44, p. 67) recognized the incongruity of grouping over twenty years ago.

> Science has sufficient breadth so that any area may be explored by a heterogeneous group with profit to all. The outcomes may not be uniform from child to child, but. . . the general objectives may appropriately be the same for all members of a class and achieved by each child at his own level of comprehension. The search for data and concomitant activities can be shared by all. Children at various stages of maturity can weigh evidence, form conclusions, distinguish between fact and opinion, suggest and try new ways of doing things, and construct apparatus, . . . and thereby experience the method (s) of science.

This sort of organization in curriculum eliminates the need for consideration of ability grouping. The students will group themselves, at one time heterogeneously, at another in a homogeneous pattern, in terms of the needs of the situation.

Self-contained and Departmentalized Patterns

Gibb and Matala (19, p. 565-585) studied the use of special teachers in a departmentalized program in comparison to self-contained classroom organization. The study was conducted in the fifth and sixth grades with the content areas of science and mathematics. On the basis of the results of this study, these investigators concluded that there is some evidence that children learn science more effectively with special teachers than in a self-contained classroom. However, it should be noted that the special teachers had more than twice the college background in science of those teachers in the self-contained classrooms. This factor probably led Gibb and Matala (19, p. 583) to observe that "The background of the teacher not only in content but also in elementary school education may be a more significant factor in developing concepts of mathematics and science than classroom organization alone". The results of this study also showed that classroom organization had little relationship to children's performance in solving problems.

A similar study was developed by Dameron (12, p. 2639-2640) with groups of eighth grade students in a junior high school situation. Mean science achievement test scores were used to compare three patterns of instruction. These patterns were:

1. the common learnings program (unified studies or core), including science as a function of the program along with English and social studies in both the seventh and eighth grades;
2. the conventional science class, taught daily as a separate subject for two semesters, one semester in the seventh grade and the second in the eighth grade;
3. the conventional science class of two semesters in the eighth grade, pupils in this group having had no formal science instruction in the seventh grade.

Analyses obtained through tests of variance and covariance on the pre-test and post-test data revealed no significant mean differences.

Mallinson (34, p. 263) contends that "research studies indicate that every accepted method for teaching elementary science is effective, if it is properly selected and used". The results of Gibb and Matala and those of Dameron appear to support this hypothesis. The results of both studies also indicate a need for continued research which hold to the same conditions in order to offer some verification.

Craig (10, p. 156) states that the chief advantage of a departmentalized program is that the instruction is likely to be more accurate than that of the regular classroom teacher. He also points out some of the disadvantages offered by departmentalized science.

> Science tends to become a subject that is locked away in a tight compartment, unrelated to other categories or activities. It tends to be integrated only with the instruction of the departmental specialists, although

> there may be scores of opportunities for integration with the classroom activities and the life experiences of the child. In the mind of the child, science becomes a subject to itself, separated from its natural contacts.

The empirical evidence is conflicting and the authoritative pronouncements for both programs are convincing. In these terms, the issue is unresolved. Thus selection of the classroom organization is based on intuitive judgements rather than concrete evidence. Pella (41, p. 92) sums the problem in the following way:

> How can we get from the "I think because I feel" stage to the "I think because of the evidence" stage in science teaching. When this occurs the worship of past practice based upon opinion will fade and practice based upon evidence will emerge. We may even cease to worship the class of 25, the laboratory of 25, the lecture as a means of teaching, the laboratory as a means of teaching, etc. We may begin to apply the ethics of science to research in science teaching.

## Use of Reading Materials

A similar problem exists with the use of textbooks. This teaching resource continues to reign supreme as the prime source of curriculum in the face of a complete lack of evidence that it represents the most effective source of information. Piltz (43, p. 368-369) states that "A great many teachers rely heavily on the textbook to shape their science program." He goes on to say that " . . . science may become almost entirely a reading activity," and then sums his feelings with the comment that "Complete reliance on learning science through the sole medium of 'reading about science' leaves much to be desired".

In a developmental program in the state of New York (35, p. 33) the need for a diversity of reading materials was recognized.

> Not enough has yet been done to provide in our classrooms the variety of science reading materials that we need in order to meet the wide range of science interests among children and also to stretch the abilities of the better readers while meeting the needs of those children with less reading skill. If we recognize that very often our groups have a spread of as much as four grades in reading achievement, and that the better teaching of reading will increase rather than decrease this spread, we should see that it is necessary to have a variety of reading materials in science available to every classroom.

A study which makes a direct comparison between the use of textbooks and multiple library references has been reported (2, p. 245-249). Two sections of eighth graders were taught by the same teacher. In one section, a textbook was used and the content of the course followed that outlined in the book. The other section used multiple library references. No textbook or other primary source of information was available to this group. The unit approach centered about directed activities was the general teaching method for both sections. The following results (2, p. 249) were reported:

> The method of multiple library references produced a superiority in mean gain scores which was statistically significant in these two instances concerning achievement: science understandings for the science students

> of average ability, and the ability to interpret reading materials in science for the science students of high ability. In the understanding of democratic behavior, superior mean gain scores were recorded for the group using multiple library references; the superiority in gains was statistically significant.
>
> There appears to be a tendency for eighth grade students using multiple library references to be, on the average, superior to eighth grade students with textbooks--in gains of science understandings and reading ability in science. There is a tendency for students using multiple library references to show greater growth in critical thinking ability; the tendency is especially evident for the high ability science students.

One of the major factors which influences behavioral changes was described earlier (p. 29 ) as individual differences. Attention to this factor can be given through the provision of a variety of learning materials. Betts (4, p. 17) provides a most thought-provoking statement in this regard.

> It is the writer's observation that many learning disabilities in the schools of today are caused by this idea of providing every child--regardless of his capacity or achievement--in a given grade with the same basal textbook. This type of regimentation undoubtedly contributes substantially to retardation in reading and to the perpetuation of individual reading difficulties. Furthermore, it is apparent that the correction of this particular situation on the basis of preventive measures is not likely to take place until every teacher becomes a student of individual differences in relation to reading activities.

Publishers of learning materials have an important stake in the directions research findings indicate to be productive. Many new materials reach the school market each year which are based on the publishers' best estimates of the needs. Some packaged materials are appearing which promise to meet all the needs of a particular program. Olsen (37, p. 342) suggests that these packages will make continued progress and will probably have most, if not all, of the following characteristics:

1. They will constitute a kind of comprehensive, synthetic curriculum which provides for systematic and continuous pupil growth.
2. They will be constructed on the basis of a cross-media approach in which visual, auditory, and motoric experiences will be bound up with the printed symbol. At the least, audio-visual tools for teachers and students will be coordinated integrally with textual materials.
3. They will make concrete provision for pupils with different learning rates, skill levels, and learning styles.
4. They will have the learner participate directly in the learning process through individualized, small-group activities like puzzles and games.
5. They will make use of self-correcting materials, through which the student will receive constant and immediate feedback on the level of his performance.
6. They will employ multilevel, variegated content materials which will make spaced reinforcement and skill transfer to other subject areas possible.
7. They will include measuring and testing devices for evaluation by teachers and students.

A reading program (39, 70 p.) has been available for the last ten years which has been pioneering with the packaged learning materials concept. It provides reading materials which allow each individual student to progress as fast and as far as his learning rate and capacity will allow.

The success which was enjoyed with the reading materials has prompted the expansion of the concept to other disciplines, including science. The science materials accommodate the individual differences of students in grades 4-6 by presenting each major concept at five different reading levels. The processes of heuristic discovery are emphasized. The rationale for the program is detailed in the teacher's handbook which accompanies the package (40, 24 p.).

The uniqueness of the reading and science learning packages is contained in the provision of multilevel materials, which come closer to meeting the needs of the individual than other available programs. Parker (38, p. 131-132) calls this uniqueness the Multilevel Philosophy which he explains as follows:

> In essence, it is a strong belief in the idea of individual progress and that this progress occurs in successive levels. But the levels are not abrupt steps; each level flows into the next. The course of this movement or flow is that of an ever-expanding helix or spiral, and it is powered by the individual's own learning.

These science materials have been the object of a recent doctoral study. Fryback (17, p. 69-70) found that, although there appear to be no achievement advantages for students who read at their level or for those who discussed the materials with others in class, achievement advantages were significant for those who did the experiments. Fryback (17, p. 77) recommends further investigation to evaluate the effectiveness of the materials for (a) arousing curiosity in science, (b) stimulating creativeness, and (c) developing skills of inquiry.

The use of the Keysort card being evaluated in the present study offers another one of the advance efforts toward such a utopian situation as that described by Olsen. However, the step from the automated materials of this study to the programmed package which Olsen describes is still a big one. The Keysort card provides the basic elements for evolution in this direction, with the next important improvement being to machine-program the curriculum. Such an evolution appears to be a necessity for provision of the packages described earlier.

But what of the textbook? Present indications are that it is also evolving into textual materials which can more adequately meet the individual needs of the learner. Olsen (37, p. 343) believes that . . .

> The single textbook of the past will rapidly become an educational fossil of the future as publishers develop packages of systematic instructional programs which at once implement the best teaching practices, the insights of current educational research, and the creative thinking of the finest scholars.

## Development of Punch Cards

The Keysort card used with the present study is one manifestation of a more general concept of punched card systems. The punched card can be of any size to fit the needs of different tasks and can be punched along the margin or in different combinations across the face.

The idea of punched card systems is not new. According to Scheele (46, p. 5), punched card accounting had its beginnings in 1890 when a tabulating machine was designed to tabulate the census data of that year. However, the Keysort card did not appear on the scene for another 35 years.

The early history of Keysort was obtained by means of private communication with Mr. J. L. Harrigan of the Royal McBee Corporation. Mr. Harrigan generously supplied the following information:

> KEYSORT was originated by an English accountant by the name of Perkins, who at the time was employed by the Dunlop Rubber Company, Ltd, in England.
>
> Mr. Perkins found that his simple idea saved his company a great amount of time and money because it speeded the sorting and summarizing of masses of detail by eliminating the typical spread sheet and other cumbersome methods. After patenting his idea it was placed on the market and was successfully sold under the trade name of "Paramount".
>
> . . . in 1932, Roger Connor, who was Sales Manager at that time, went to England to acquaint himself with

> the "Paramount" method and to study its applications and sales potentials. He immediately saw in Paramount <u>tremendous</u> possibilities for handling a great need in McBee's natural market, and before leaving England he consummated a deal for the rights to the American patents.
>
> . . . this new product was given the name "KEYSORT" and was made available to the sales force . . . Each year has brought new ideas for its use--better production methods--and many improvements are in process at all times.

Indeed, many uses have been found for the Keysort card. Cost accounting and sales analysis were among the earlier applications. Librarians (48, p. 871 and 953) soon discovered the potential held by Keysort for simplifying their operations. Hospital administrators have been able to increase operational efficiency by employing the punched card systems (13, p. 366 and 45, p. 538).

Colleges have found the system useful for keeping student records. Bemis (3, p. 40) reports that the use of the use of the notched-card system has "sharply reduced the incidence of errors, by an efficient and economical system, that provides far better control over that unpredictable factor known as 'the student'".

Application of the Keysort card to the problems of the schools has been directed toward grade reporting and class scheduling. Herbert (24, p. 129-137) points out that the punched-card system has enabled his school system to tailor the schedule to the student and speed up class programming, effecting a saving in valuable instructional time. Long (32, p. 108) reports that the use of the Keysort card for grade reporting not only saves the time of teachers but also attacks the problem of dropouts because the "system makes it possible to sort out the students who are having difficulties early in the year".

The vast majority of applications of the Keysort card to tasks in the educational field have been administrative. The literature is conspicuously devoid of curricular applications. One of the earliest and few uses of Keysort for recording and rapid retrieval of instructional information was reported by Green (20, p. 638-640). He was able to keep data regarding various qualitative tests in organic analysis readily accessible for checking accuracy in different analysis schemes.

A comprehensive survey of applications of punched cards to tasks related to science is supplied by Casey, et al (9, 697 p.). In addition to task descriptions, a keyed and annotated bibliography is included as a separate chapter. This is an excellent sourcebook for developments prior to 1958.

No applications of punched card methods could be located in the literature which were directly related to the methods used in the present study. It appears safe to assume, therefore, that the present use represents a pioneering and original application of the Keysort card.

## Summary

The literature has been searched for information which is relevant to the present study. This search has revealed generalizations about the nature of the science learner and the science learnings. The attempt was made to show empirical data which would support these generalizations and in a few instances added support was reported which took the form of statements from recognized authorities in the field. The overall impression is that a great deal of verifying research needs to be initiated. Much of the data comes from individual studies in which the conditions are difficult, if not impossible, to duplicate.

This review has been divided into three major sections. The first section dealt with patterns of curriculum organization as they relate to scope and sequence. The rationale was developed which suggests that content is structured by the learner. Teaching then is a matter of creating a rich environment in which the learner discovers structures. Four major factors of learning basic to the present study were identified. These are motivation, assimilation, equilibration, and individual differences. It was suggested that these factors were effectively utilized when the learner has the opportunity to practice scientific behavioral processes of investigation. Recent studies further suggest that the science sequence be

based on these same behavioral processes.

The second section was concerned with patterns of classroom organization. In contrast to the question of homogeneous versus heterogeneous grouping, the literature suggests a setting so flexible that students may group themselves in a manner appropriate to the learning situation. Such an environment appears most consistent in relation to the nature and methods of learning described earlier. However, more research appears necessary on the relative values of departmentalized versus self-contained classroom organizational patterns. Considerable evidence seems to favor the use of multiple sources of information to meet the needs of the learner as he prepares for a rapidly changing future. These studies lend both theoretical and empirical support to the classroom pattern recommended for use with the materials of the present study.

The final section of the chapter is devoted to a brief survey of the development of punch cards. The use of these cards is widely distributed but only one reference was located which reported the use of the cards for the retrieval of instructional information. This section of the search adds support to the belief that the present study is unique in the field of curriculum research.

The purpose of this review was to reveal to the reader research in those phases of education which has a bearing on the present investigation. With this research in mind the reader can evaluate the significance of the problem of this study in terms of its objectives and findings.

# THE STUDY

## Introduction

The significance of a study can be appraised in terms of the clarity of its purpose, originality of its design, and its contribution to knowledge. The purpose of this study has been described in Chapter I and its relationship to what is already known has been considered in Chapter II. The material to be presented in this chapter will be concerned with a description of the design of the study and the materials used with that design.

Curriculum materials have been placed on Keysort punch cards and made available to teachers for use with students. A measuring instrument has been developed and has been used for the appraisal of student growth in those classrooms where the cards were used. The first two sections of this chapter will provide a complete description of the Keysort materials and of the measuring instrument. The last section will contain a discussion of the procedures used in the study.

## Science Teachers' Adaptable Curriculum

The following discussion of the Science Teachers' Adaptable Curriculum (abbreviated STAC) proceeds in three phases. The first phase considers the origin of the program, the second spells out the design details, and the last phase presents the ways in which the program has been applied to real situations.

Origin of STAC

The Portland High School Curriculum Study was initiated in the Portland, Oregon Public Schools during the 1958-59 school year. The Board of Directors asked representatives from nine Oregon colleges and universities to make a detailed study of curriculum for potential college students in the Portland high schools. The study was financed by the Fund for the Advancement of Education and touched most areas of the curriculum. A detailed report (29, 195 p.) of the results of the entire study has been published for the interested reader.

The major part of the report of recommendations from the science committee dealt with courses generally termed "college preparatory." However, weaknesses were recognized in the general science classes which were observed and recommendations were made for their improvement. These recommendations were in tune with others being made at the time, ie., de-emphasize the technology of science, give more attention to the investigatory nature of science.

In the fall of 1961, a committee of high school science teachers was organized to study the recommendations of the college consultants relative to general science. On the basis of the study, this committee made preparations for a summer writing session to write curriculum for general science. Dr. Donald W. Stotler, Supervisor of Science for the Portland Public Schools, was familiar with uses of Keysort cards in other situations and suggested to the committee that a way be brainstormed for their use as a curriculum device.

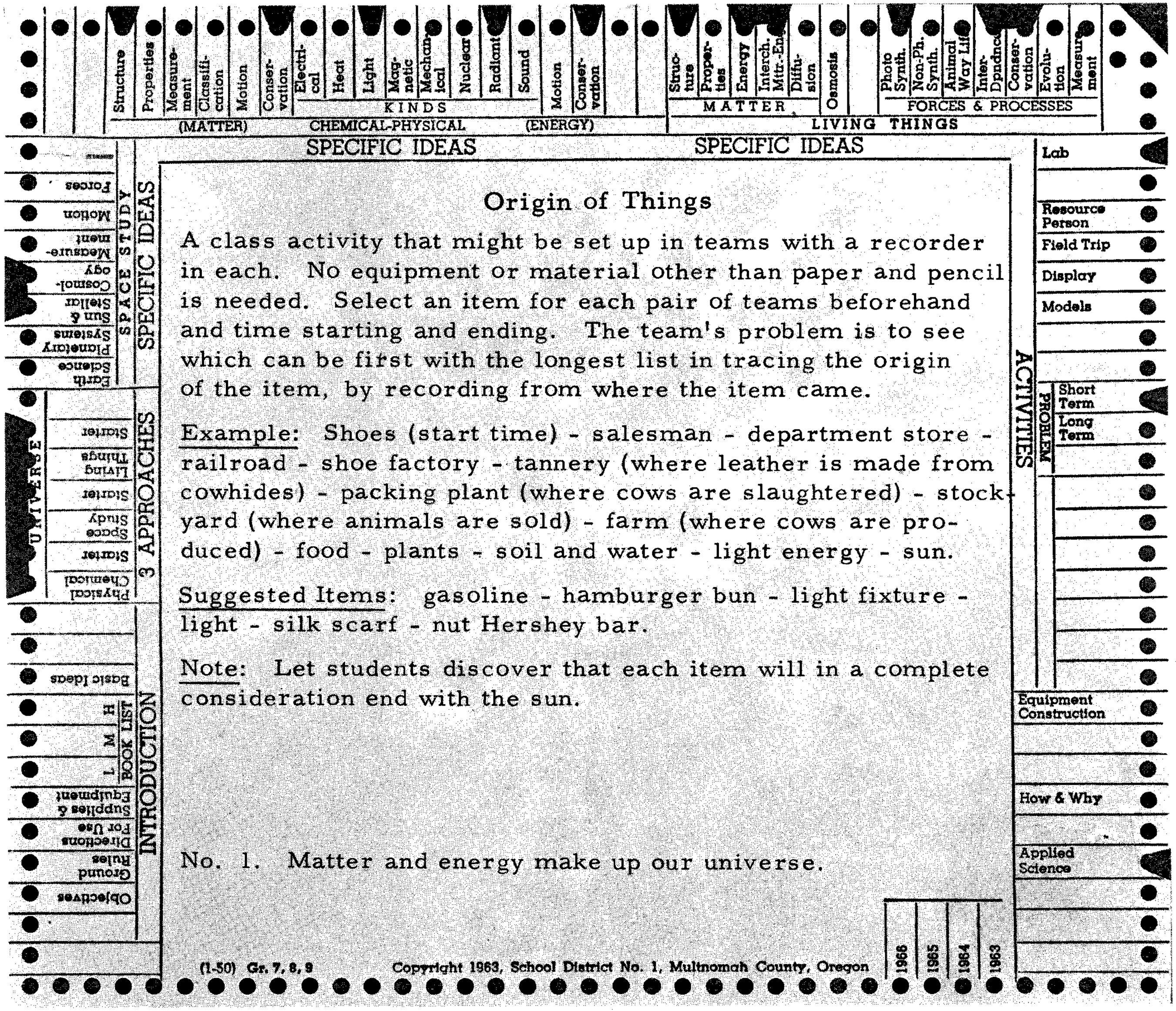
The summer writing session, 1962, was devoted to developing a program to be printed on the margin of the card, writing learning materials to be printed on the center portion of each card, and formulating the philosophy and ground rules for the classroom use of the resulting package of cards. The decks of curriculum materials were printed and prepared for distribution to general science teachers. These efforts produced nearly 300 cards, each containing a separate problem, project, and/or teaching idea printed on the central part of the card.

A summer institute conducted concurrently with the writing session assisted in developing the philsophy of the STAC program. The composition of the institute was ninth grade general science teachers with three upper grade elementary teachers also in attendance. Several of the ninth grade teachers and all three of the elementary teachers agreed to use the STAC program during the 1962-63 school year.

The program which is printed on the margin of each card is divided into four parts: Introduction, Approaches, Specific Ideas, and Activities (see Figure 1, p. 61). The Introduction is concerned with the objectives, ground rules, use, supplies and equipment, book lists, and basic ideas. Thus if the user wishes to study any of these features of the program, he merely places a sorting needle through the hole adjacent to the desired idea. When the deck of cards is raised from the table surface by the sorting needle, the desired card or cards will fall from the deck. The user will note that the card is notched to correspond with the content printed on the central portion of the card.

That section of the margin labelled "3 Approaches" offers teachers the option of one or a combination of content areas: Physical-Chemical, Space Study, and Living Things. When the sorting needle is threaded into a hole corresponding to one of these areas, all cards having content related to that area will fall from the deck. Each Approach has starter activities designed to initiate the study.

The content material associated with a particular Approach may be sorted into the several concepts listed in the "Specific Ideas" section. The teacher has the professional responsibility as well as the opportunity to organize these ideas in the order which is most consistent with the needs and interests of the class.





## Origin of Things

A class activity that might be set up in teams with a recorder in each. No equipment or material other than paper and pencil is needed. Select an item for each pair of teams beforehand and time starting and ending. The team's problem is to see which can be first with the longest list in tracing the origin of the item, by recording from where the item came.

Example: Shoes (start time) - salesman - department store - railroad - shoe factory - tannery (where leather is made from cowhides) - packing plant (where cows are slaughtered) - stockyard (where animals are sold) - farm (where cows are produced) - food - plants - soil and water - light energy - sun.

Suggested Items: gasoline - hamburger bun - light fixture - light - silk scarf - nut Hershey bar.

Note: Let students discover that each item will in a complete consideration end with the sun.

No. 1. Matter and energy make up our universe.

(1-50) Gr. 7, 8, 9



Figure 1. The marginal program and an activity are shown for a typical STAC card.

The fourth section of the card labelled "Activities" directs the user to several resource possibilities. These include listings of resource persons, field trips, and displays as well as short and long term projects. Open spaces are available for additional ideas as they develop.

Design of STAC

Four factors which play a major role in influencing behavior were identified in Chapter II (page 30). These factors are motivation, assimilation, equilibration, and individual differences. All of these factors have a direct relationship to the present study and are included in the design structure of the STAC project.

The key word in describing the design structure of STAC is "flexibility". It was recognized that the teachers are individuals just as are the students in their classes. Therefore, a program should be designed which is flexible enough to provide for teacher differences as well as the differences of the students. The STAC materials do this through provision of three major content areas from which to choose. Background strengths of the teachers can be matched with one the major areas. Students' science interests and abilities can also be matched with the diverse content provided within the major content theme selected.

Assimilation is provided within the framework of the program. This factor is dependent on the amount of mismatch which the individual learner encounters in his environment. The diversity of the materials in the STAC sets is sufficient for the teacher to maintain a balance of the familiar and unfamiliar for the individual student. Thus, through the other important process of equilibration or self-regulation, assimilation can occur at rates appropriate to the individual.

Equilibration is also an important concept in relation to the continued improvement of the materials. Feedback on the usefulness of the materials in encouraged from the teachers. Suggestions for the improvement of the content and approach from all teachers in the system offers a close tie between theory and practice. It also produces a constant self-regulation or equilibration of the curriculum which is at once modern and evolutionary rather than periodically out-of-date and revolutionary.

The mechanics of the feedback are rather extensive. A group of teachers is selected to act as a review committee. This committee has the responsibility for checking the accuracy and appropriateness of the suggestions submitted. Subject matter specialists from the colleges serve as consultants to further check the accuracy of the science content. Since the STAC program is organized at three different levels of the elementary school

(K-3, 4-6, and 7-9), the feedback committees are also selected from these three areas. The original committees also had developmental responsiblities, since no materials existed at the K-3 and 4-6 levels. The plan of organization is to have new feedback committees each year, with one person serving from each committee for two years to provide continuity.

The advantages of such a design are numerous. The STAC materials can be thought of as a flexible handbook or source-book for teachers. In the past, the usual method for implementing a curriculum was to have a specialist produce what represented to him the best approach to be used with that content in the classroom. This material was bound into a single volume and distributed to those for whom it was intended. Accompanying this distribution was a set of directions on how to use the material and a leaflet describing all the virtues of the new material. Customarily, the teacher found several pages which could not fit his program and discarded the material as inapplicable to his situation.

The STAC program was written by teachers for teachers. Implementation was planned to include some sort of experienced help, either through the supervisor's office or by taking an in-service class. Both the strengths and weaknesses were pointed out and assistance was requested from the classroom teacher in correcting the weaknesses. Curriculum development and improvement thus became the concerted effort of all members of the teaching staff in the district.

An important element in the motivation of students is often the immediacy of materials related to current interests. The STAC program provides a variety of directions which can be quickly retrieved from the package of cards, thus supporting the interest with immediate reinforcement. Additional ideas are available from the deck which can act to sustain and regulate the pattern of activity.

The classroom environment recommended for the accomplishment of these patterns of learning and revision is one similar to that found in the research laboratory. This type of environment allows for the use of heuristic discovery. The teacher acts in the role of research director and defines the boundaries of investigation. The students engage in the pursuit of knowledge much the same as scientists. As Bruner (7, p. 14) puts it, "The schoolboy learning physics _is_ a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else". Behavioral change is enhanced through the active involvement of the four learning factors, because the learner is now the seeker of knowledge. In this environment, the learner has the opportunity to use any or all of the behaviors mentioned in Chapter II, page 32.

Application of STAC

The effective use of the Keysort STAC materials required that objectives, ground rules, and directions for handling be established. These features were developed by the writing committee during the summer of 1962.

Objectives for General Science Course. General science is a part of the total curriculum offered within the school district; therefore, the general objectives of the school system apply to this course. General science is a part of the K-12 science sequence; therefore, the objectives of the total science program apply to this course. General science has specific objectives which can be evaluated. They are: (a) build concepts--help the students gain insight into natural phenomena; (b) think logically--help students gain confidence in effective methods of scientific inquiry; and (c) stimulate curiosity--create the desire for further study on the part of the students.

Ground Rules for Teaching General Science. STAC cards are designed to develop basic course concepts but the particular course sequence is the responsiblity of each teacher. The STAC program attempts to provide a variety of materials and activities adaptable for (a) teachers who have background in one or several areas of science; (b) students who vary in abilities and interests;

and (c) laboratory facilities that are designed for teaching life and/or physical sciences.

The teacher directs the learning experiences in a manner similar to that of a director of a research laboratory and students discover concepts for themselves. Lecture method is held to an absolute minimum.

The course must have a continuity and sequence ("thread" of a story). The discovery of certain concepts and principles should lead to other related concepts and principles.

The students must have access at all times to the science book shelf in the classroom. Reading material covering a whole range of reading difficulty and topics are added or deleted as the teacher and students find changes necessary.

The student record book is for the student's use and shall be used in the same way that a research scientist uses his records--as a tool which helps him make new and better discoveries. Occasionally the teacher may examine the materials and suggest ways to improve the records as is done by a director of a research laboratory. Such examinations will not be part of the student's grade.

Student's written papers shall be based on the experimental studies. They shall be drawn from the record book in the manner similar to the way a scientist writes a paper from his records.

A section in a regular three-hole school notebook can serve as the "record book". The written papers should be:

1. based on data from research
2. written in such a way that others can read and understand it
3. have a purpose which is explained
4. reported in such a way that a reader can duplicate the experiment and check results
5. stated so that needs for further research are pointed out in the results
6. written in acceptable grammatical form and composition.

Homework shall be based on the needs of the student and an outgrowth of a particular activity in which the student is involved (classroom activity, laboratory activity, or class research activity).

Evaluation shall be individualized to each student, shall be part of the learning process, shall be the basis for student grades, and shall relate to course goals. Teacher observation and subjective judgment, student self-evaluation and written tests closely resembling best learning experiences may be used for evaluation purposes. Students' grades shall be recorded periodically to show any change in attitudes.

Laboratory activities shall be conducted according to safe laboratory practices and all activities involving living things shall be conducted with reverence and appreciation for life.

<u>Directions for Use of STAC.</u> The Science Teachers' Adaptable Curriculum has been designed to meet the following criteria:

1. It is a laboratory course and, as such, should follow research laboratory procedures.

2. It is based on discovery approach and depth of understanding.

3. It is planned to meet the needs of teachers who have physical-chemical, life science, earth science, and astronomy content backgrounds.

4. It is designed to provide similar coverage regardless of approach used.

5. It allows the teacher to plan a year's curriculum that will fit the needs of each class and of each student yet stay within the suggested goals.

6. It encourages the teacher to preplan the course in such a way that continuous study ("thread" or story) runs through the entire year's work, rather than a study divided into blocks of disconnected concepts.

7. It is designed for maximum class size of 25 equipped with a room library of multiple titles covering a wide range of reading levels rather than individual texts.

8. It is planned for flexible physical facilities which will provide adequate laboratory work space and be equipped with tools, science supplies, and building materials that allow research-type laboratory experiences.

9. It is designed to provide science experiences for grades seven, eight, and nine.

10. It is designed for continuous revision so that all activities will provide the best learning experiences available, and be based upon the latest science discoveries.

11. It is designed for continuous revision by the school district staff. Teachers are requested to submit to the science supervisor suggested activities that add to, supplement, improve, or correct the STAC cards. Such activities will be evaluated by a committee of teachers and, on approval, will become a part of STAC. The number of STAC cards will be kept to a minimum. A small number of excellent experiences that meet the needs of teachers and students rather than a large number of experiences is desirable.

The STAC cards provide quick and easy selection of curriculum materials. Cards can be placed in the file at any time and in any order. A STAC selector needle will separate all cards relating to a specific title listed on the margin of the card. The selector needle is an ice-pick-type device, pointed at one end and small enough to pass easily through the holes along the margin of the card. An ice pick will serve as a selector or one can be made from stiff wire.

In order to separate desired cards from the deck, one should use the following directions:

1. Arrange the cards so that all clipped corners are in the same location.

2. Place the cards so that all edges are even.

3. Select the desired title and "thread" the selector needle through the hole by that title. Be sure the needle passes through all the cards.

4. Turn the needle at an angle and raise it up. STAC cards pertaining to the selected title will fall from the pack.

The mechanics of planning a year's work can be accomplished by following a set of general directions. Individuals will alter these recommended steps as familiarity develops.

1. Turn the STAC cards to "Introduction". Select and review "Directions for Use". Select and review "Objectives", "Ground Rules", "Supplies and Equipment", "Book List", and "Basic Ideas". These cards provide familiarity with the purpose and mechanics of the course.

2. Turn the STAC cards to "Approaches". Select the one approach consistent with the background and preparation of the person making the selection. All cards relating to that area will fall. Regardless which approach is selected, about 65 percent of the cards will fall.

   Sort out the "Starter" for the selected approach. Several cards suggesting ways to get started will fall out. Select those that best fit the needs.

   Turn STAC cards to "How and Why". Cards giving specific help in teaching procedure, laboratory methods, and directions for making and using equipment will fall.

   The "Approaches", "Starter", and "How and Why" cards form the nucleus of the year's work. The remainder of the cards may be put aside.

3. The story or "thread" to be developed for the year should now be planned. Turn to "Specific Ideas" in the selected approach and sort out the first topic to be considered. Review all sorted materials. Sort and review the "Activities" from the first topic.

   Repeat this process for each of the "Specific Ideas" to come under consideration. Fit the selected ideas and activities to the "thread" to be followed, the interests, abilities, and needs of the students, and the facilities and time available.

> Review the remainder of the cards in the approach selected to prepare for individual requests of students. Seek ways of relating these special requests to the selected theme.

Other Activities. The interest in the STAC materials spread during the fall of 1962, especially among the elementary teachers. Numerous requests were received in the supervisor's office for sets of materials. However, only those persons who could be given individual assistance were provided with materials. It was felt that direct work with one experienced with the materials would be necessary in order to achieve minimum success with the program. When the requests exceeded the available time, plans were made for extensive in-service training.

An in-service course was offered during the Winter Term of 1963 to selected individuals from the science departments of each of the ten comprehensive high schools. In many cases, these were persons who had participated in either the writing session or training session during the preceding summer. The philosophy and mechanics of STAC formed the base of the course. Other elementary science programs in existence at the time were also discussed and evaluated.

During the Spring Term, 1963, each of the science teachers who had attended the Winter Term course taught a similar course to elementary teachers. Representatives from each of the elementary schools attended a STAC class at their area high school. In many cases, the representatives were picked by their building principals, who were asked to select a person who had potential for becoming a STAC representative in the school. Six of the eleven teachers involved in the present study attended the Spring Term course. The other five received assistance during the experimental year from the STAC representative in his building.

Plans were underway for offering in-service opportunities during the following 1963-64 school year. These plans included extension of the program to all levels of the elementary school. At that time, the STAC program was still geared to grades seven, eight, and nine. Two types of classes were planned for each of the three levels of elementary school (primary, K-3; intermediate, 4-6; and upper, 7-9). One type would be continuous throughout the school year. It was designed for those teachers who were inexperienced in both science content and use of discovery techniques with students. The other type was renewable each term and was designed for those teachers inexperienced with discovery techniques. These classes were reasonably successful and were continued for another year (1964-65).

## Portland Science Test

The pattern of development for the Portland Science Test has extended over a period of six years and has included numerous revisions. This pattern will be unfolded for the reader in three parts. The first part will reveal the origin of the test, the second part will disclose the design criteria, and the third section will be concerned with the methods used for the revision, the reliability test, and the validation of the instrument.

### Origin

A committee of Portland teachers and supervisors was organized in the fall of 1959 for the express purpose of brainstorming a test for science. The first meeting was held in the Curriculum Center of the Portland Public Schools. The need for a science test arose from the dissatisfaction with existing science evaluation instruments.

The first year was spent looking at all available tests and examining all possible audio-visual media which might be used in a new design. Numerous discussions were concerned with what science education is and is not. Several goals were established as a consequence of these discussions and deliberations. These goals are stated and described as follows:

1. Produce an instrument which places a minimum reliance on reading skill.

   The testing instruments examined required a reading skill to such an extent that the tests were, in fact, evaluating reading ability of the examinee. Evaluation of science skill was valid only for those with high reading ability.

2. Produce an instrument which evaluates knowledge of the ways in which scientists learn (processes) as well as what scientists have learned (products).

   The science tests examined by the committee were found to require excessive recall of information with little attention given to the ways in which the information was learned. The members of the committee felt that both aspects of scientific knowledge are important and should receive at least equal attention.

3. Produce an instrument consistent with the Portland science program.

   The major emphasis in the evolution of the present Portland science program has been placed on the investigative patterns of learning. It was the feeling of the committee members that an evaluation instrument should be established which would reveal whether or not these patterns were in fact being encouraged in classroom practice. It was the hope that high student scores would indicate that teachers were providing opportunities for active student participation in investigative processes.

4. Produce an instrument which could be appropriately administered to students in grades four through twelve.

   Standardized tests with norms based on Portland students offers information useful to the improvement of local instructional programs. The committee members felt that a single test might be developed which could be given to students in grades four through twelve and would yield achievement and

> diagnostic data. Such a test needed items which would challenge students throughout the continuum of ability.

The second year saw activity directed toward the established goals. Pictures were evaluated for possible usefulness as the basis for test items. Questions which dealt with both process and product were written about pictures. It was soon apparent that specific criteria must be established both for the writing of process and product questions and for the selection of pictures. These criteria are described in the next part of the present chapter.

The results of the second year's activity included, in addition to the criteria, a six-picture test with process and product questions about each and a rough draft of a teachers' handbook describing the intent of the test. The test was administered to a sample of fifth and sixth grade students in the classrooms of the committee members. The test results were subjected to item analysis by the Testing Department and weak items were revised in terms of this analysis.

The efforts of the test committee for the third year, 1961-62, were channeled into the production of more items and pictures for experimental testing and into the revision of the teacher's handbook. The work on the test items resulted in a try-out test composed of 18 pictures, with three process and three product questions about each for a total of 54 questions. The teachers' handbook was revised into a tentative publication, subject to modification by those teachers who would be involved in the experimental use of the test. No further revisions have been made of this handbook.

The committee decided early in the fourth year, 1962-63, that two forms of the test should be developed. The test produced the previous year was split into two equal parts and the committee developed these two forms into ten-picture, 80-item tests, with 40 process and 40 product items in each form. Also the number of responses for each item was increased from four to five.

These two forms were experimentally administered to random samples of students in the spring of 1963. These testing data were subjected to item analysis and the results reported to the science supervisor's office. During the summer of 1963, the items revealed most useful by the item analysis were collected into a single ten-picture, 62-item test (the odd-numbered items were process and the even-numbered items were the product questions).

The newly-revised test was handed out to the members of the committee at the first meeting of the fifth year, 1963-64. For the first time, the test had an official title which was <u>Portland Science Test</u>, 1963-64 Fall Edition (see Appendix I). The test was administered to all ninth graders in the city in November of that year. Plans for validating the test were announced at the meeting. The validation scheme consisted of comparing the student scores on the test with judgments concerning the same students by their science teachers.

Committee efforts for the 1963-64 school year were devoted to production of more items and to the revision of the Portland Science Test, 1963-64 Fall Edition, in terms of the item analysis of the fall testing. Committee members also began considering other media for extracting valuable test data. The year ended with the revision completed and the data in for validation but these data were not processed until the fall of the next school year, 1964-65.

The revised form of the test was administered in November, 1964, under the title of Portland Science Test, 1964-65 Edition (see Appendix II). The results from this testing were also subjected to the item analysis procedure. The analysis was completed and is reported in another part of this chapter. The committee work continued for the improvement of present materials and the production of new testing concepts. However, further consideration of the activities of the committee are beyond the scope of the present study.

## Design Criteria

The initial limitations placed on the development of a science testing instrument were that it contain pictures and a series of questions about the pictures. The questions were to be so designed that correct responses would reveal understanding of both the processes and the products of science.

Criteria for use in the selection of pictures and sketches were established by the committee. It was decided that the pictures and sketches should

1. set the problem in the student's mind.

2. provide the visual percepts of the problem.

3. stimulate thought in the problem area.

4. serve as a reference for stimulation in probable solution.

The question of subject matter limitations was considered at length by the committee. Ten basic concepts or big ideas were identified. Five of these were drawn from the physical sciences and five from the biological sciences.

1. Space is vast.

2. The universe is composed of matter and energy which is probably the same everywhere.

3. All things are relative to the point of observation--time, space, matter, and energy.

4. Motion in the universe seems continuous, orderly, and controlled.

5. The physical laws of the universe affect all natural phenomena, including its largest and smallest portions.

6. Living matter is an organization of molecules complex enough to effect reproduction.

7. Living things adapt to the environment.

8. There is great variety in living and non-living things.

9. Living things are interdependent.

10. Sunlight is the original source of energy which maintains life on earth.

The definition of the terms "process" and "product" was necessary in order for the committee members to write to these concepts. Process items were defined as those items which are designed to require the student to think, ie., to link together a sequence of two or more mental responses in order to select the best of the possible answers set forth in the test item. Product items were defined as those items designed so that the desired response can be made by simple recall, ie., one mental response.

It was immediately recognized that the process items could be of several varieties. The limiting criteria which were originally identified by the committee included the following process skills:

1. Problem recognition--present a challenging situation and ask the student to select the response which most clearly states the problem.

2. Hypothesis choosing--pose a problem and ask the student to choose the most likely hypothetical solution.

3. Experiment choosing--present an hypothesis and ask the student to select the experiment that would provide the most productive data.

4. Generalization choosing--present specific data to the student and ask him to choose the response which most nearly combines or summarizes the data in one comprehensive statement.

5. Relevancy choosing--present a situation, ie., problem, experiment, hypothesis, or generalization, and ask the student to choose the response which is most relevant to the situation.

These five process skills were used throughout most of the developmental stages of the test. However, in the final revision for the Portland Science Test, 1963-64 Fall Edition, the last two, "generalization choosing" and "relevancy choosing", were eliminated since no items could be identified which tested these skills.

Methods of Test Analysis

Several references were made to test revisions in terms of item analysis during the discussion of the origin of the test. This process has been the prime source of revision data throughout the stages of development. For this reason, the procedure will be considered in detail. Methods for the determination of reliability and validity will also be described in detail.

Item Analysis. This type of appraisal of the individual items on a test is performed in order to determine the internal reliability of the instrument. The analysis extracts two types of information about the item. It provides an indication of the difficulty and the discriminating power displayed by an item.

The difficulty of an item can be described as the proportion of a sample of the examinees that marks the item correctly. This Difficulty Index (percent correct) may range from 0 percent to 100 percent. An item having an index of 0 percent or 100 percent is not discriminating and therefore presents no functional information. This situation would be possible only when all the examinees mark an item correctly, or when none of the examinees mark the item correctly. Thus, the most discriminating items are those of about 50 percent difficulty.

The Discrimination Index of a test item refers to the degree to which success or failure on the item correlates with the score on the test. A single test item has high discriminating power if the examinees who answer it correctly score higher on the test than those who answer it incorrectly. An item has no discriminating power when there is no difference in the tested ability of the examinees who answer the item correctly and those who answer it incorrectly.

The Discrimination Index is an estimated correlation coefficient which may range from a $+1.00$ to a $-1.00$. The upper 27 percent and the lower 27 percent of a sample of examinees is selected. The percentage of correct responses on an item from each group is determined and these values used to enter a conversion table for the Discrimination Index. Garrett (18, p. 368) suggests that Discrimination Indices of 0.20 or more are regarded as satisfactory.

In actual practice, a minimum Discrimination Index of 0.40 was used for accepting items for inclusion in future revisions of the test. An analysis of responses was made of the weak items and improvements were made in terms of this analysis.

Test Reliability. Both editions of the Portland Science Test were evaluated for reliability through the application of the "rational equivalence" method described by Garrett (18, p. 340). The value of the reliability coefficient thus calculated was 0.85 for both editions. According to Garrett (18, p. 342), the "rational equivalence" method provides "a minimum estimate of reliability - we may feel sure that the test is at least as reliable as we have found it to be".

Test Validity. All ninth grade students in the Portland Public Schools took the 1963-64 Fall Edition of the Portland Science Test in November of 1963. Concurrently all science teachers of ninth grade students in the Portland schools attended a meeting in which they were requested to observe their students during the year in preparation for providing information relative to both the process and product abilities of their students in the spring of 1964. It was agreed at this meeting that the teachers would attempt to identify only those students who, in their judgment, were at the extremes of a process scale and those who were at the extremes of a product scale.

A questionnaire was sent to all science teachers of ninth grade students in the spring of 1964 (see Appendix III). The teachers were requested to fill out this questionnaire naming students who fit on the various scales. These questionnaires were returned and subsequently the names of 202 students were submitted for the Process evaluation (high--117; low--85) and 178 names of students were submitted for the Product evaluation (high--97; low-81).

The names of the students submitted by the teachers were compiled into lists and their Process and Product raw scores on the Portland Science Test were tabulated. This provided two kinds of data on these students: one, teacher judgment as to whether they were at the top or bottom of the Process or Product scale and, two, their Portland Science Test scores. With these data, judgments had to be made on the kind of statistical analysis to be used for providing a coefficient of correlation between judgment and test score. The assumption was made that the high-low judgments provided by the teachers regarding these students represented a true dichotomy. This assumption allowed the use of a point biserial correlation. A point biserial coefficient of correlation was calculated relating the teacher judgments of students to their test scores obtained on the Portland Science Test. These data provided an external criterion for the determination of validity.

The unique character of this analysis lies in the fact that teacher judgment about students was compared with the scores these same students obtained on a science test. By means of such external criteria, the validity of the testing instrument has been evaluated. The results of these correlations are contained in Table I. Note that the point biserial correlation coefficient is 0.72 when those students picked for Process were compared with the scores they got on the Process section of the Portland Science Test. Correlation of their Product scores with teacher Process judgment obtained a coefficient of 0.76. When those students placed at the extremes of the Product scale by teachers were compared with their Product scores, the coefficient was 0.76. Comparing the teacher Product judgment for these same students with their Process scores produced a coefficient of 0.69.

Table I. Summary of Point Biserial Correlations

| Teacher Judgment | Correlated With | | Significance of Difference at Five Percent Level of Confidence |
|---|---|---|---|
| | Process Score | Product Score | |
| Process | 0.72 | 0.76 | None |
| Product | 0.69 | 0.76 | None |

The coefficients obtained by correlating teacher Process judgment with both student Process and Product scores were converted to z functions. Application of the critical ratio to the difference between the two z's revealed no significance at the five percent level of confidence. The same procedure was followed for determining the significance of the difference between the coefficients obtained by correlating teacher Product judgment with student Process and Product scores. Again there was no significant difference at the five percent level of confidence. These data from this limited sample suggest that students who excel in understanding of science concepts also are proficient in using the processes of scientific investigation.

The results of the item analysis to determine reliability of the Process and Product items are shown in Figures 2 and 3. An examination of these results shows that the majority of the items fall above the Discrimination Index of 0.20. As indicated earlier (page 83), items with Discrimination Indices of 0.20 or more are regarded as satisfactory. The rating scales at the top of Figures 2 and 3 were devised by the Testing Department of the Portland Public Schools.

The method of comparing external criteria of teacher judgment with the testing results obtained by the same students yields correlation coefficients which are significantly high. These high coefficients

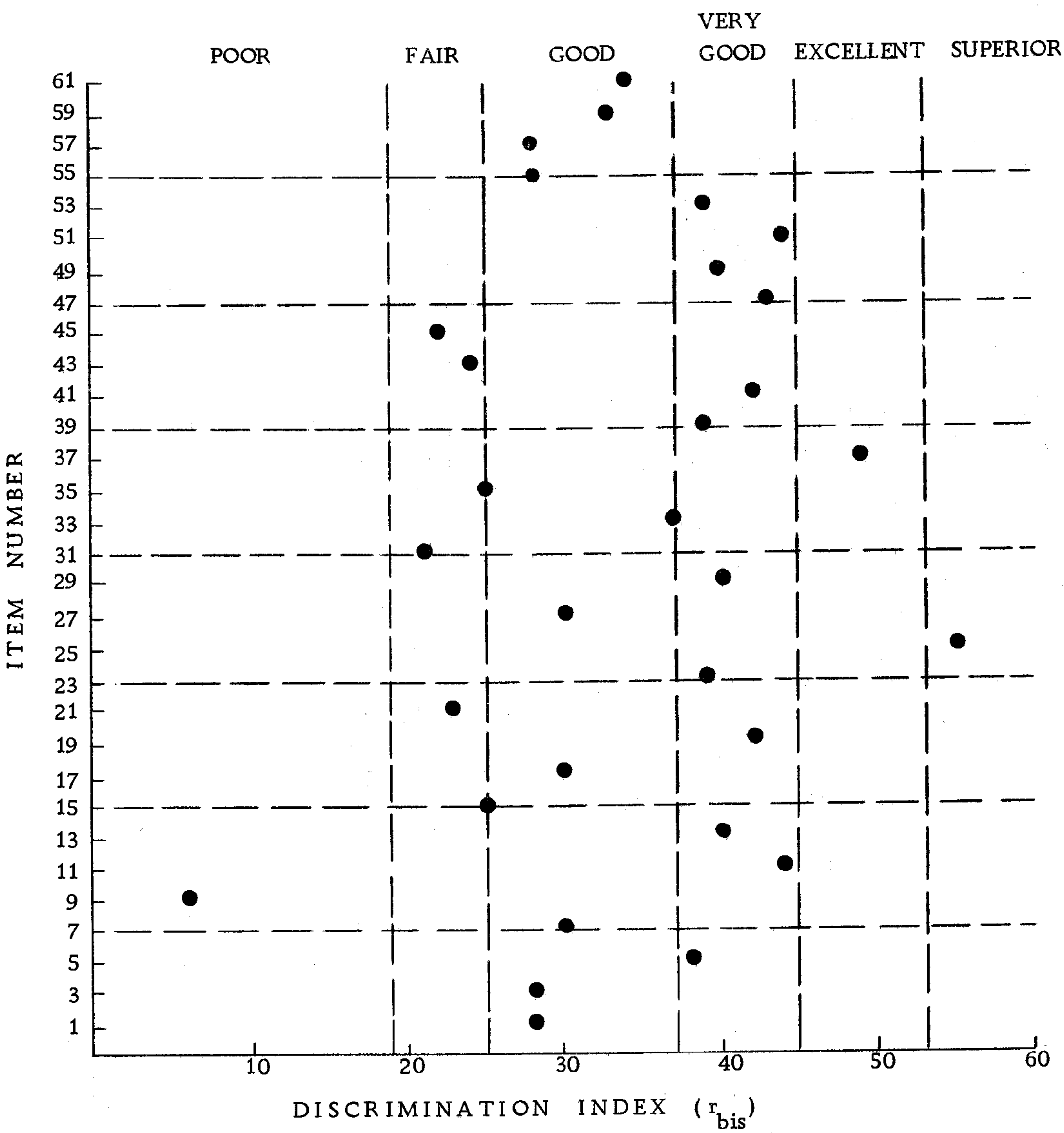



Figure 2. Discrimination power of the process items, 1963 Fall Edition, Portland Science Test.

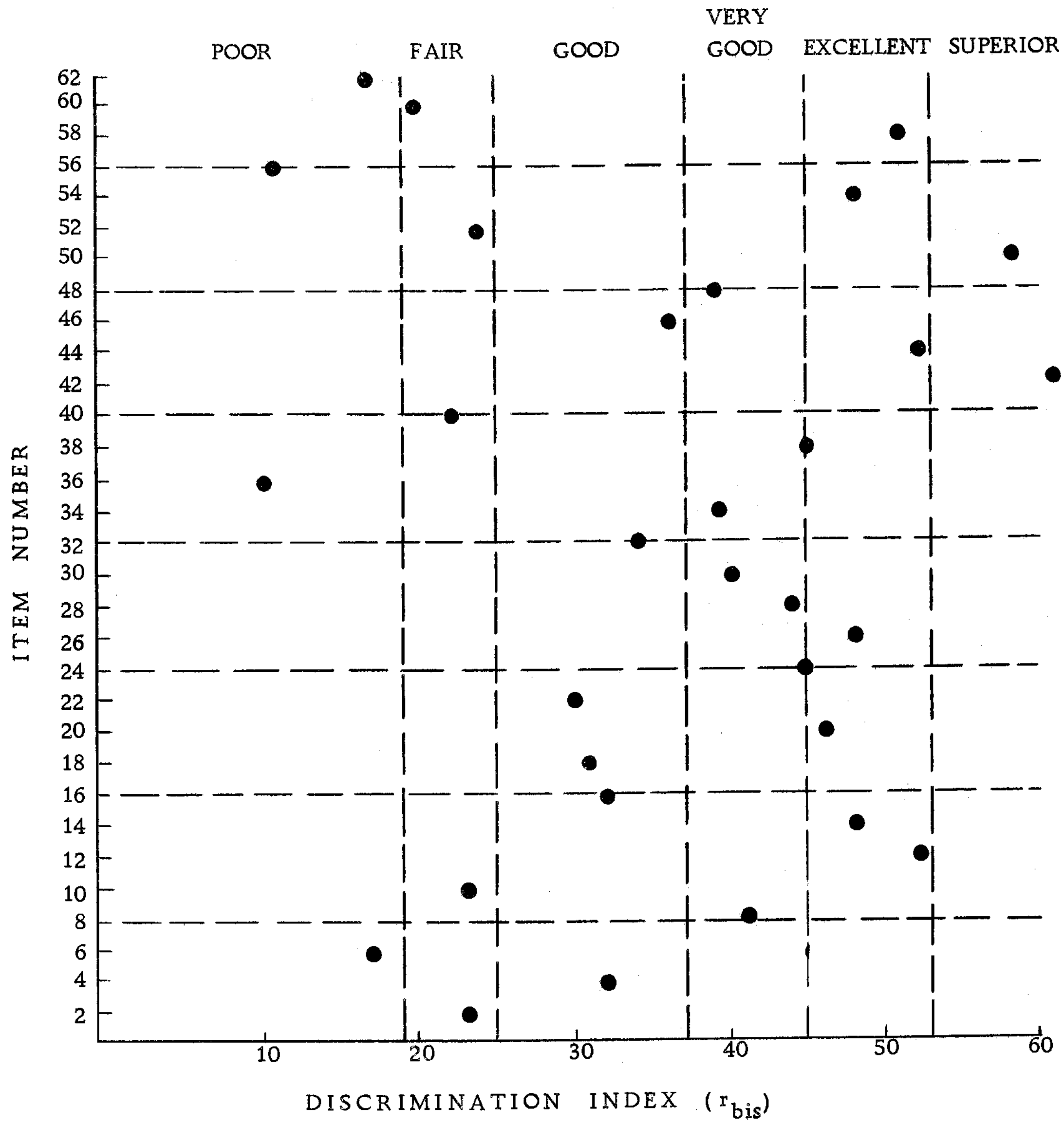



Figure 3. Discrimination power of the product items, 1963 Fall Edition, Portland Science Test.

probably mean that the Portland Science Test is yielding the kind of information about students which teachers are also looking for and teaching to when working with their students. The validity indices of the item analysis offer support to the point biserial validity coefficients. Both sets of data support the conclusion that the Portland Science Test is a reliable and valid testing instrument for evaluation and diagnoses of pupil progress in the field of science in the Portland Public Schools.

## Procedures Used in the Study

The Science Teachers' Adaptable Curriculum program was made available to elementary teachers in the fall of 1963. It was the intent of this investigation to appraise the effect of this program on the learning achievements of students. A measuring device was developed with the advice of and validated by the researcher for the purpose of measuring the acquired process skills and content knowledge of students.

The control year for this study was from September of 1962 until June of 1963. The experimental year extended from September of 1963 until June of 1964. Testing of the control group was done in November of 1963 and the experimental group was tested in November of 1964.

Selection of Population

A questionnaire was sent to every eighth grade teacher in the Portland Public Schools in November, 1963 to determine the approximate number using the STAC program (see Appendix IV). Forty eighth-grade teachers indicated at that time that they were using the materials. The decision to involve only eighth grade teachers was based on the fact that the materials were available to teachers of seventh and eighth grades and that all eighth grade students were subject to a city-wide testing program at the beginning of their ninth grade in which the Portland Science Test was used.

In May, 1964 the researcher observed classes and interviewed personally each of the 40 teachers who originally indicated that he was using the materials. Of these, eleven eighth grade teachers were identified as using the materials according to the prescribed directions given in the ground rules. However, long-term observation of these teachers in classroom practice was not achieved. This factor prompts the assumption that the materials were, in fact, used in the manner established in the ground rules and directions.

The class rolls of these eleven teachers were obtained from the schools involved for both the 1962-63 and 1963-64 school years. These groups of students thus formed the populations to be involved in the study. The control population of 261 students was with the eleven teachers during the 1962-63 school year when the STAC program was not being used. The experimental population of 254 students was with the same teachers during the 1963-64 school year when the STAC program was in use.

## Nature of the Population

The students in the population of the present study attended schools located in areas with concentrations of middle and lower socio-economic groups. Students from the upper socio-economic background were represented in fewer numbers than would be expected from random sampling.

The placement of the students in the various classes was carried out with no general concern for ability. The students in the control and experimental groups were drawn from the same population and there is no reason to believe the selection methods differed for the two groups involved.

The teachers appeared reasonably well-prepared to teach science if college hours are used as a criterion for judgment. The average for the eleven teachers was 34 quarter hours of undergraduate science with a range of 7 to 85. Four of the eleven had masters degrees in education; the remainder held B. S. degrees. All were experienced teachers. They had taught an average of 10.8 years with a range of 6 to 21. Attendance at summer school between the control and experimental years could have been a decisive factor in the results; a check of records revealed that none had attended a 1963 summer session (see Table VII, p. 105).

Science was offered to the students in a home-room setting. This environment was most conducive to achieving the conditions of the experiment. However, the home-room setting was used also with the control group so this condition should have a negligible effect on the results of the study.

## Collection and Treatment of Data

The control and experimental groups were tested under standard conditions along with all ninth graders in the city in November, 1963 and November, 1964 respectively. Means and standard deviations were calculated for the total ninth grade populations. The answer sheets for the control and experimental groups of the present study were then separated from those of the total populations. Means and standard deviations were determined for the control and experimental groups on a Monroe calculator independently by Mr. Peter Wolmut, Assistant Supervisor of Testing for the Portland Public Schools, and by the researcher. The results were confirming.

The raw score means and standard deviations were then converted to standard score values. This conversion required a linear transformation in which the equation for a straight line, $y = ax + b$, was used (18, p. 312). Locally, the standard scores are designated as "P" scores. The conversion formula for the transformation of raw mean to standard mean is

$$\overline{X}_P = A\overline{X}_R + B \qquad (1)$$

where

$\overline{X}_P$ = mean of the standard "P" scores

$\overline{X}_R$ = mean of the raw scores

A = $\sigma$ of the "P" scores (10) divided by the $\sigma$ of the raw scores

= $10/\sigma_R$

B = mean of "P" scores (50) minus the ratio of 10 times raw mean to raw $\sigma$

= $50 - (10\overline{X}_R/\sigma_R)$

Conversion to standard deviations of "P" scores is accomplished using the following formula:

$$\sigma_P = A \times \sigma_R \qquad (2)$$

The A and B values described above are derived on the basis of the total ninth grade population. Formulas (1) and (2) are then used for the conversion of specific data.

The significance of the difference between the means of the control and experimental groups was determined by application of the critical ratio. This comparison is accomplished using the following formulas:

$$CR = D/SE_D \qquad (3)$$

where

CR = critical ratio

D = obtained difference in the means of the control and the experimental groups

$SE_D$ = standard error of the difference between the means

$$= \sqrt{\frac{\sigma^2_1}{N_1} + \frac{\sigma^2_2}{N_2}} \qquad (4)$$

$\sigma^2_1$ = "P" score variance of the control group

$\sigma^2_2$ = "P" score variance of the experimental group

$N_1$ = number of students in the control group

$N_2$ = number of students in the experimental group

The critical ratio was applied to the differences obtained between process means, product means, and total means. The results of these calculations are reported in the next chapter.

## Summary

The materials and conditions of the present study have been examined in detail. The materials included the Keysort cards of the Science Teacher's Adaptable Curriculum and two editions of the Portland Science Test. The conditions described a procedure for provision of a learning environment which permits assimilation of the skills of scientific investigation and of knowledge of scientific concepts.

The Science Teachers' Adaptable Curriculum was treated in three parts. These three parts were origin, design, and applications of the program. Three aspects of the Portland Science Test were discussed in parts titled "Origin", "Design Criteria", and "Methods of Test Analysis." The philosophy and intent of the materials are contained in these discussions.

The last part of the chapter spelled out the procedures followed in the study. Methods used in the selection of the populations were described along with the nature of that population. The patterns used in the collection and treatment of the data were explained in detail.

# PRESENTATION AND INTERPRETATION OF THE FINDINGS

## Introduction

The experimental design of this study is of the "Post-test Only, Control Group" type described by Campbell and Stanley (8, p. 195). It is based on the law of the single variable and takes the following form:

$$\begin{array}{ccc} R & & 0_1 \\ R & X & 0_2 \end{array}$$

Eleven different classes ($R_1$, $R_2$, $R_3$, . . . $R_{11}$) were post-tested ($0_1$) after having experienced a normal curriculum program. Eleven new classes were post-tested ($0_2$) after having completed the experimental curriculum program (X) with the same teachers. The statistics presented in this chapter are the results of collecting data according to this experimental design. Included in this presentation are the raw scores derived from the testing, the converted standard scores, and the analyses of mean differences.

## Raw Score Data for Ninth Grades

The Portland Science Test was administered to students in two successive ninth grades of the Portland Public Schools (1963-64 and 1964-65). The presentation of the data obtained in the program will be discussed in terms of the individual years.

The Portland Science Test, 1963-64 Fall Edition, was given to all ninth graders in the Portland Public Schools in November, 1963. The results of this testing were machine-scored through the Testing Department. The raw scores were prepared for computer programming and the mean and standard deviation were calculated for the total scores. At a later time, it was recognized that means and standard deviations were needed for the process and product scores. The answer sheets for the total ninth grade population were randomly sampled by selecting every tenth sheet from that population. The means and standard deviations were calculated for the product score, the process score, and the total score. These results are reported in Table II. A test was performed to determine the difference between the mean and standard deviation of the total scores from the sample and the mean and standard deviation of the total scores extracted from the entire population. The difference was not significant.

Table II. Summary of Raw Score Data for All Ninth Graders

| | 1963-64 | | | 1964-65 | | |
|---|---|---|---|---|---|---|
| Category | Process | Product | Total | Process | Product | Total |
| Sample Number | 437 | 437 | 437 | 5392 | 5392 | 5070 |
| $\bar{X}_R$ | 17.6 | 18.1 | 35.7 | 16.4 | 17.3 | 33.9 |
| $\sigma_R$ | 5.16 | 5.20 | 9.78 | 4.62 | 5.33 | 9.37 |

The Portland Science Test, 1964-65 Edition, was administered to all ninth graders in the Portland Public Schools in November, 1964. The results of this testing were also machine-scored and means and standard deviations extracted by the Testing Department. These data are reported in Table II. It will be noted that the mean and standard deviation are based on a different sample number for the total than for process and product. These are the values reported out of the Testing Department and the difference has no effect on the statistics used in this study.

The raw score means and standard deviations were used to calculate the "P" score conversion factors, reported in Table III. In order for the test scores to be directly comparable, they must be converted to a standard scale. On such a scale, the mean for the population is 50 and the standard deviation is 10. The constants, A for standard deviation and B for mean, which accomplish this conversion are the values reported as "P" score conversion factors. These constants were used for converting the raw score means of the control and experimental groups to standard score means.

Table III. Conversion Factors and Formulas for Obtaining "P" Scores

| | 1963-64 | | | 1964-65 | | |
|---|---|---|---|---|---|---|
| Constants | Process | Product | Total | Process | Product | Total |
| A | 1.936 | 1.922 | 1.023 | 2.167 | 1.876 | 1.068 |
| $(A = \frac{10}{\sigma_R})$ | | | | | | |
| B | 16.0 | 15.2 | 13.5 | 14.4 | 17.5 | 13.8 |
| $(B = 50 - \frac{10\overline{X}_R}{\sigma_R})$ | | | | | | |

## Standard Score Data and Mean Differences

The data summarized in Table VI are the results of applying the "P" score conversion factors to the raw means and standard deviations contained in Tables IV and V. Formulas (1) and (2) on page 93 were used to accomplish the conversion.

Examination of the class means and standard deviations shows the amount of the total mean differences attributable to each class. The volume of mean gain or loss is shown graphically in Figure 4. It appears that a major contribution to the total mean loss can be traced to Group 4. The mean loss of this group appears disproportionate in all three instances, but especially in "Product" and "Total" mean loss.

Table IV. Summary of Raw Data for Control Group, 1963-64

| | | Process | | Product | | Total | |
|---|---|---|---|---|---|---|---|
| Group | N | Mean | S. D. | Mean | S. D. | Mean | S. D. |
| 1A | 27 | 19.6 | 4.67 | 19.6 | 4.35 | 39.2 | 8.36 |
| 2A | 20 | 18.1 | 5.27 | 19.4 | 4.95 | 37.5 | 9.52 |
| 3A | 22 | 18.9 | 5.15 | 17.2 | 6.57 | 36.1 | 11.14 |
| 4A | 26 | 18.8 | 3.70 | 20.4 | 3.49 | 39.2 | 6.47 |
| 5A | 39 | 17.6 | 4.71 | 17.6 | 4.82 | 35.2 | 8.86 |
| 6A | 26 | 17.9 | 5.02 | 17.6 | 4.64 | 35.5 | 8.76 |
| 7A | 19 | 18.8 | 4.48 | 19.3 | 5.81 | 38.2 | 9.99 |
| 8A | 9 | 16.7 | 5.96 | 17.0 | 4.85 | 33.7 | 9.91 |
| 9A | 25 | 18.1 | 6.34 | 18.7 | 4.29 | 36.8 | 9.84 |
| 10A | 26 | 16.1 | 4.80 | 16.3 | 4.92 | 32.4 | 8.98 |
| 11A | 22 | 16.2 | 5.52 | 16.2 | 5.83 | 32.4 | 10.76 |
| Total | 261 | 17.9 | 5.04 | 18.2 | 5.04 | 36.1 | 9.37 |

Table V. Summary of Raw Data for Experimental Group, 1964-65

| | | Process | | Product | | Total | |
|---|---|---|---|---|---|---|---|
| Group | N | Mean | S. D. | Mean | S. D. | Mean | S. D. |
| 1B | 25 | 16.6 | 4.66 | 17.3 | 5.09 | 33.9 | 9.24 |
| 2B | 26 | 16.4 | 5.02 | 16.8 | 6.69 | 33.2 | 10.93 |
| 3B | 23 | 15.3 | 5.24 | 15.7 | 5.88 | 31.1 | 10.73 |
| 4B | 22 | 14.6 | 4.32 | 15.5 | 4.81 | 30.1 | 8.33 |
| 5B | 20 | 17.0 | 3.73 | 16.9 | 5.17 | 33.9 | 8.49 |
| 6B | 20 | 18.0 | 2.56 | 19.2 | 3.33 | 37.2 | 5.31 |
| 7B | 20 | 18.6 | 3.56 | 19.4 | 4.55 | 38.0 | 7.64 |
| 8B | 24 | 15.1 | 5.73 | 15.0 | 6.77 | 30.1 | 12.23 |
| 9B | 23 | 15.8 | 4.97 | 16.3 | 5.80 | 32.2 | 10.20 |
| 10B | 28 | 15.8 | 4.46 | 17.2 | 5.44 | 33.0 | 9.15 |
| 11B | 23 | 15.3 | 4.88 | 13.9 | 3.95 | 29.1 | 8.32 |
| Total | 254 | 16.2 | 4.65 | 16.6 | 5.50 | 32.8 | 9.59 |

Table VI. Summary of "P" Score Means and Standard Deviations

| | 1963-64 Control | | | | | | 1964-65 Experimental | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Process | | Product | | Total | | Process | | Product | | Total | |
| Group | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| 1 | 53.9 | 9.04 | 52.9 | 8.36 | 53.6 | 8.55 | 50.4 | 10.10 | 50.0 | 9.55 | 50.0 | 9.87 |
| 2 | 51.0 | 10.20 | 52.5 | 9.51 | 51.9 | 9.74 | 49.9 | 10.88 | 49.0 | 12.55 | 49.3 | 11.67 |
| 3 | 52.6 | 9.97 | 48.3 | 12.63 | 50.4 | 11.40 | 47.6 | 11.36 | 47.0 | 11.03 | 47.0 | 11.46 |
| 4 | 52.4 | 7.16 | 54.4 | 6.71 | 53.6 | 6.62 | 46.0 | 9.36 | 46.6 | 9.02 | 45.9 | 8.90 |
| 5 | 50.1 | 9.12 | 49.0 | 9.26 | 49.5 | 9.06 | 51.2 | 8.08 | 49.2 | 9.70 | 50.0 | 9.07 |
| 6 | 50.7 | 9.72 | 49.0 | 8.92 | 49.8 | 8.96 | 53.4 | 5.55 | 53.5 | 6.25 | 53.5 | 5.67 |
| 7 | 52.4 | 8.67 | 52.3 | 11.17 | 52.6 | 10.22 | 54.7 | 7.71 | 53.9 | 8.54 | 54.4 | 8.16 |
| 8 | 48.3 | 11.54 | 47.9 | 9.32 | 48.0 | 10.14 | 47.1 | 12.42 | 45.6 | 12.70 | 45.9 | 13.06 |
| 9 | 51.0 | 12.27 | 51.1 | 8.25 | 51.1 | 10.07 | 48.6 | 10.77 | 48.1 | 10.88 | 48.2 | 10.89 |
| 10 | 47.2 | 9.29 | 46.5 | 9.46 | 46.6 | 9.19 | 48.6 | 9.66 | 49.8 | 10.21 | 49.0 | 9.77 |
| 11 | 47.4 | 10.69 | 46.3 | 11.21 | 46.6 | 11.01 | 47.6 | 10.57 | 43.6 | 7.41 | 44.9 | 8.89 |
| TOTAL | 50.7 | 9.76 | 50.2 | 9.69 | 50.4 | 9.59 | 49.5 | 10.08 | 48.6 | 10.32 | 48.8 | 10.24 |

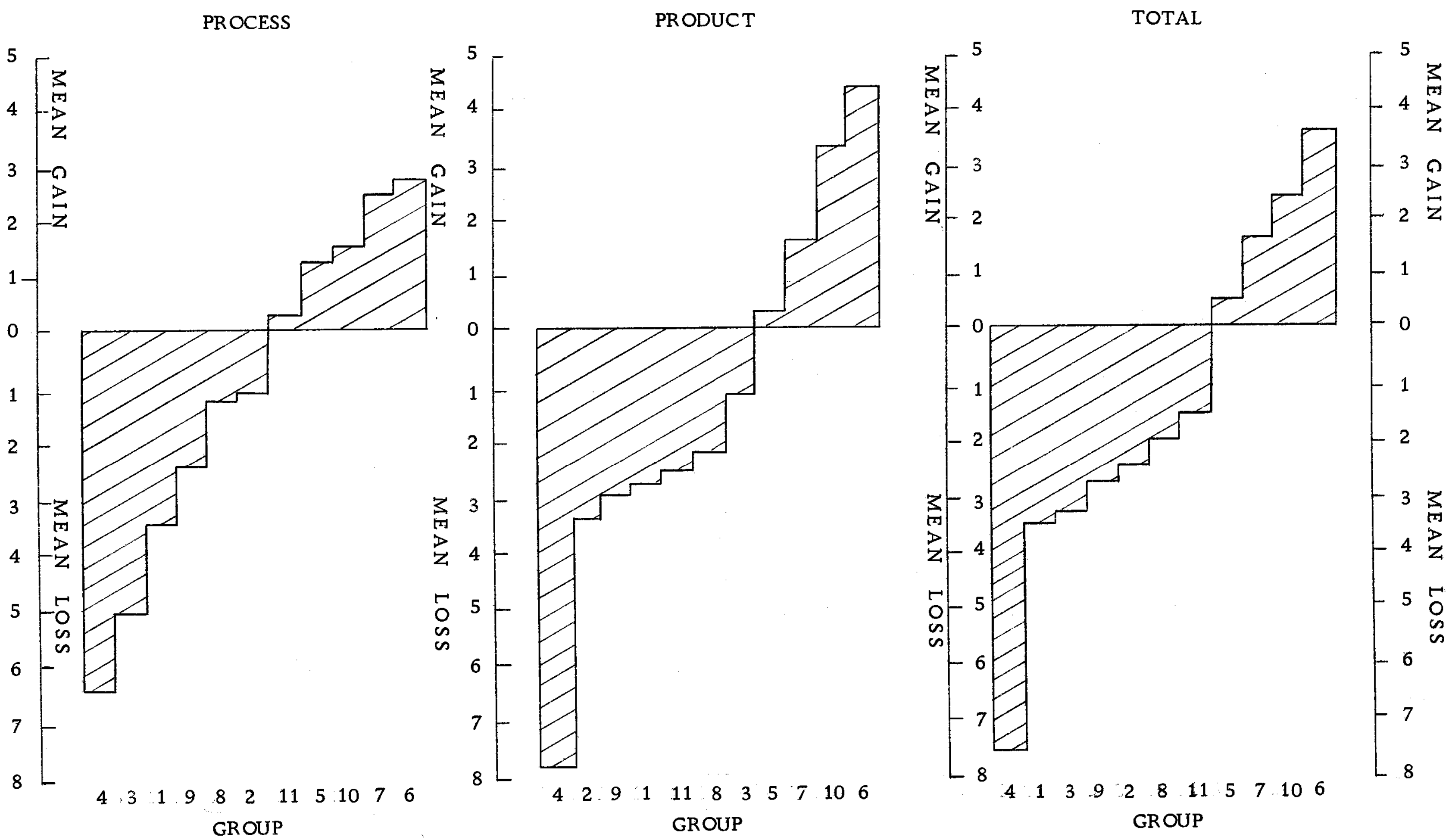



Figure 4. Individual "P" Score Mean Changes from One Year (1963-64) to the Next (1964-65).

A summary of teacher data is contained in Table VII. Nothing is revealed in this summary that would show cause for the extent of the mean loss of Group 4. However, information has come to the author since the close of the test year which indicates that the teacher of Group 4 was suffering from extreme mental strain during the experimental year of the study. This evidence prompts the hypothesis that the mean loss of Group 4 is due more to teacher influence than to the conditions of the study. This hypothesis has support in the fact that another group from the same school, containing a random assortment of students, showed a mean gain during the experimental year.

A comparison of the type of STAC training shown on Table VII with the mean changes pictured in Figure 4 is revealing. The teachers who attended the STAC in-service are predominant (four out of six) in the mean loss group while those receiving individual help appear predominantly (three out of five) in the mean gain group. This could be due mainly to student differences. It appears more likely that the difference is caused by provision of individual assistance in the new program and/or by the fact that two persons were working as a team.

Table VII. Summary of Teacher Data

| Teacher | Years Taught | Highest Degree and Year Awarded | Quarter Hours of Undergraduate Science | STAC Training | Summer School 1963 |
|---|---|---|---|---|---|
| 1 | 7 | MEd 1962 | 22.5 | In-service[1] | No |
| 2 | 12 | MEd 1964 | 85.0 | STAC Rep.[2] | No |
| 3 | 13 | BS 1951 | 51.0 | In-service | No |
| 4 | 7 | BS 1951 | 39.0 | In-service | No |
| 5 | 6 | BS 1942 | 35.0 | STAC Rep. | No |
| 6 | 11 | MS in Ed 1956 | 37.5 | STAC Rep. | No |
| 7 | 14 | BS 1950 | 27.0 | STAC Rep. | No |
| 8 | 16 | MEd 1949 | 7.5 | In-service | No |
| 9 | 4 | BS 1961 | 18.0 | STAC Rep. | No |
| 10 | 8 | BS 1957 | 18.0 | In-service | No |
| 11 | 21 | BS 1950 | 27.0 | In-service | No |

[1] Attended In-service course, spring, 1963
[2] Received help from STAC Representative

The critical ratio was used to test the significance of differences in the process, product, and total means. The results of these tests are summarized in Table VIII.

Table VIII. Results of Tests for Significance of Mean Differences

| Statistic | Process | Product | Total |
|---|---|---|---|
| D | 1.2 | 1.6 | 1.6 |
| $SE_D$ | 0.88 | 0.88 | 0.87 |
| CR | 1.36 | 1.82 | 1.84 |

In the description of the problem of this study, it was stated that the null hypotheses would be tested at the one percent level of confidence. These hypotheses were stated as follows:

1. The use of the automated science curriculum will have no effect on the science process learnings of eighth grade students.

2. The use of the automated science curriculum will have no effect on the science product learnings of eighth grade students.

3. The use of the automated science curriculum will have no effect on the total science learnings of eighth grade students.

Statistical significance at the one percent level means that the experimenter can feel confident that the observed difference would occur only one time out of 100 due to chance if the true difference were zero. Thus the null hypothesis is rejected if the critical ratio equals or exceeds 2.58. At the five percent level of confidence, the null hypothesis is rejected if the critical ratio equals or exceeds 1.96.

The critical ratios reported in Table VIII are all below the required 2.58 of the one percent level of confidence. Therefore none of the three null hypotheses listed above are rejected.

## Summary

Raw score means and standard deviations of total ninth grade populations have been presented and the methods used for equating the two groups described. The resulting conversion factors were reported. Raw score data for the control and experimental groups were tabulated and the results of applying the conversion factors to the raw score group means has been presented. The volume of mean gain or loss for individual groups has been pictured graphically and discussed. Teacher data regarding teaching experience, college training, and in-service attendance has been presented and discussed.

Critical ratios were computed on the differences of the total group process, product, and total means to test the null hypotheses. None of three null hypotheses were rejected at the one percent level of confidence.

# SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

## Summary

This study was designed to measure the effects, if any, of an automated science curriculum on the science learnings of eighth grade students. This curriculum involved the use of Keysort cards as a flexible teacher's handbook and included in the directions for use a teaching method which required the direct involvement of students in the scientific behaviors of investigation.

The study was initiated at a critical juncture in the changing science curriculum of the Portland Public Schools. The control students attended eighth grade during the year prior to the introduction of the automated curriculum. The experimental group attended eighth grade during the first year the automated curriculum was used and the only year that was uncomplicated by previous student experiences with the program. Thus, an evaluation has been possible of the impact of a new program on 254 pupils in 11 classes.

The populations of students included in the study were selected because they attended the classes of eleven specifically-identified teachers. These teachers were selected from approximately 200 eighth grade teachers as the only ones using the automated curriculum in a manner appropriate to its design. During the control year when these eleven teachers were pursuing a science program of their own design, a total of 261 students were involved. The experimental year, when these same eleven teachers were using the automated materials, produced 254 students for evaluation. The students were programmed into these classes with no special attention to ability, thus providing heterogeneous grouping.

Two aspects of the student learnings were measured. The control group was tested with the Portland Science Test, 1963-64 Fall Edition, which evaluated science process skills and science concept development. These process skills included those of "problem recognition", "hypothesis choosing", and "experiment choosing". The concepts included a general representation from the various disciplines of science.

The learnings of the experimental group which were evaluated were the same process skills and science concepts as those for the control group. The test used during the second year was a revised form of that used the first year and titled Portland Science Test, 1964-65 Edition. The reliability and validity of both editions of the test were determined in the usual manner and were found to be satisfactory for the purposes of this study.

The results of the testing for both years were collected and raw score means and standard deviations were calculated. These data were normed on the total ninth grade populations for both years.

The significance of the difference between the process, product, and total means of the control and experimental groups was tested by finding the critical ratio.

As a result of the analyses of the test results, and within the limitations of the study, the following results can be reported:

1. The use of the automated science curriculum did not make a measurable difference in the science process learnings of eighth grade students.

2. The use of the automated science curriculum did not make a measurable difference in the science product learnings of eighth grade students.

3. The use of the automated science curriculum did not make a measurable difference in the total science learnings of eighth grade students.

The statement of the first result indicates that the students acquired skill equally during the two years for using the scientific behaviors of investigation. Both groups had similar facility for selecting appropriate hypotheses and experiments and were able to recognize the existence of the problem involved.

The second result indicates that the students of both the control and experimental groups acquired similar understanding of the science concepts included in the test. The use of the automated materials apparently offered neither detriment nor advantage to the students during the experimental year.

The third reported result is an indication of the over-all effects of the use of the automated materials. It is an outgrowth of the evaluation of mean differences between total scores achieved by the groups of students. This result clearly shows that the use of the automated materials had no significant over-all effect on the learning achievements of the students in the experimental group.

## Conclusions

The major contribution of the present study relates directly to the issue of a static versus an evolutionary curriculum base. Notable evidence is presented which supports the use of carefully considered experimental programs without harming the future of children. No gains were achieved by the experimental group over the control group but, of even greater consequence, no mean loss was suffered by the experimental group. A program which can produce these results the first year holds promise for better results in the future as improvements are made and as teachers become familiar with its design. It is possible, then, to incorporate an evolutionary curriculum base into an educational system and retain a high-quality learning program.

The success of any new curriculum program is dependent on many factors. Some of these factors are familiarity with the goals of the program, adequate time to develop the learning activities and adapt them to the individual classroom setting, availability of the necessary supplies, equipment, and reading materials, and personal enthusiasm for achieving success with the program. These factors will be examined more closely in the following paragraphs.

The goals of the STAC program were spelled out in detail on the cards. These were discussed at length in the in-service class. Presumably, the topic was discussed in those situations where the teacher received assistance from the STAC representative. At least, no relationship appeared between the type of STAC training received and the achievement of the individual groups to indicate less understanding on the part of those who did not attend the in-service class. In fact, the trend is just the opposite. The conclusion could be stated that the goals were understood by all teachers involved, and put into practice most effectively by those who were receiving individual help.

Characteristically, teachers are subjected to a pressure which is unrelenting. This is particularly true of the elementary teacher who finds himself in the self-contained classroom. The responsibility for the major portion of the instructional program demands a special sort of resourcefulness. All those involved in this study were experienced with this classroom pattern. However, the necessary time to implement a new program adequately may not have been available. Therefore, adequate developmental time each day for those attempting to implement the program must be assured in order to achieve improved results with the automated curriculum.

The pattern used for obtaining a variety of reading materials has been described in detail. In addition to this availability, the study teachers were provided with reading materials specially allotted for the STAC program. The resource was adequate. The provision of the necessary equipment and supplies is another matter. Much of the science materials used in elementary schools are the results of the ingenuity and resourcefulness of the teacher. Ordinarily, varieties of standard science supplies and equipment are not available. This was the case with the teachers in the present study. Thus, another factor for effecting improved results could be the improvement of accessibility of science supplies.

A most important factor to the success of a trial run of an experimental program is the personal involvement and enthusiasm of those conducting the pilot program. Indeed, the initial measured success of many experimental programs may lie chiefly in this one factor. This has been described as the "Halo" or "Hawthorne" effect. In order for this effect to display itself, the study participants must be aware that an experiment is being carried out. They take pride in having been picked to participate and recognize that their selection implies an ability not present in those excluded from the project. This implication produces an "I won't-let-them-down" attitude and obviously has a favorable effect on the results of the experiment. None of the study teachers knew of the existence of this study nor of his involvement in it. The conclusion can be stated that the "Hawthorne effect" is not a limitation of this study, since no reason for its existence could be detected.

## Recommendations

The success of a study of this kind is dependent in large measure on the kind and amount of useful knowledge produced. That knowledge is useful if it provides an indication of the present status of a program, and if it yields data which point to productive directions for future action. The preceding sections summarized the findings and presented the conclusions regarding the present status of the STAC program. This section will be devoted to the recommendations for further research which have been suggested by the results of the present study.

On the basis of the findings presented in this study the investigator recommends that:

1. a longitudinal evaluation program be initiated:
    a. to compare the science process and product learnings of students who were with the same teachers in succeeding years with the original control students.

b. which includes the establishment of separate experimental groups:

   1) one of which is closely regulated in terms of the availability of science supplies to determine the effect of this variable.

   2) another of which includes a given amount of time set aside each day for the teacher to use for planning the use of the automated curriculum.

   3) and yet another of which provides for individual assistance from experienced consultants.

2. the evaluation instrument be broadened to include a wider variety of process skills than those included in the Portland Science Test.

3. continued experimentation with the automated curriculum include the specification of desired behavioral or process skills with each activity. These skills should be stated in the form of action objectives and be the same as those evaluated by the Portland Science Test.

4. a study be considered with pre-service teacher-education programs to determine:

   a. the appropriateness of providing curricula at the college level which offers students direct experiences in the scientific behavioral processes.

b. the relationship of such programs to successful teaching in a school system which emphasizes heuristic discovery as the basic student experience.

In summary, the use of the Keysort card for rapid retrieval of curriculum ideas was one of the prime features of the present study. The dynamics are present for this project to evolve into a computerized storage and retrieval system. Several steps have already been taken and others can be proposed which will hasten this evolution.

The feasibility and efficiency of feedback committees have already been demonstrated. New and improved materials for the project have been screened by the committees and improved card programs have been recommended. College specialists have provided valuable consultant services in the review of the accuracy of the content. A man who specializes in programming computers has been hired and is studying ways to streamline the curriculum in preparation for data processing.

Undoubtedly, the single most significant progress has been achieved by a committee of teachers of elementary and high school science. This committee operates under the joint aegis of the Portland Public Schools and the Louis W. and Maud Hill Foundation. It carries the banner of "Cybernetics Committee" and has directed its efforts toward the application of computer techniques to the problems of curriculum. Preparations have been completed to establish a pilot program in an entire elementary school (K-4) in September, 1966.

The results of the present study are a clear indication that methods of rapid retrieval can be used in a manner as efficient as was possible with prior techniques. Moreover, these results were achieved during the first year of trial. The recommendation is in order, therefore, that efforts be continued in the directions now being explored. Through these efforts, teachers will surely be freed of the unhuman chores connected with teaching and become truly professional. Equally important, the individualized curriculum about which Foshay speaks, can become a reality. Thus the individual will be freed for the art of full living in balance with his environment.

# BIBLIOGRAPHY

1. Atkin, J. Myron. A study of formulating and suggesting tests for hypotheses in elementary school science learning experiences. Science Education 42:414-422. 1958.

2. Barrilleaux, Louis E. A comparison of textbooks and multiple library references - a report on the initial phases of an experimental study. School Science and Mathematics 63:245-249. 1963.

3. Bemis, Hazel T. Punched card system needn't be complex to give complete control. College and University Business 37:38-40. Aug. 1964.

4. Betts, Emmett Albert. Foundations of reading instruction with emphasis on differentiated guidance. New York, American Book, 1946. 759 p.

5. Blough, Glenn O. Developing science programs in the elementary school. In: Rethinking science education: The fifty-ninth yearbook of the National Society for the Study of Education, Part I. Chicago, 1960. p. 112-135.

6. Blough, Glenn O. Teaching and evaluating science in the elementary school. In: Rethinking science education: The fifty-ninth yearbook of the National Society for the Study of Education, Part I. Chicago, 1960. p. 136-151.

7. Bruner, Jerome S. The process of education. Cambridge, Harvard University Press, 1961. 97 p.

8. Campbell, Donald T. and Julian C. Stanley. Experimental and quasi-experimental designs for research on teaching. In: Handbook of research on teaching, ed. by N. L. Gage. Chicago, Rand McNally, 1963. p. 171-246.

9. Casey, Robert S., et al. (eds.) Punched cards: their applications to science and industry. 2d ed. New York, Reinhold, 1958. 697 p.

10. Craig, Gerald S. The program of science in the elementary school. In: A program for teaching science: The thirty-first yearbook of the National Society for the Study of Education, Part I. Chicago, 1932. p. 133-162.

11. Curtis, Francis D. Some contributions of educational research to the solution of teaching problems in the science classroom. In: A program for teaching science: The thirty-first yearbook of the National Society for the Study of Education, Part I. Chicago, 1932. p. 77-90.

12. Dameron, J. D. A study of the science achievement test scores of eighth-grade pupils in selected junior high schools. Ph. D. thesis. Lawrence, University of Kansas, 1959. (Abstracted in Dissertation Abstracts 20:2639-2640. Jan. 1960).

13. de Caprariis, Hugo V. and Joseph R. Minahan. We stopped giving our narcotics away. American Journal of Hospital Pharmacy 21:366-371. 1964.

14. Duckworth, Eleanor. Piaget rediscovered. Journal of Research in Science Teaching 2:172-175. 1964.

15. Dunfee, Maxine and Julian Greenlee. Elementary school science: research, theory and practice. Washington, D. C., Association for Supervision and Curriculum Development, 1957. 67 p.

16. Foshay, Arthur W. Come join our individuality. Educational Leadership 20:45-55. Oct. 1962.

17. Fryback, William H. Evaluation of multi-level reading materials, intra-class discussion techniques and student experimentations on achievement in fifth grade elementary science. Ph. D. thesis. Corvallis, Oregon State University, 1965. 114 numb. leaves. (Microfilm)

18. Garrett, Henry E. Statistics in psychology and education. New York, Longmans, Green and Co., 1958. 478 p.

19. Gibb, E. Glenadine and Dorothy C. Matala. Study on the use of special teachers of science and mathematics in grades 5 and 6. School Science and Mathematics 62:565-585. 1962.

20. Green, John W. The uses of punched cards in the teaching of qualitative organic analysis. Journal of Chemical Education 28:638-640. 1951.

21. Hamilton, Norman K. et al. A current issue in education - new theories of learning and instruction. In: School Bulletin. Portland, Oregon Public Schools, March 1964, p. 2-6.

22. Heathers, Glen. A process-centered elementary science sequence. Science Education 45:201-206. 1961.

23. Henderson, Kenneth B. Research on teaching secondary school mathematics. In: Handbook of research on teaching, ed. by N. L. Gage. Chicago, Rand McNally, 1963. p. 1007-1030.

24. Herbert, John J. Class scheduling and grade reporting aided by marginally punched card system. The Bulletin of the National Association of Secondary School Principals 47:129-137. Feb. 1963.

25. Hoffmaster, Edmund S., James W. Latham, Jr., and Elizabeth D. Wilson. Design for science. The Science Teacher 31:15-17. Nov. 1964.

26. Hubbell, Lawrence. An investigation in the use of the filmstrip method, the pupil activity method, and the textbook method in presenting science concepts to eighth grade pupils (1957). The Bulletin of the National Association of Secondary School Principals 46:140-141. Feb. 1962.

27. Hurd, Paul DeH. Science education for changing times. In: Re-thinking science education: The fifty-ninth yearbook of the National Society for the Study of Education, Part I. Chicago, 1960. p. 18-38.

28. Kessen, W. and Paul B. Sears. Statement of purposes and objectives of science education in school. Journal of Research in Science Teaching 2:3-6. 1964.

29. Kitzhaber, Albert R., Robert M. Gorrell, and Paul Roberts. Education for college: improving the high school curriculum. New York, Ronald Press, 1961. 195 p.

30. Livermore, Arthur H. The process approach of the AAAS Commission on Science Education. Journal of Research in Science Teaching 2:271-282. 1964.

31. Lockard, J. David. The secondary school curriculum projects. The Science Teacher 32:48-49. May 1965.

32. Long, Frank. How improved grade reporting can help your district. School Management 7:104-108. Mar. 1963.

33. Lundstrom, Donald and Lawrence Lowery. Process patterns and structural themes in science. The Science Teacher 31:16-19. Sept. 1964.

34. Mallinson, J. V. The current status of elementary science. School Science and Mathematics 61:252-270. 1961.

35. Maw, Wallace H. and Ethel W. Maw. Information recognition by children with high and low curiosity. Educational Research Bulletin 40:197-201. 1961.

36. New York State Education Department, Division of Elementary Education, Bureau of Curriculum Development. Improving instruction in elementary school science - a guide for study groups. New York, The University of the State of New York, 1949. 48 p.

37. Olsen, James. The coming revolution in textbooks. AV Communication Review 12:337-343. Fall 1964.

38. Parker, Don H. Schooling for individual excellence. New York, Thomas Nelson and Sons, 1963. 285 p.

39. Parker, Don H. Teacher's handbook, SRA reading laboratories, elementary edition. Chicago, Science Research Associates, 1958. 70 p.

40. Parker, Don H. and Donald W. Stotler. Teacher's handbook, learnings in science II. Chicago, Science Research Associates, 1963. 24 p.

41. Pella, Milton O. Some problems in science education. Journal of Research in Science Teaching 3:90-92. 1965.

42. Piaget, Jean. Development and learning. Journal of Research in Science Teaching 2:176-186. 1964.

43. Piltz, Albert. Review of science textbooks currently used in elementary schools. School Science and Mathematics 61:368-380. 1961.

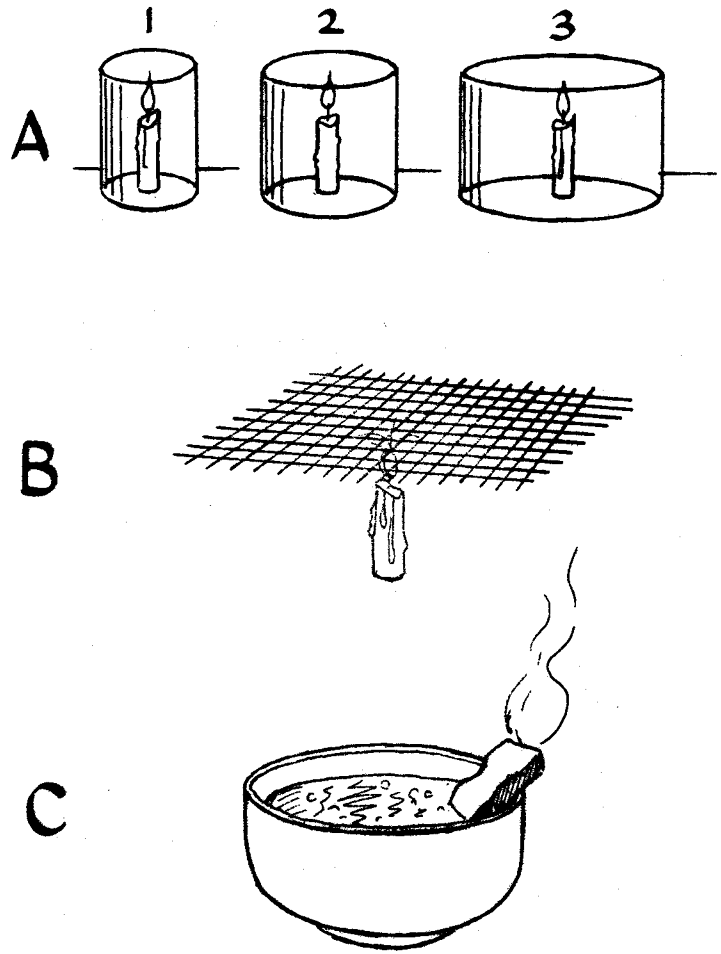



FIGURE I

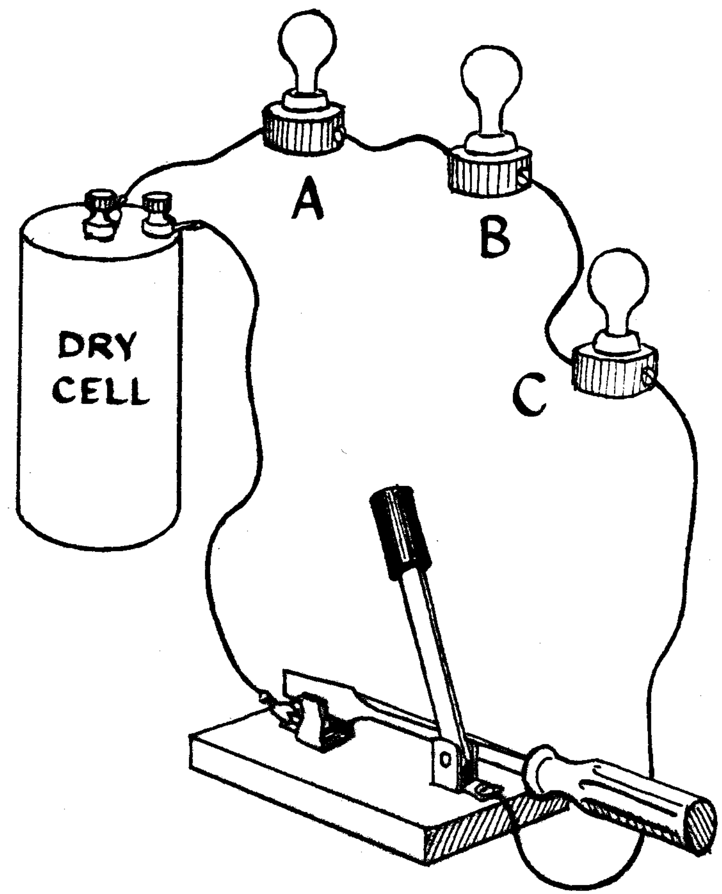



FIGURE II

FIGURE I

| HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT) |
|---|---|

1. The candles in (A) of Figure I will go out:

   A. at the same time
   B. 1, 2, 3
   C. 2, 1, 3
   D. 3, 2, 1
   E. 3, 1, 2

2. The flame of a candle will burn most brightly in:

   A. carbon dioxide
   B. nitrogen
   C. oxygen
   D. air
   E. chlorine

3. The copper screen (B) prevents the flame from going through it because:

   A. air pressure changes above and below the screen
   B. the holes in the screen are too small
   C. there is too little oxygen above the screen
   D. copper absorbs heat too rapidly
   E. the flame is too weak

4. The energy used in the candles above came originally from the:

   A. earth's gravitational force
   B. earth
   C. oceans
   D. sun
   E. sky

5. A piece of clay flower pot could be used as a wick for the oil lamp (C) of Figure I because it:

   A. doesn't burn
   B. will let oil pass through it
   C. helps oil burn
   D. glows when heated
   E. is hard

6. When a candle flame is blown out, the smoke is mostly:

   A. carbon
   B. air
   C. water
   D. hydrogen
   E. dirt

---

FIGURE II

7. In Figure II the screwdriver is being used:

   A. as a tool
   B. as a switch
   C. to increase the electricity
   D. to decrease the electricity
   E. as a fuse

8. When there is a complete circuit, the electricity is:

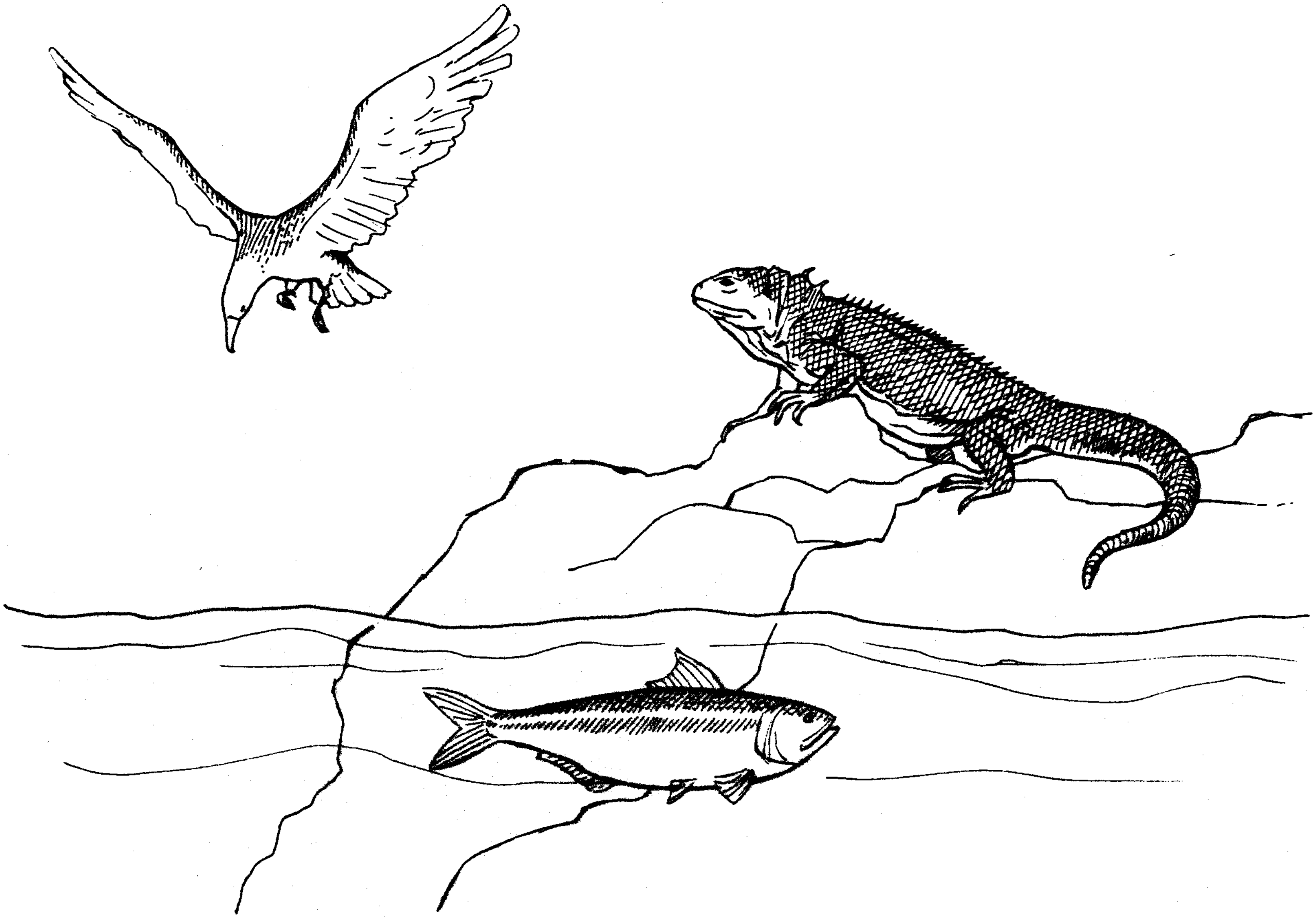
   A. used up
   B. flowing
   C. always coming from a battery
   D. less dangerous
   E. condensing

9. If you unscrew and take out light bulb (B)

   A. bulb (A) will remain lit
   B. bulb (C) will remain lit
   C. bulbs (A) and (C) will go out
   D. bulbs (A) and (C) will get brighter
   E. none of the above is correct

10. Household current is usually:

   A. 110 and 220 volts
   B. 300 and 400 volts
   C. 75 and 100 volts
   D. 75 and 150 volts
   E. 15 and 25 volts



| HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT) |
|---|---|

11. Iguanas move slowly. They appear rather stupid and yet they are still alive on this island. This is probably because they:

    A. were created on this island
    B. have few natural enemies on the island
    C. are healthy
    D. like to live on this island
    E. taste bad to other animals

12. The use of color, shading, or pattern for protection is called:

    A. striping
    B. control
    C. camouflage
    D. dark and light
    E. matching

13. The shading on the fish above probably means that:

    A. enemies follow it
    B. enemies live above and below it
    C. enemies attack from the front
    D. it has no enemies
    E. fish like different colors

14. The space around these animals is called their:

    A. life space
    B. area
    C. environment
    D. evolution
    E. world

15. This bird was accidentally sprayed with red paint. This is dangerous for him because:

    A. he doesn't like the odor
    B. his enemies can see him easily
    C. the paint got on his nest
    D. insects won't go near him
    E. the other birds will fight him

16. An animal that can change its color to match its background is the:

    A. dog
    B. mouse
    C. bat
    D. chameleon
    E. rattlesnake

17. Many fish and birds are darker on top than underneath. This is probably because:

    A. they live in the same area
    B. birds fly and fish swim
    C. the sun tans them on top
    D. they are better protected that way
    E. they look better like that

18. When an animal changed color, pattern or shading over many years the process is called:

    A. adoption
    B. adaptation
    C. adhering
    D. absorption
    E. abrasion

19. Iguanas are green in color. One family began to develop white spots. This is dangerous for them because:

    A. they can be easily seen by their enemies
    B. it shows that they are sick
    C. white spots are ugly
    D. they are prettier than the rest of the iguanas
    E. they will look different

20. Animals change through the years. These changes are the result of:

    A. assimilation
    B. isolation
    C. revolution
    D. evolution
    E. time

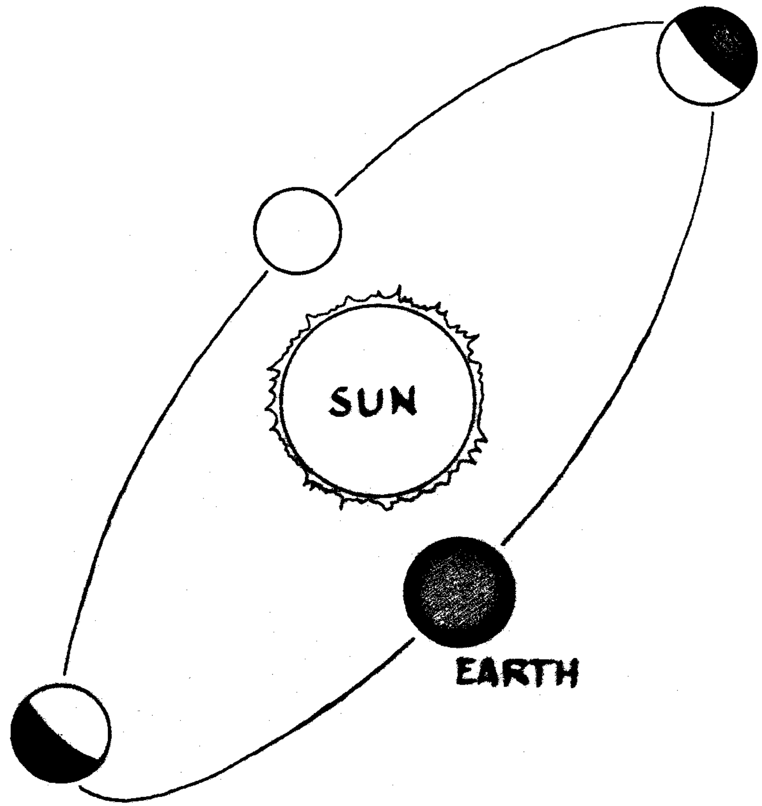



FIGURE I

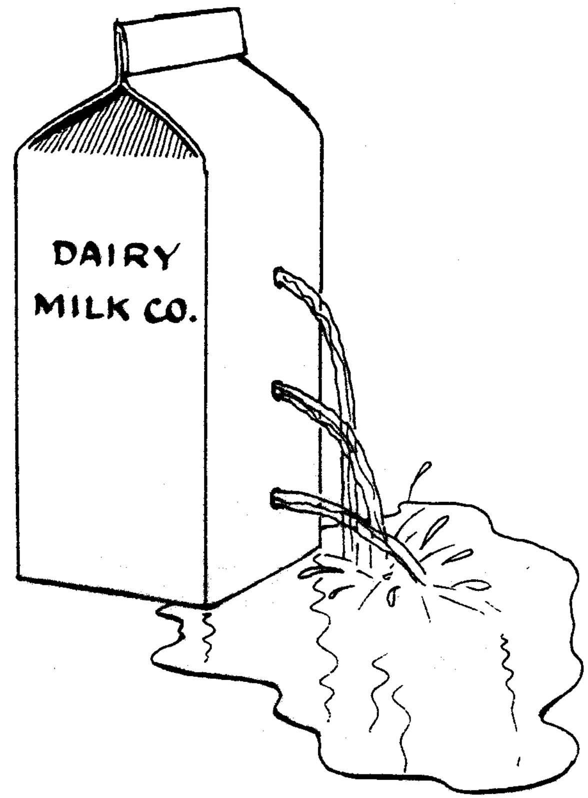



FIGURE II

FIGURE I

| HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT) |
|---|---|

21. A scientist wants to know what the sun is made of. He may learn most about it by studying the sun's:

   A. movements
   B. light
   C. size
   D. heat
   E. distance

22. The sun is made of:

   A. gases
   B. solids
   C. liquids
   D. stones
   E. galaxies

23. Day and night are the result of the fact that the earth:

   A. is solid
   B. is round
   C. moves in space
   D. spins
   E. has a magnetic field

24. A light year measures:

   A. light
   B. heat
   C. distance
   D. infinity
   E. time

---

FIGURE II

25. To make all three streams shoot out the same distance you might:

   A. make all the holes larger
   B. turn the container upside down
   C. place the container in a tub of water
   D. turn the container on its side
   E. shake the container

26. At room temperature water is:

   A. level
   B. liquid
   C. soft
   D. solid
   E. smooth

27. The reason for the hole at the top of the carton is to allow:

   A. you to see the water
   B. air to enter the carton
   C. water to get into the carton
   D. light into the carton
   E. the carton to be emptied rapidly

28. One way to clean water is to use the process of:

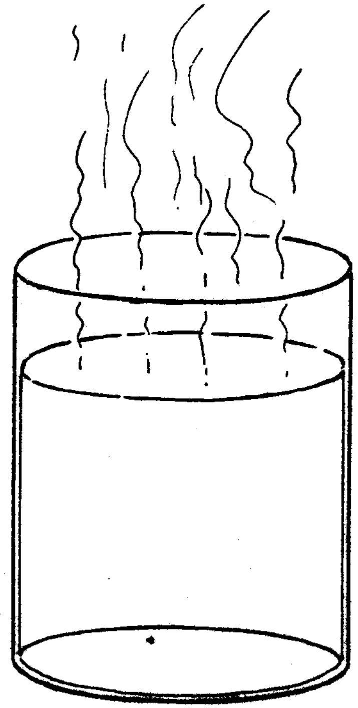
   A. distillation
   B. contraction
   C. expansion
   D. electrification
   E. conflagration

29. The demonstration in Figure II shows that:

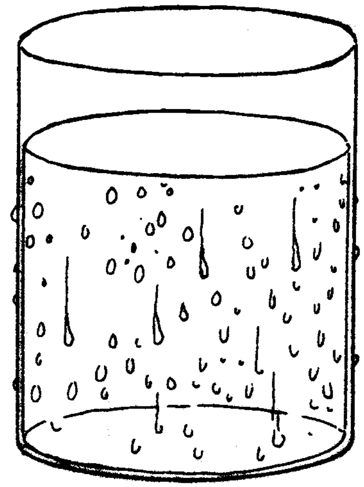
   A. water moves at different speeds
   B. the greater the depth the greater the pressure
   C. water leaks out the holes in the milk carton
   D. water is liquid
   E. air pressure causes the water to shoot out as it does

30. Water is made of:

   A. carbon and acids
   B. nitrogen and oxygen
   C. hydrogen and oxygen
   D. oxygen and carbon dioxide
   E. carbon dioxide and hydrogen



HOT WATER
A



COLD WATER
B

HOW WE FIND OUT
(PROCESS)

31. Molecules in jars (A) and (B) move at different speeds. The best way to compare these speeds would be to:

A. place a drop of ink in each jar
B. place your finger in each jar
C. weigh each jar of water
D. place the jars in a strong light
E. float a cork in each jar

33. If you wanted to find out if more salt would dissolve in hot water than in cold water, a good experiment would be to:

A. put salt in glasses of hot water
B. stir salt into hot and cold water
C. put more salt in a glass of cold water than a glass of hot water
D. compare the amounts of salt that could be dissolved in jar (A) and jar (B)
E. add salt to jar (B) and cool it

35. Drops of water appeared on the outside of jar (B). In order to find out whether this water leaked through the jar you could:

A. cover the jar tightly
B. check some of the drops of water under a microscope
C. feel the inside and outside of the jar with your finger
D. add coloring to the jar and place it in a tub of clear water
E. check the air in the room for water content

WHAT IS KNOWN
(PRODUCT)

32. If the cold water were to freeze, the jar might break because water:

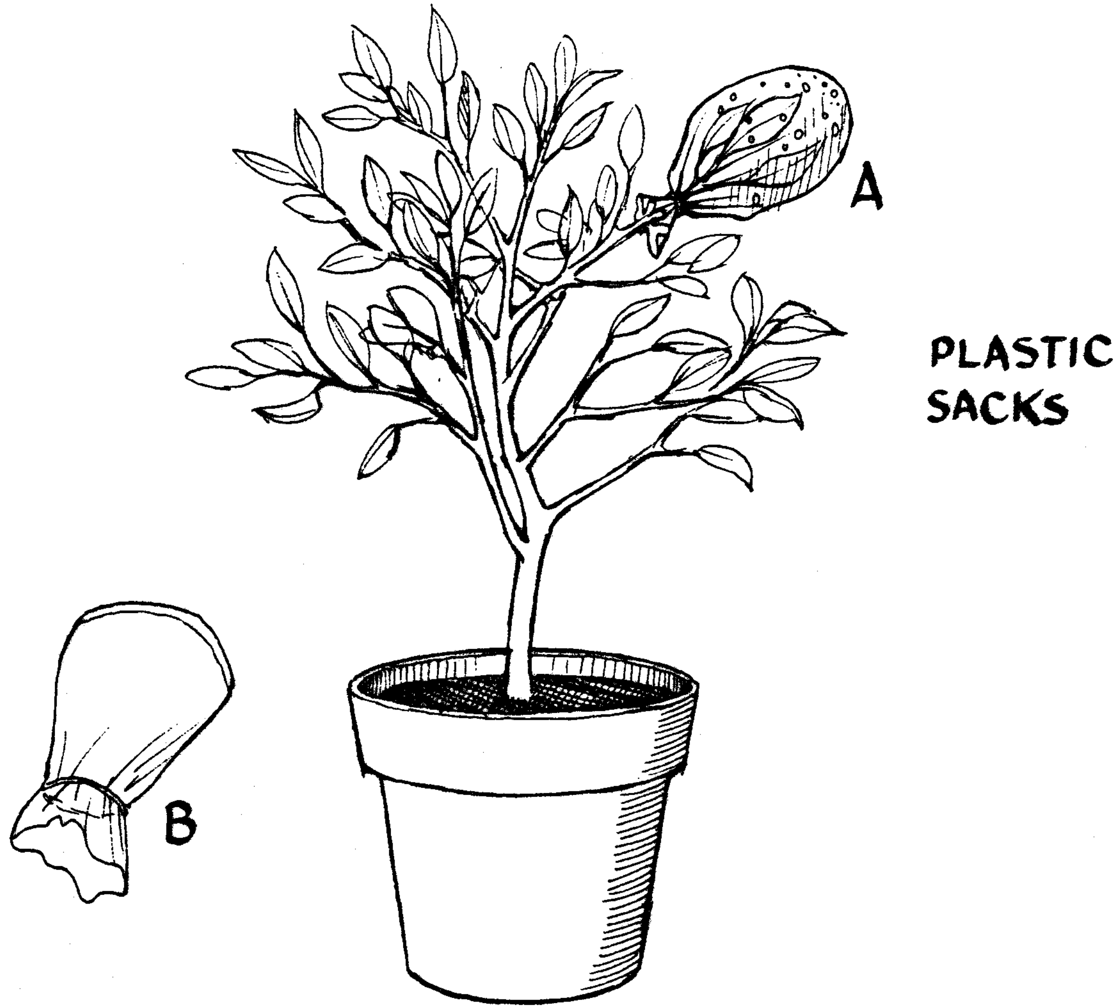
A. expands when heated
B. contracts when cooled
C. expands when it changes to ice
D. breaks the glass when it is cooled
E. becomes heavier when cooled

34. Water freezes at $32^{o}$F. If you dissolved as much salt as possible in a jar of hot water and then cooled the water to $34^{o}$F. :

A. salt would appear in the jar
B. the water would freeze
C. salt would float on top of the water
D. the water would taste saltier
E. the water would turn white

36. Dew forms on grass because:

A. the grass is cooler than the air around it
B. the water in the air turns to liquid when cooled
C. molecules of water move closer together when cooled
D. the temperature of the air is higher than the temperature of the grass
E. all of the above


A
PLASTIC
SACKS
B

HOW WE FIND OUT (PROCESS)

37. Plastic sack (A) has drops of what in it? (B) has none. This difference is probably due to moisture--?

A. from the plastic
B. from the air
C. moving from outside to inside the sack
D. from the leaves
E. from the plant stems

39. The best experiment to show that a plant receives water from the soil would be to:

A. add colored water to the soil
B. put colored water on the leaves
C. check the amount of water in the leaves
D. weigh the water in the soil
E. crush the plant and measure the moisture

41. The best way to measure the amount of water given off by the plant is to:

A. feel the leaves
B. weigh the soil after watering
C. weigh the soil before watering
D. weigh the water added in watering
E. collect the water evaporated from each plant

WHAT IS KNOWN (PRODUCT)

38. Water vapor becomes liquid when it is:

A. darkened
B. lighted
C. cooled
D. heated
E. vaporized

40. What is shown in the demonstration above?

A. osmosis
B. transpiration
C. chlorophyll
D. respiration
E. exasperation

42. Water in a plant moves:

A. from leaf, to stem, to roots
B. from roots, to stem, to leaf
C. through leaves only
D. through roots only
E. through stem only

HOW WE FIND OUT
(PROCESS)

WHAT IS KNOWN
(PRODUCT)

43. A basic difference between plants and animals is that:

A. animals breathe and plants don't
B. plants die sooner than animals
C. plants sway back and forth
D. animals move about more
E. plants are larger than animals

44. Living things may best be divided into:

A. animals, insects, fish
B. animals and plants
C. men, insects, birds, fish
D. old things and new things
E. large and small plants and animals

45. In an experiment the squirrel was kept in a cold room for a week. The scientist was probably trying to check:

A. the body temperature of the squirrel
B. the hunger of the squirrel when cold
C. whether the squirrel's fur was enough to keep him warm
D. how much he moved when cold
E. all of the above

46. All plant and animal life began with:

A. simple cells
B. the earth
C. ancient floods
D. volcanoes
E. dust

47. Green plants were placed in a dark room. They died because:

A. they couldn't breathe
B. they couldn't find food
C. the soil became spoiled
D. light couldn't get to them
E. they were not used to the dark

48. Chlorophyll in plants helps them to:

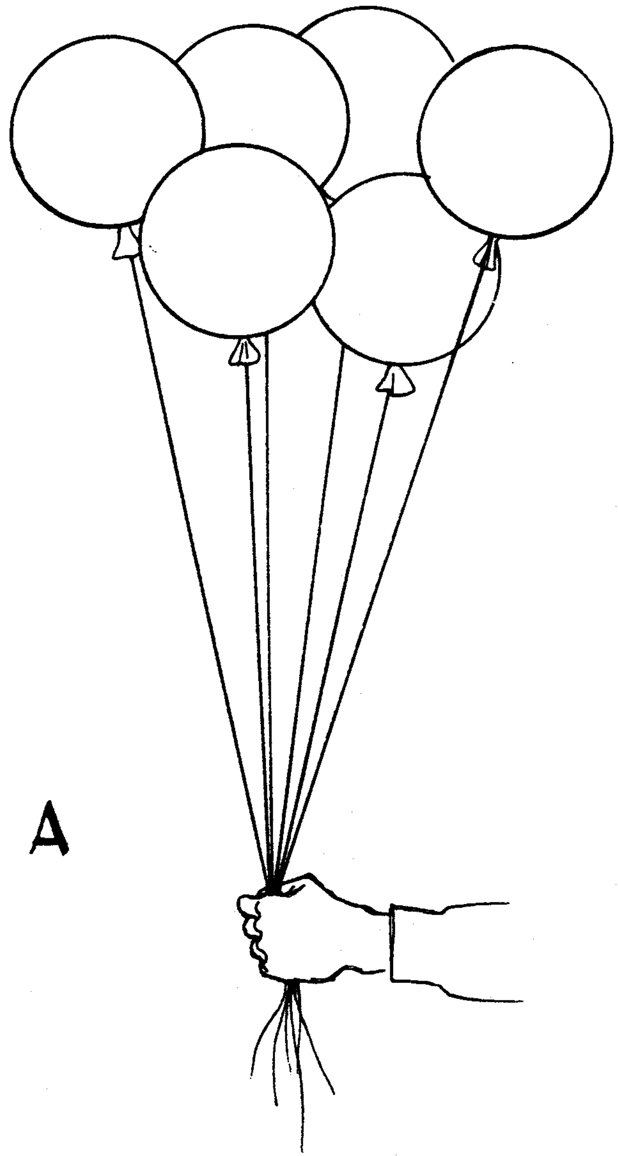
A. make food
B. breathe
C. hold water
D. produce seeds
E. move about

49. A boy cut a ring through the bark around the trunk of a tree. In five years the tree was dead. From this we can tell that:

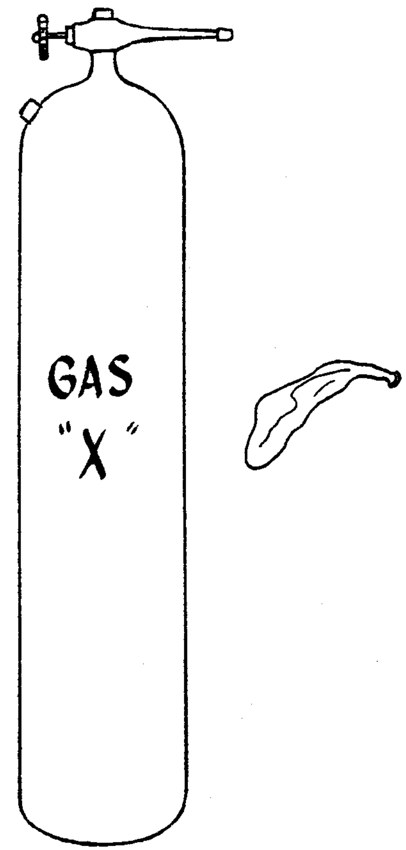
A. the bark didn't get enough light
B. the bark got hurt
C. the bark carried food
D. the sap leaked out
E. the bark died

50. An animal scientist (zoologist) divided animals into groups by studying their:

A. shape
B. color
C. size
D. structure
E. speed



A




B

HOW WE FIND OUT
(PROCESS)

51. You fill the balloon (B) with gas "X". The balloon rises. This shows that gas "X":

A. is lighter than air
B. contracts when released from the tank
C. is heavier than air
D. expands rapidly when released from the tank
E. is colder than the air around it

53. You could make the balloons expand more by placing them:

A. on a high mountain peak
B. in a low valley
C. in a refrigerator
D. in front of a fan
E. under water

55. If these balloons were taken to the moon, they would:

A. flatten out
B. expand
C. contract
D. fall to the surface of the moon
E. remain the same

WHAT IS KNOWN
(PRODUCT)

52. The balloons (A) are in this position because:

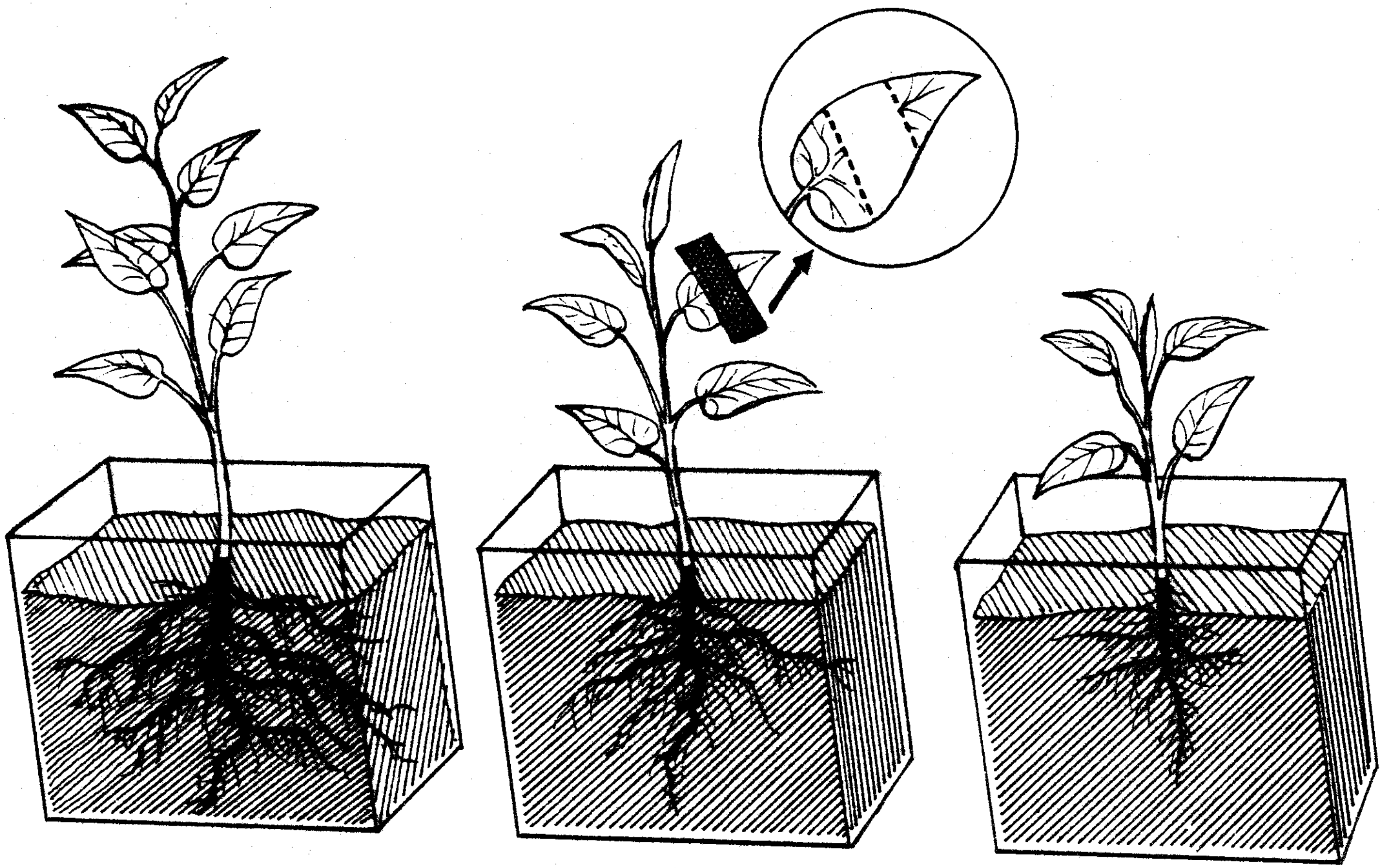
A. the gas inside is less dense than the gas outside
B. the strings are nylon
C. the warm sun made them rise to where they are
D. the balloons are filled with carbon dioxide
E. none of the above

54. When a balloon expands the gas molecules in it are:

A. farther apart
B. closer together
C. escaping through the balloon
D. changing their form
E. becoming larger

56. You fill the balloons in (A) with different gases. The balloon which will rise the fastest is filled with:

A. oxygen
B. hydrogen
C. ozone
D. natural gas
E. helium



A B C

HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT)

57. The roots in (B) can be made to grow down instead of to the left by:

A. watering directly under the plant
B. giving the plant more light
C. turning over the soil
D. putting a bright light to the right of the plant
E. taking the paper strip off of the leaf

58. The roots of these plants help hold the soil tight. This prevents:

A. explosion
B. washing
C. erosion
D. ploughing
E. soil formation

59. An important advantage that animals have over plants is that they:

A. move about more
B. can smell food
C. move faster
D. are stronger
E. breathe oxygen

60. Roots grow downward because:

A. leaves grow upward
B. plants are straight
C. the earth is soft
D. the rainwater pushes them
E. of gravitational force

61. One part of a leaf from plant (B) was covered with black paper for a week. At the end of the week that part of the leaf was yellow. This was probably due to the absence of:

A. carbon dioxide
B. oxygen
C. light
D. minerals
E. water

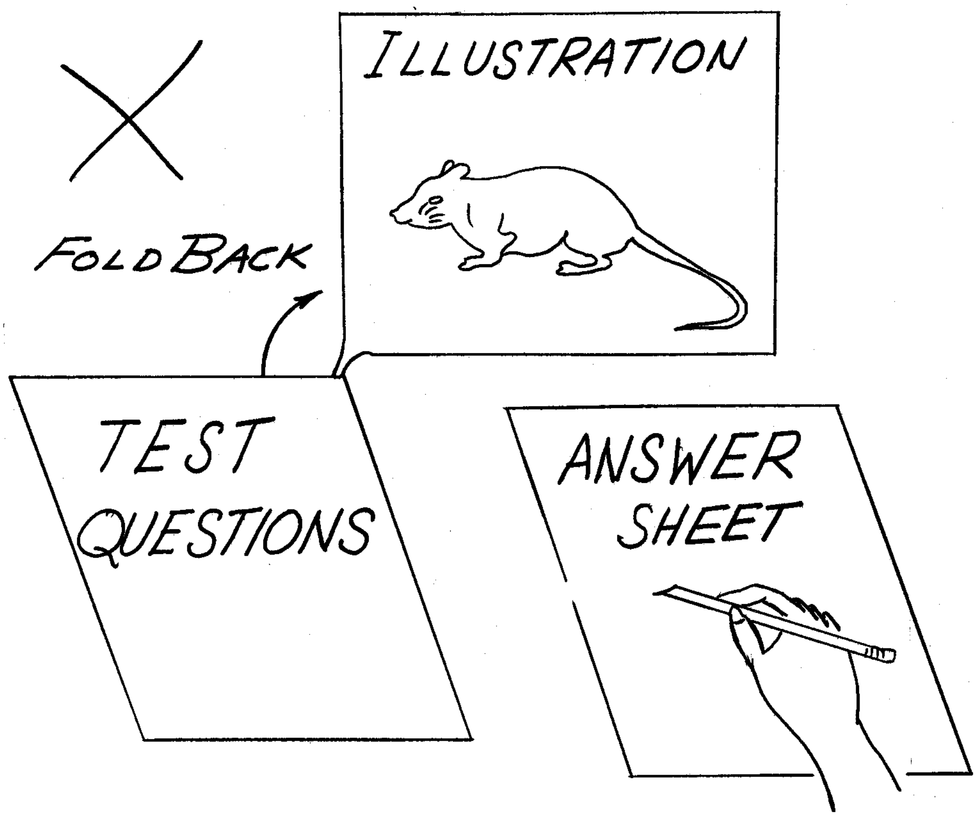
62. Plants bend toward light. This is called:

A. photosynthesis
B. photography
C. phototropism
D. flowering
E. twisting

APPENDIX II

1964-65 EDITION

# PORTLAND SCIENCE TEST



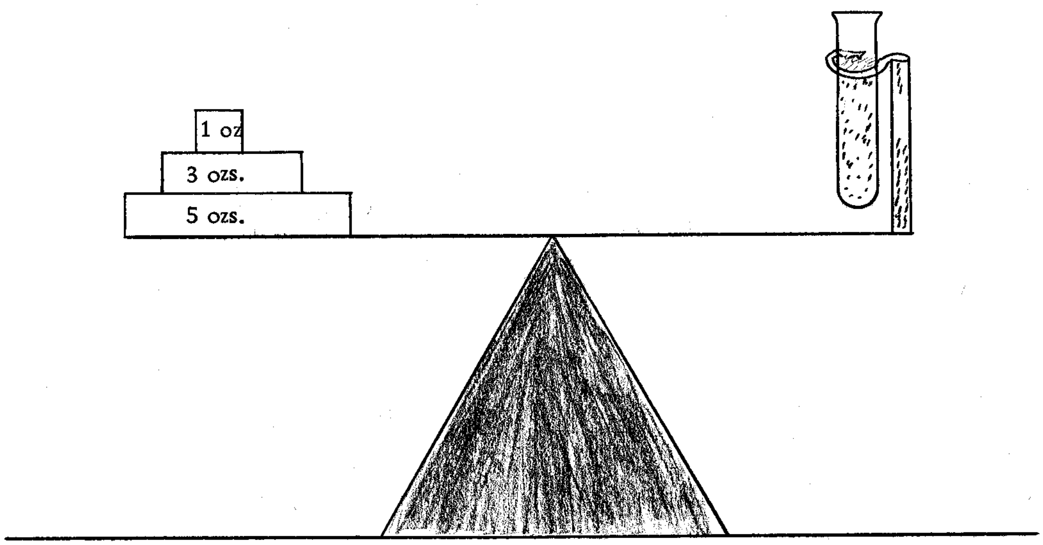

PLEASE DO NOT OPEN THIS TEST BOOKLET

LOOK AT THE COVER. Above is a picture of the way the test booklet has been designed to be used. Notice that the sheets are stapled in the right-hand corner. Therefore, you turn the pages from the left-hand side and fold back as shown. Each page of the test questions refers to a picture.

Right-handed students may place their answer sheet as shown. (Left-handed students should place their answer sheet above the test booklet in the space marked X). This enables one to see the picture, the questions, and the answer sheet at the same time.

<u>Do not turn the page until you are told to do so.</u>

EXAMPLE




HOW WE FIND OUT
(PROCESS)

1. The picture above shows:

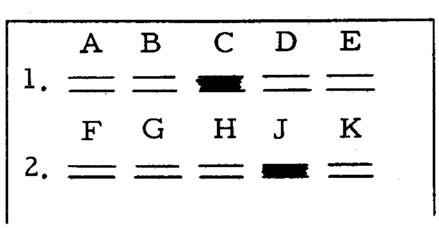
A. Bottle of water
B. See-saw
C. Balance for weighing
D. Pyramid
E. None of these

WHAT IS KNOWN
(PRODUCT)

2. The figure on the right is:

F. Thermometer
G. Beaker
H. Flask
J. Test Tube
K. Crucible

Answer Sheet Example



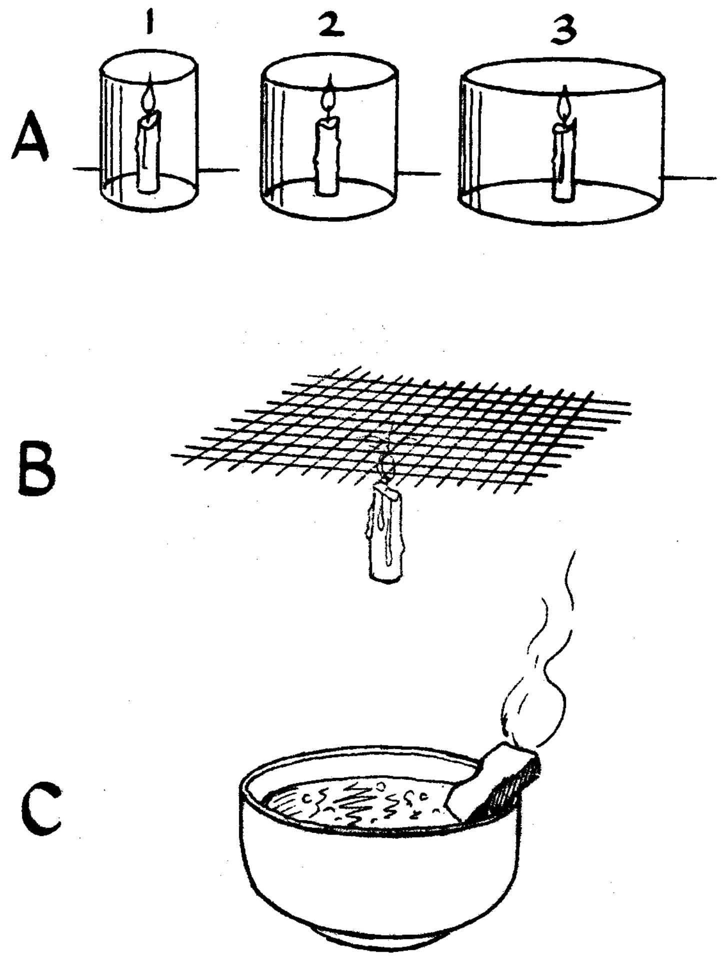



FIGURE I

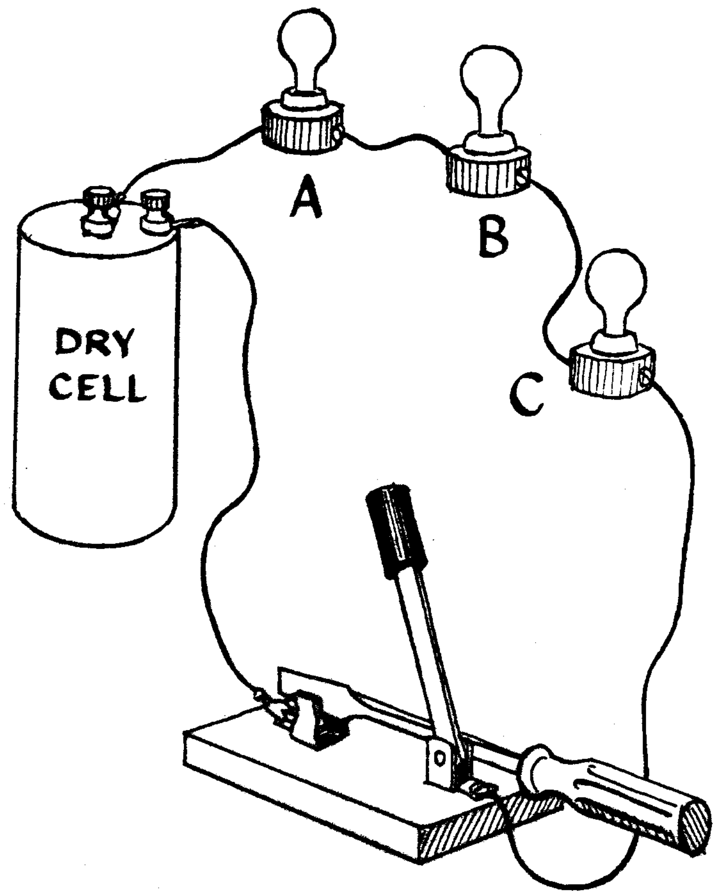



FIGURE II

## FIGURE I

HOW WE FIND OUT (PROCESS)

1. The candles in Figure I (A) will go out in which order?
   - A. at the same time
   - B. 1, 2, 3
   - C. 2, 1, 3
   - D. 3, 2, 1
   - E. 1, 3, 2

3. The copper screen in Figure I (B) stops the flame from going through it because:
   - A. air pressure changes above and below the screen
   - B. the holes in the screen are too small
   - C. there is too little oxygen above the screen
   - D. copper takes heat too fast
   - E. the flame is too weak

5. A piece of clay flower pot could be used as a wick for the oil lamp in Figure I (C) because it:
   - A. doesn't burn
   - B. will let oil pass through it
   - C. helps oil burn
   - D. glows when heated
   - E. is hard

WHAT IS KNOWN (PRODUCT)

2. The flame of a candle will burn most brightly in:
   - F. carbon dioxide
   - G. nitrogen
   - H. oxygen
   - J. air
   - K. chlorine

4. The energy used in the candles in Figure I came first from the:
   - F. earth's gravity
   - G. earth
   - H. oceans
   - J. sun
   - K. fat of animals

6. When you blow a candle flame out the smoke is:
   - F. carbon
   - G. air
   - H. steam
   - J. hydrogen
   - K. dirt

---

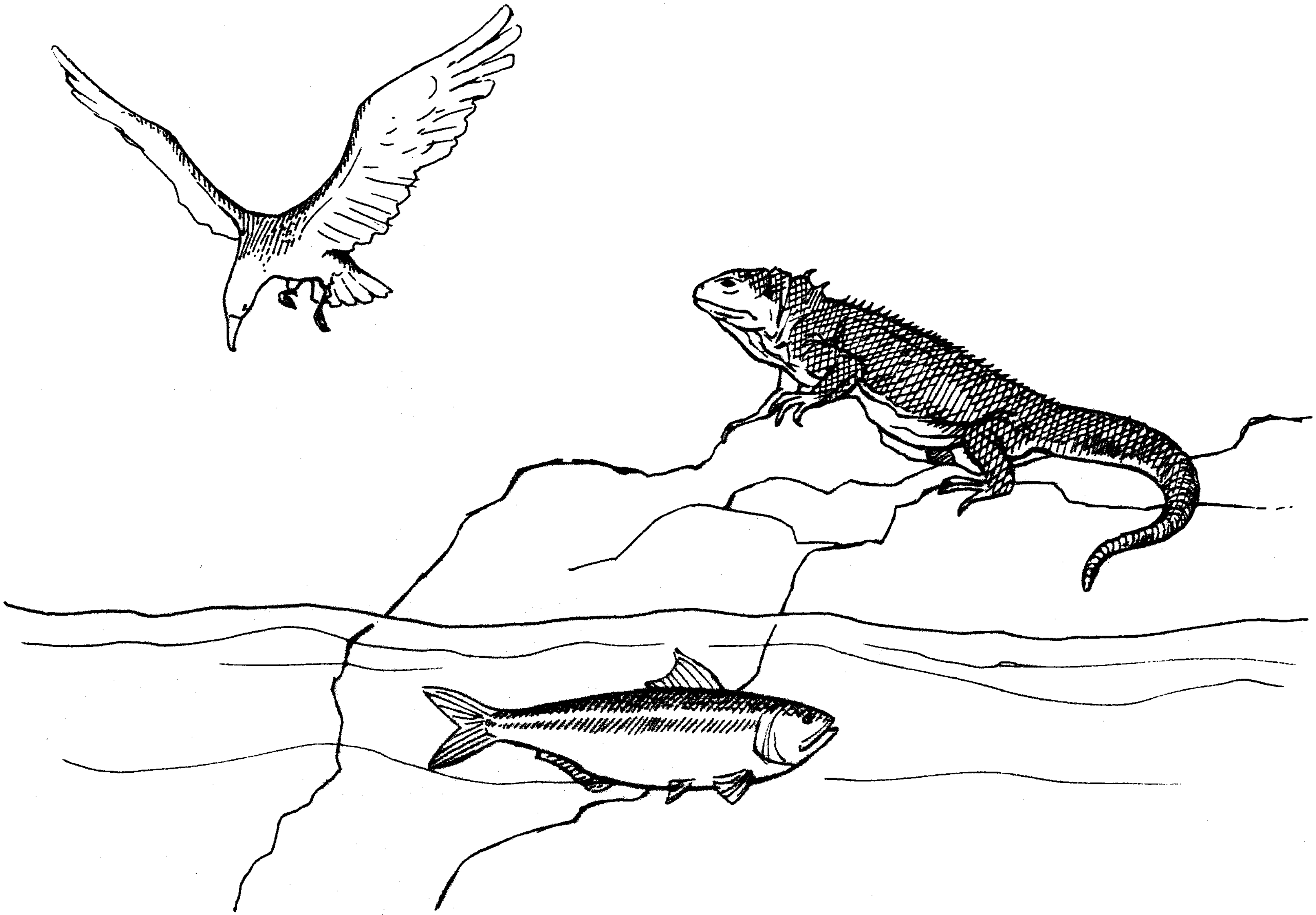
## FIGURE II

7. In Figure II the screwdriver is being used:
   - A. as a lever
   - B. as a switch
   - C. to turn up the electricity
   - D. to turn down the electricity
   - E. to stop the flow of electricity

9. If you unscrew and take out light bulb (B):
   - A. bulb (A) will remain lighted
   - B. bulb (C) will remain lighted
   - C. bulbs (A) and (C) will go out
   - D. bulbs (A) and (C) will get brighter
   - E. bulbs (A) and (C) will get dimmer

8. When there is a complete circuit, the electricity is:
   - F. used up
   - G. flowing
   - H. coming from a battery
   - J. less dangerous
   - K. collecting

10. Household Electrical code says that the voltage must be at least:
    - F. 115 and 230 volts
    - G. 300 and 400 volts
    - H. 75 and 100 volts
    - J. 75 and 150 volts
    - K. 110 and 240 volts



HOW WE FIND OUT
(PROCESS)

11. Iguanas move slowly. They look stupid but are still alive on this island. This is probably because they:

A. were born on this island
B. have few enemies on the island
C. are healthy
D. like to live on this island
E. taste bad to other animals

13. The shading on the fish in the picture probably means that:

A. enemies follow it
B. enemies live above and below it
C. enemies attack from the front
D. enemies are color blind
E. fish like different colors

15. The black bird in the picture was born white. This is dangerous for him because:

A. he doesn't like the color
B. his enemies can see him easily
C. the sun hurts his eyes
D. insects won't go near him
E. the other birds will fight him

17. Many fish and birds are darker on top than below. This is probably because:

A. they live in the same place
B. birds fly and fish swim
C. the sun tans them on top
D. they are better protected that way
E. they live in dark places

19. Iguanas are green in color. One family began to develop white spots. This causes trouble for them because:

A. they can be easily seen by their enemies
B. it shows that they are sick
C. green and white do not go together
D. they cannot find food easily
E. they will look different

WHAT IS KNOWN
(PRODUCT)

12. The use of color, shading, or pattern for protection is called:

F. striping
G. control
H. camouflage
J. dark and light
K. matching

14. The space around these animals is called their:

F. life space
G. area
H. environment
J. evolution
K. world

16. An animal that can change its color to match its background is the:

F. praying mantis
G. quail
H. jack rabbit
J. chameleon
K. rattlesnake

18. When an animal changes color, pattern, or shading over many years, the process is called:

F. adjustment
G. adaptation
H. adhering
J. absorption
K. abrasion

20. Animals change through the years. These changes are the result of:

F. assimilation
G. isolation
H. revolution
J. evolution
K. time

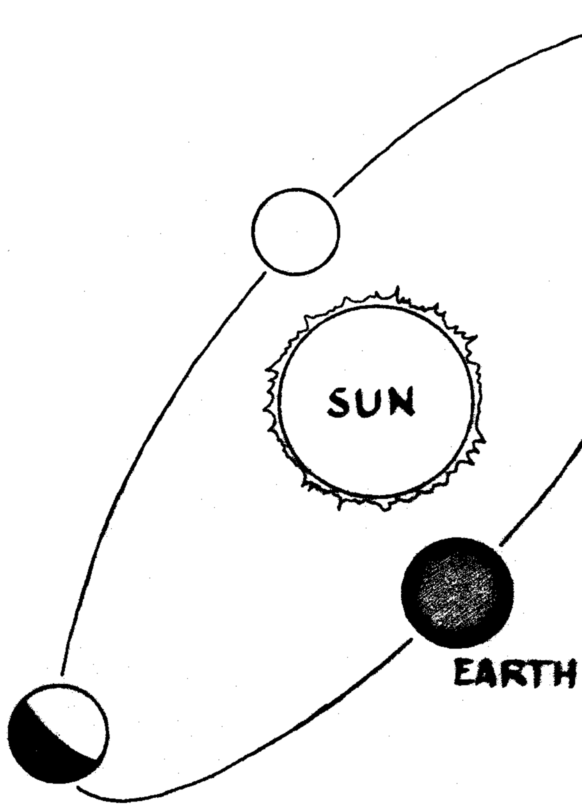



FIGURE I

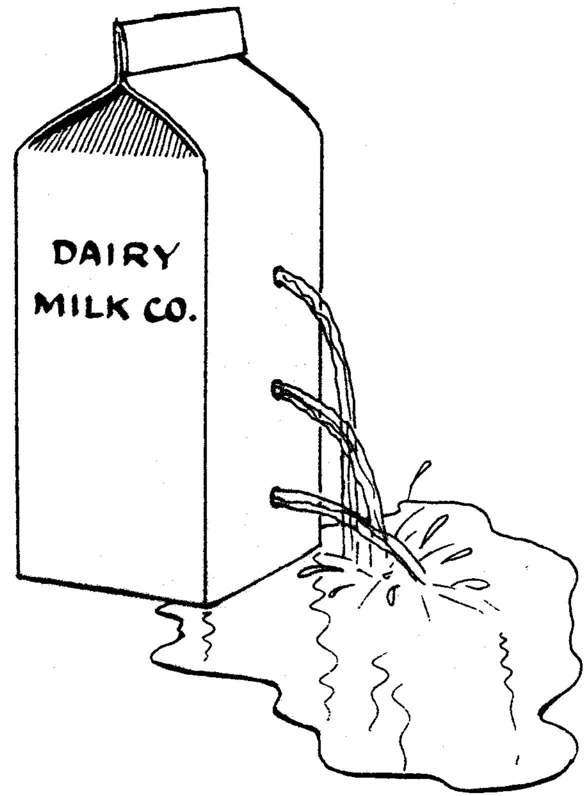



FIGURE II

FIGURE I

| HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT) |
|---|---|

21. A scientist wants to know what the sun is made of. He may learn most about it by studying the sun's:
    - A. movements
    - B. light
    - C. size
    - D. spots
    - E. distance

22. The sun is made of:
    - F. gases
    - G. liquid metal
    - H. universes
    - J. molten rock
    - K. galaxies

23. Day follows night because the earth:
    - A. reflects light
    - B. is round
    - C. moves in space
    - D. spins
    - E. acts like a magnet

24. A light year measures:
    - F. light
    - G. space
    - H. distance
    - J. speed
    - K. time

---

FIGURE II

25. To make all three streams shoot out the same distance you might:
    - A. make all the holes larger
    - B. turn the carton upside down
    - C. place the carton in a tub of water
    - D. turn the carton on its side
    - E. shake the carton

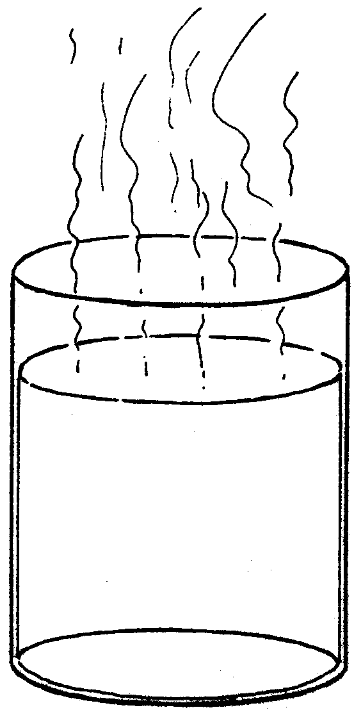
26. At room temperature water is:
    - F. level
    - G. liquid
    - H. soft
    - J. cold
    - K. smooth

27. The reason for the hole at the top of the carton is to let:
    - A. you check the level of the water
    - B. air into the carton
    - C. water into the carton
    - D. light into the carton
    - E. the carton empty fast

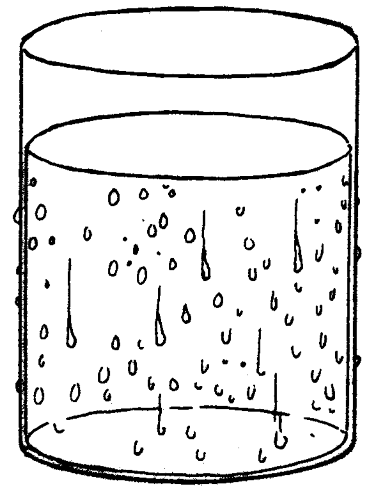
28. One way to clean water is to use the process of:
    - F. distillation
    - G. contraction
    - H. expansion
    - J. electrification
    - K. conflagration

29. The demonstration in Figure II shows that:
    - A. water moves at different speeds
    - B. the deeper the water the greater the pressure
    - C. water flows out the holes in the milk carton
    - D. water is liquid
    - E. air pressure causes the water to shoot out

30. Water is made of:
    - F. carbon and acids
    - G. nitrogen and oxygen
    - H. hydrogen and oxygen
    - J. oxygen and carbon dioxide
    - K. carbon dioxide and hydrogen



HOT WATER
A



COLD WATER
B

HOW WE FIND OUT
(PROCESS)

WHAT IS KNOWN
(PRODUCT)

31. Molecules in jars (A) and (B) move at different speeds. The best way to compare these speeds would be to:

A. place a drop of ink in each jar
B. place your finger in each jar
C. weigh each jar of water
D. place the jars in a strong light
E. float a cork in each jar

32. If the cold water were to freeze, the jar might break because water:

F. expands when heated
G. contracts when cooled
H. expands when it changes to ice
J. breaks the glass when it is cooled
K. becomes heavier when cooled

33. To find out if more salt would mix in hot water than in cold water, a good experiment would be to:

A. put salt in glasses of hot water
B. add salt to jar (A) and cool it
C. put more salt in a glass of cold water than a glass of hot water
D. compare the amounts of salt that mixed in jar (A) and jar (B)
E. add salt to jar (B) and cool it

34. Water freezes at 32°F. If you mixed as much salt as possible in a jar of hot water and then cooled the water to 34°F.:

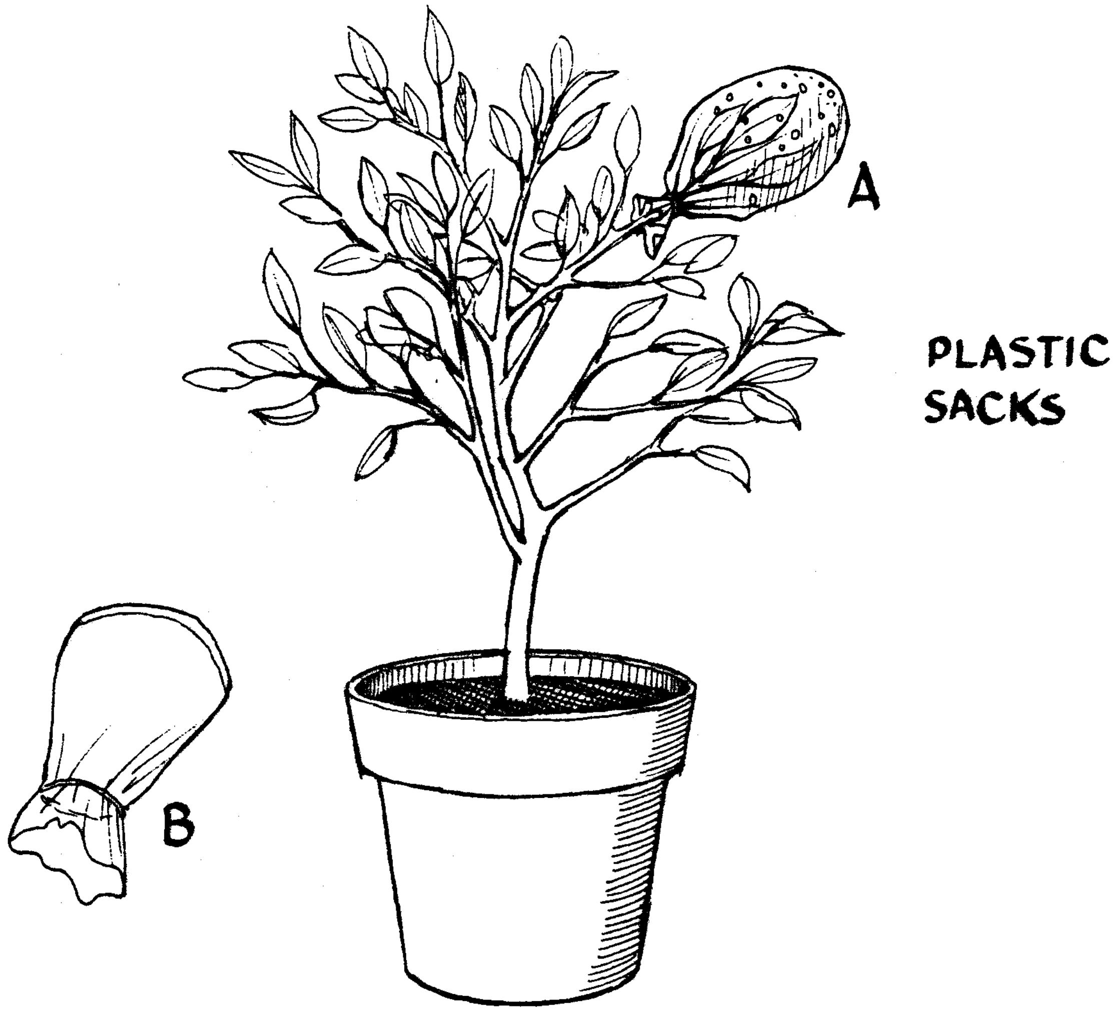
F. salt would appear in the jar
G. the water would evaporate
H. salt would float on top of the water
J. the water would taste saltier
K. the salt would freeze

35. Drops of water appeared on the outside of jar (B). To find out if this water leaked through the jar you could:

A. look at the jar for holes where water might get out
B. check some of the drops of water under a microscope
C. feel the inside and outside of the jar with your finger
D. cover the top of the jar tightly and watch the water level for several days
E. check the air in the room for water

36. Sometimes you can see dew on grass because:

F. the grass is cooler than the air around it
G. the gas in the air condenses when it is cooled
H. molecules of water move closer together when cooled
J. the temperature of the air is higher than the temperature of the grass
K. all of the above


A
PLASTIC SACKS
B

| HOW WE FIND OUT (PROCESS) | WHAT IS KNOWN (PRODUCT) |
|---|---|

37. Plastic sack (A) has drops of water in it. (B) has none. This is probably due to moisture--

    A. from the plastic
    B. from the air
    C. moving from outside to inside the sack
    D. from the leaves
    E. from the plant stems

38. Water vapor becomes liquid when it is:

    F. darkened
    G. lighted
    H. cooled
    J. heated
    K. dried

39. The best way to show that a plant takes water from the soil would be to:

    A. add colored water to the soil
    B. put colored water on the leaves
    C. check the water in the leaves
    D. weigh the water in the soil
    E. crush the plant and measure the water

40. What is shown in the demonstration above?

    F. assimilation
    G. transpiration
    H. chlorophyll
    J. evaporation
    K. exasperation

41. The best way to measure the water given off by the plant is to:

    A. feel the leaves
    B. weigh the dirt after watering
    C. weigh the dirt before watering
    D. weigh the water added in watering
    E. collect the water evaporated from each plant

42. Water in a plant moves:

    F. from leaf, to stem, to roots
    G. from roots, to stem, to leaf
    H. through leaves only
    J. through roots only
    K. through stem only

HOW WE FIND OUT
(PROCESS)

WHAT IS KNOWN
(PRODUCT)

43. A scientist placed leg bands on the squirrels and birds in the park. He was trying to find out if they

A. were easier to catch
B. had babies faster
C. hibernated
D. left the area
E. ate different kinds of food

44. Living things may best be divided into:

F. animals, insects, fish
G. animals and plants
H. men, insects, birds, fish
J. old things and new things
K. large and small plants and animals

45. In an experiment the squirrel was kept in a cold room for a week. The scientist could have been trying to watch:

A. the body temperature of the squirrel
B. the hunger of the squirrel when cold
C. if the squirrel's fur would keep him warm
D. how temperature affects a warm blooded animal
E. how much he moved when cold

46. All plant and animal life began with:

F. simple cells
G. the earth
H. ancient floods
J. carbon
K. dust

47. Green plants were placed in a dark room. They died because:

A. they couldn't breathe
B. they couldn't find food
C. the dirt became spoiled
D. light couldn't get to them
E. they were not used to the dark

48. Chlorophyll in plants helps them to:

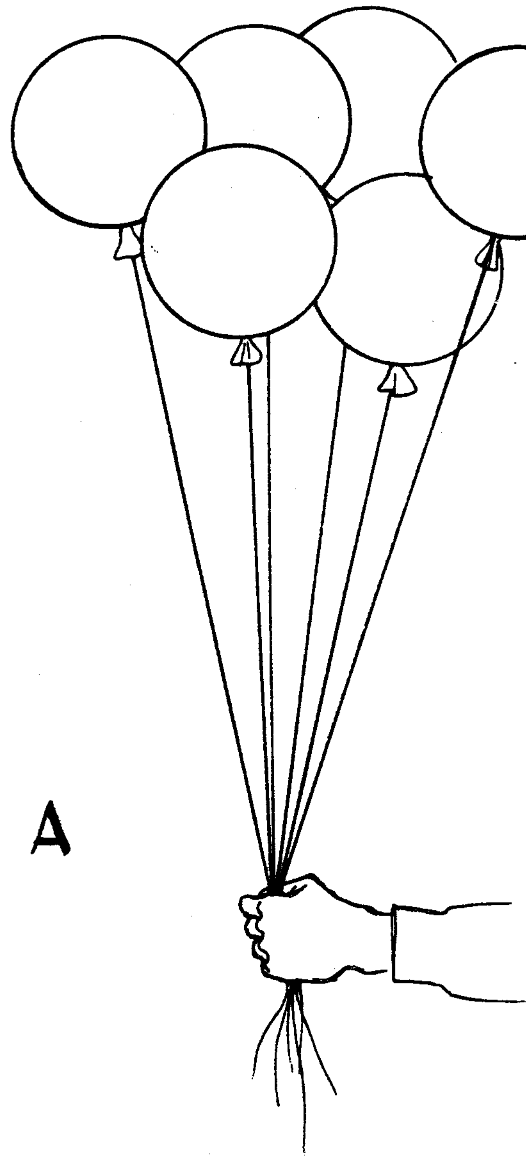
F. make food
G. breathe
H. hold water
J. produce seeds
K. move about

49. A boy cut a ring through the bark around the trunk of a tree. In five years the tree was dead. From this we can tell that:

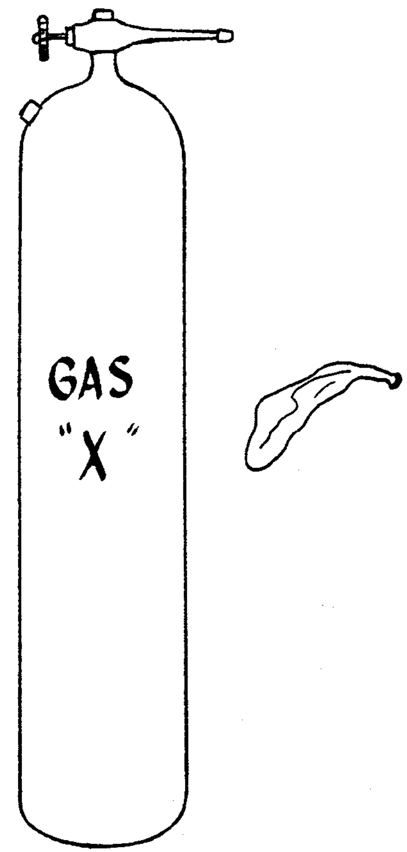
A. the bark didn't get enough light
B. the bark got hurt
C. the bark carried food
D. disease germs entered the cut
E. the bark died

50. An animal scientist (zoologist) divides animals into groups by studying their:

F. shape
G. habits
H. size
J. structure
K. movement



A




B

HOW WE FIND OUT
(PROCESS)

51. You fill the balloon (B) with gas "X". The balloon rises. This shows that gas "X":

A. is lighter than air
B. gets smaller when it is let out of the tank
C. is heavier than air
D. gets larger when it is let out of the tank
E. is colder than the air around it

53. You could make the balloons get larger by placing them:

A. on a mountain peak
B. below sea level
C. in a refrigerator
D. in front of a fan
E. under water

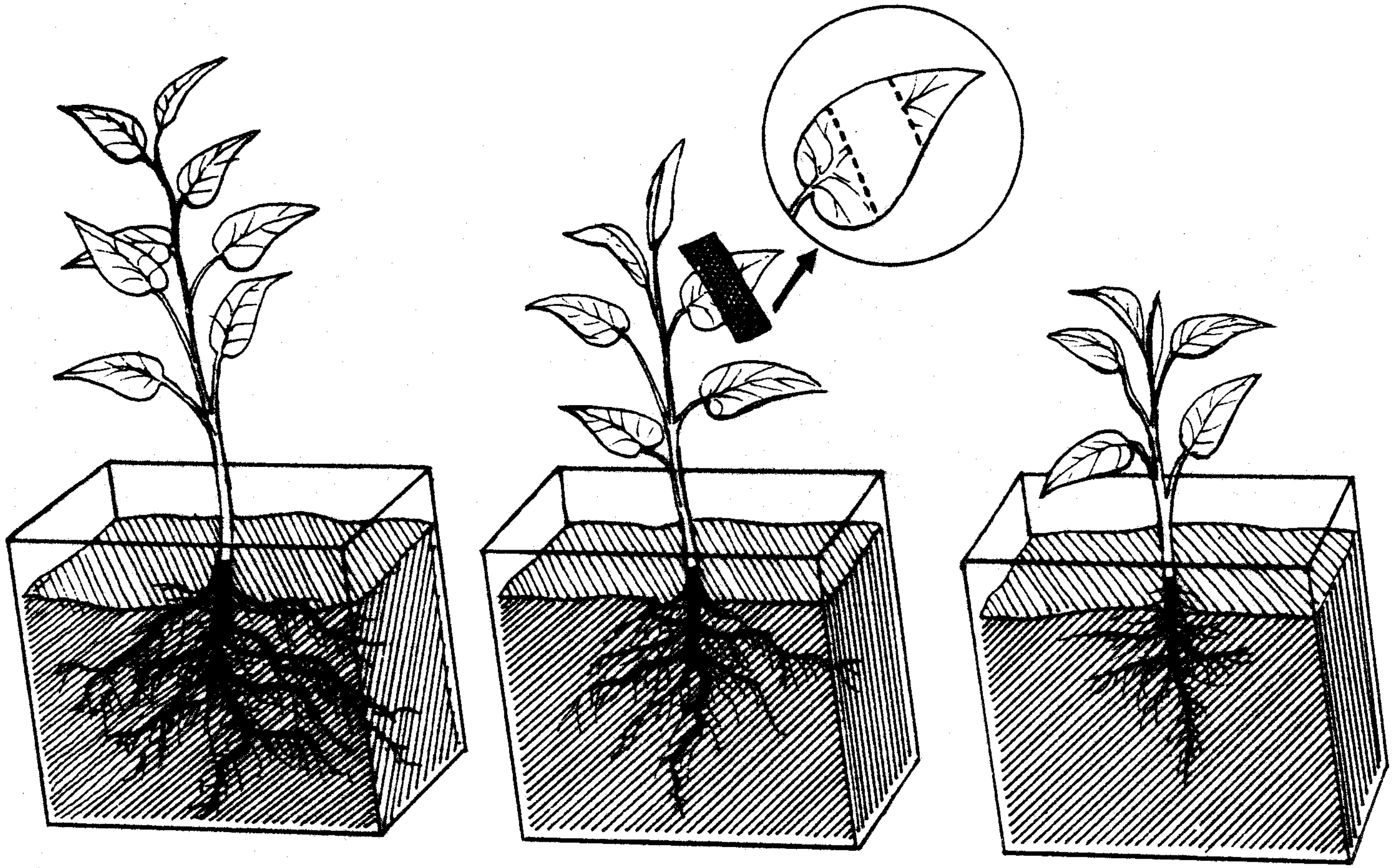
WHAT IS KNOWN
(PRODUCT)

52. The balloons (A) are up in the air because:

F. the gas inside is lighter than the gas outside
G. the strings are nylon
H. the warm sun made them rise to where they are
J. the balloons are filled with carbon dioxide
K. all gases are lighter than air

54. When a balloon gets larger the gas molecules in it are:

F. farther apart
G. closer together
H. getting out through the balloon
J. changing their form
K. getting larger



A B C

HOW WE FIND OUT
(PROCESS)

55. The roots in (B) can be made to grow down instead of to the left by:

A. watering directly under the plant
B. giving the plant more light
C. turning over the soil
D. fertilizing the soil
E. watering to the right of the plant

57. An important advantage that animals have over plants is that they:

A. move about more
B. can smell food
C. move faster
D. grow faster
E. breathe oxygen

59. One part of a leaf from plant (B) was covered with black paper for a week. At the end of the week that part of the leaf was yellow. This was probably because the leaf did not get:

A. carbon dioxide
B. oxygen
C. light
D. minerals
E. water

WHAT IS KNOWN
(PRODUCT)

56. The roots of these plants help hold the soil tight. This prevents:

F. explosion
G. washing
H. erosion
J. ploughing
K. soil formation

58. Roots grow down because:

F. leaves grow up
G. plants are straight
H. the earth is soft
J. the rainwater pushes them
K. of the force of gravity

60. Plants bend toward light. This is called:

F. solar movement
G. photography
H. phototropism
J. flowering
K. twisting

# APPENDIX III

## PORTLAND SCIENCE TEST QUESTIONNAIRE
PORTLAND PUBLIC SCHOOLS
631 NORTHEAST CLACKAMAS STREET
PORTLAND, OREGON

From: John S. Hutchinson

To: Science Teachers of Ninth Graders

Last Fall, 1963, general science teachers met as a group to discuss the means for testing the validity of the Portland Science Test. It was decided at that time that the science teachers of ninth graders would name two or three students who definitely rate at one end or the other of the scales shown below. Please consider the Process Scale separately from the Product Scale. Students should be placed at either end of the Process Scale independently of the knowledge they have of the facts of science. A bright student may not think scientifically whereas an average student may exhibit great facility with the scientific processes. Please consider the following scientific processes in selecting students for placement:

1. Ability to identify problems.

2. Ability to select hypotheses.

3. Ability to choose relevant experiments.

Please list the names of two or three ninth graders from each class who appear to fall at the extremes of the scales below. Do not hold the numbers inviolate. You may have no one in a class who fits at either end of the scale. List only those who in your judgment fit the extremes of the classification scale. Please return the lists by May 25.

Process Scale

10 9 8 7 6 5 4 3 2 1

Thinks Scientifically or Does Not

Product Scale

10 9 8 7 6 5 4 3 2 1

Knows a Lot of Science Information or Does Not

APPENDIX IV

STAC (SCIENCE TEACHERS ADAPTABLE CURRICULUM)
SCIENCE QUESTIONNAIRE
FOR
TEACHERS OF EIGHTH GRADE

Dear Eighth Grade Teacher:

Last year a new approach for assisting teachers in planning science experiences was introduced in a few pilot classes for evaluation. This is now known as the STAC Program. The use of these materials has been extended as teachers have shown interest and obtained assistance in their use.

The purpose of this questionnaire is to ascertain:

1. The present extent of use of STAC cards at the eighth grade level.
2. The effectiveness of the program.
3. The need for further assistance in its use.

Please complete the attached form by responding in each category. The completed questionnaire should be returned to the office of the Supervisor of Science by November 27, 1963.

Donald W. Stotler
Science Supervisor

NAME ________________________________ SCHOOL ________________________

I. HOW MANY YEARS HAVE YOU TAUGHT? (COUNT THIS YEAR) ________

II. WHERE DID YOU TEACH LAST YEAR? ____________________ WHAT GRADE? _________

III. IF YOU HAVE A 7-8 TEACHING COMBINATION, HOW MANY EIGHTH GRADERS ARE IN THE GROUP? ________

IV. ARE YOU USING THE STAC PROGRAM FOR YOUR SCIENCE INSTRUCTION? _________ IF SO, TO WHAT EXTENT?

A. ________ FOR AN OCCASIONAL LESSON

B. ________ AS A SKELETON OUTLINE FOR THE YEAR'S SCIENCE INSTRUCTION

C. ________ AS THE SOLE SOURCE OF IDEAS FOR SCIENCE INSTRUCTION

D. ________ OTHER (PLEASE EXPLAIN) ______________________________

V. IF YOU ARE NOT USING THE STAC PROGRAM, PLEASE CHECK YOUR REASONS BELOW.

A. __________ I AM UNFAMILIAR WITH THE STAC PROGRAM (CHECK HERE IF INFORMATION IS DESIRED ________).

B. __________ I HAVE EXAMINED THE STAC PROGRAM AND REJECT IT BECAUSE:

__________ 1. INADEQUATE ALTERNATIVES
__________ 2. TOO OPEN-ENDED
__________ 3. INADEQUATE SUPPLIES
__________ 4. MARGINAL INDEX TOO COMPLEX
__________ 5. CONTENT TOO STRUCTURED
__________ 6. WRITTEN AIDS INCOMPLETE

C. __________ I AM INVOLVED IN A DIFFERENT PILOT PROGRAM IN SCIENCE (PLEASE NAME: ______________________________)

D. __________ THE TEACHING OF SCIENCE IS NOT ONE OF MY RESPONSIBILITIES.

E. __________ OTHER (PLEASE EXPLAIN) ______________________________

VI. WHERE DO YOU TEACH SCIENCE? SPECIAL CLASS __________ (# of students) HOMEROOM __________ (# of students)

BOTH __________ NEITHER __________. IF BOTH, OR NEITHER, PLEASE EXPLAIN

______________________________

VII. WHERE DID YOU TEACH SCIENCE LAST YEAR? SPECIAL CLASS __________ (# of students)

HOMEROOM __________ (# of students) BOTH __________ NEITHER __________. IF BOTH, OR NEITHER, PLEASE EXPLAIN ______________________________

VIII. DID YOU PARTICIPATE IN ANY PILOT OR SPECIAL SCIENCE TEACHING PROGRAMS LAST YEAR? __________

IF SO, PLEASE SPECIFY

A. __________ STAC

B. __________ ILLINOIS ASTRONOMY

C. __________ PRINCETON GEOLOGY

D. __________ OTHER (PLEASE NAME) ______________________________

IX. ARE YOU TAKING OR DO YOU PLAN TO TAKE ANY SCIENCE IN-SERVICE CLASSES THIS YEAR? __________

| | TAKING NOW | PLAN TO TAKE |
|---|---|---|
| IF SO, PLEASE SPECIFY | ______ | ______ |
| A. STAC (FULL YEAR) | ______ | ______ |
| B. STAC (ONE TERM) | ______ | ______ |
| C. ZOO CLASS | ______ | ______ |
| D. OMSI CLASS | ______ | ______ |
| E. OTHER (PLEASE NAME) | ____________ | ____________ |