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ABSTRACT

This handbook, compiled by the Oklahoma State Science Committee, presents the basic philosophy of a school science program. Curriculum models in the publication are taken from several elementary science course improvement projects. Program organization and evaluation, relationships of science to the total school program, preparation of elementary teachers, and the use of educational media are also described. The last half of the handbook contains several model lessons. (CP)

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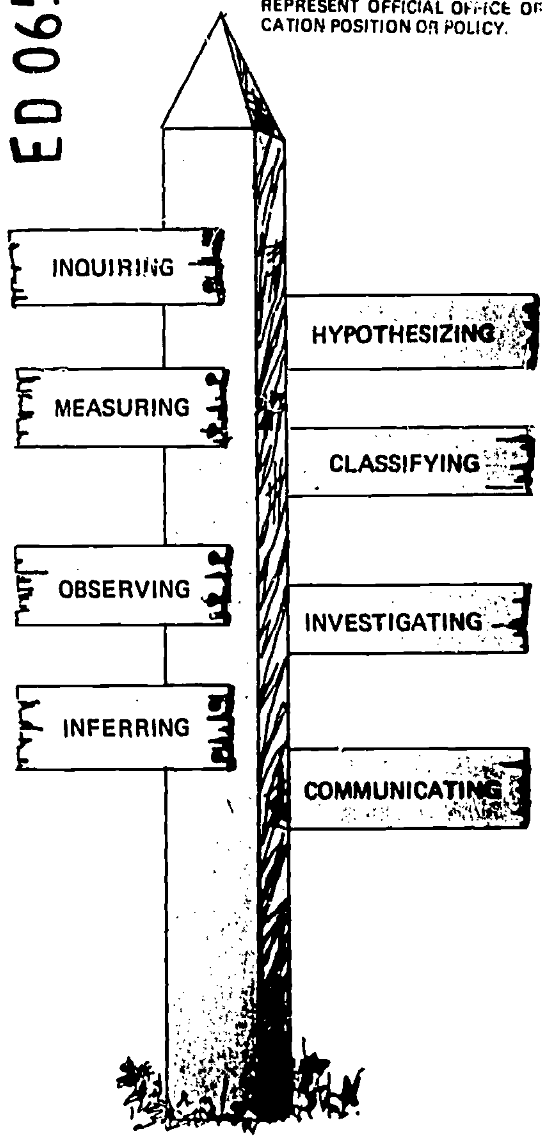
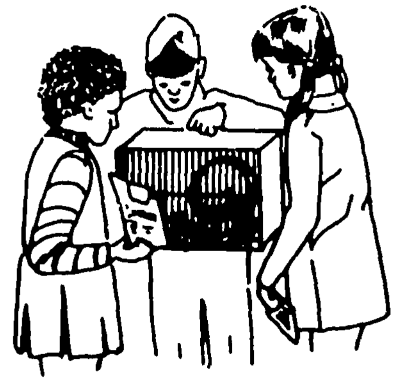
THE IMPROVEMENT OF SCIENCE INSTRUCTION IN OKLAHOMA

Grades K-6



routes for learning

Recommendations of
The State Science Committee
of
THE OKLAHOMA CURRICULUM IMPROVEMENT COMMISSION



THE OKLAHOMA STATE DEPARTMENT OF EDUCATION
Leslie Fisher, Superintendent
1971

THE IMPROVEMENT OF SCIENCE INSTRUCTION

IN

OKLAHOMA

(K-6)

THE OKLAHOMA CURRICULUM IMPROVEMENT COMMISSION
William D. Carr, Chairman
Clifford Wright, Executive Secretary
and
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in Science

OKLAHOMA STATE DEPARTMENT OF EDUCATION
Leslie Fisher, Superintendent
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FOREWORD

The tremendous impact of science upon the world today is obvious to all. Science has become so important a force in modern society that it touches upon every endeavor. Increased interest and rapid advance in science make it necessary to frequently re-evaluate and redesign our curriculum.

The curiosity and interest of the student must be aroused to the point of his seeking understanding of the material world and developing habits and skills that will promote continuation of the inquiry process. A science curriculum designed with versatility, flexibility, and challenge must be made available to every school. This publication is designed to meet these modern demands.

The State Department of Education gratefully acknowledges the contributions of the State Committee Members of the Oklahoma Curriculum Improvement Commission which have prepared this guide.

It is hoped this guide will be of valuable assistance to the teachers and administrators of the state. I am confident the excellent materials contained in this handbook will be of great value to all schools of the state that seek to use them objectively and professionally.

Leslie Fisher
State Superintendent
of Public Instruction

ACKNOWLEDGEMENTS

We wish to extend special thanks to all who have helped in the preparation of this booklet. This material will serve as a guide and not a body of laws. The success of any guide rests on its effectiveness in use. Those who contributed to this guide feel that it will be helpful to teachers. It is not intended that this bulletin be a course of study or a curriculum outline. Rather it is the intention of the committee to acquaint the elementary teachers with the experimental studies underway and give them assistance in using the techniques of "inquiry" in their teaching of science.

It would be impossible to mention all of the persons who directly or indirectly assisted in the production of this guide. We do want to list the members of the State Science Committee, whose cooperation and untiring efforts have made this publication possible.

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CHAPTER I

SCIENCE, DISCOVERY AND CHILDREN

THE UNITY OF SCIENCE

As teachers we have all faced the question, "What is science?".

The term science covers many facts, natural laws, and a variety of subject matter. Yet it has a unity recognized by all.

The heart of all science is inquiry! In all areas of science, regardless of the kinds of objects or materials used, the scientist makes *his own* observations, asks *his own* questions, performs *his own* experiments, and draws *his own* conclusions. This approach remains the basic significant characteristic of all science, not the body of facts obtained. However, it is through such an approach that the accumulation of knowledge (facts) in each area of science is achieved.

THE BASIC PHILOSOPHY FOR AN ELEMENTARY SCHOOL SCIENCE PROGRAM

We as teachers subscribe to the overall goal of education which is to provide the individual with a means for improving himself and the society in which he lives.

Traditionally, science teaching has involved the teaching, memorizing and applying of so-called "scientific laws or facts." We feel that every effort should be made to break away from this traditional method at all levels. We believe that to develop an understanding of an ability to utilize the fundamental concept of science as inquiry, a teaching approach different from the one many teachers now use, must be employed. The inquiry approach to elementary science teaching, we feel, is the logical and productive approach.

Science is a natural vehicle with which to develop a child's ability to think objectively. In order to accomplish this goal, however, the emphasis in science teaching must shift from the teaching of facts to the development of a child's ability to observe carefully, collect information, and draw logical inferences. In other words the child acquires *his* scientific information only through *his own* powers of observation and inductive inferences. *The process,* therefore, *of arriving at an item of scientific information becomes* more important than the *information obtained.* If such logical philosophy is adopted, the actual objects used in making critical observations and drawing inferences are not important. These objects can be buttons, rocks, plants, animals, or any convenient and available items.

The inquiry approach discussed above has a remarkably beneficial effect in increasing the interest of the child in science and in increasing his ability to think logically in other areas. Such an approach gives the child excellent opportunities to learn to express himself accurately and concisely. This ability has value in all the other disciplines.

The inquiry approach to science teaching necessitates that teachers adopt the attitude that science is an intellectual process. This attitude may not have been developed through the formal education in science which the teacher has experienced. It is important that procedures be developed within the framework of teacher education which will enable the prospective teacher to become involved with science as an intellectual process, not a body of laws and facts.

We recognize that elementary school children, as well as many elementary teachers, have not had experiences and opportunities to acquire the basic knowledge of scientific laws and facts with which to observe and interpret correctly all of the events involved in the learning situation created in the science classroom or laboratory. We also recognize that one cannot leave a class "wondering, with no basis for understanding, what they have observed." However, this is where successful teaching occurs. The successful teacher takes advantage of the "wondering" and *guides* the student into finding (not gives) a satisfactory (and correct) explanation. It is the way of searching for laws and facts which is important and this, both teacher and students must accept and understand. *The student must seek to know and understand the "laws and facts" as answers* to his questions and needs rather than be given them as information for which he may eventually have a use.

PURPOSES OF ELEMENTARY SCHOOL SCIENCE

The general purpose of the elementary school is to develop the rational powers of the mind, that is, the ability to think.[1] Science experiences make their unique contribution to the development of this ability to think by leading children to develop:

the ability and *confidence* to inquire.

understandings of matter, life, energy and their interactions.

The accomplishment of these objectives will encourage the transfer of learning from one context to another and help children become thinking, creative citizens.

THE NATURE OF INQUIRY

The term inquiry can be most succinctly defined as a search for information and understanding. This, of course, implies that the person (adult or child) conducting the search has a general notion of the problem he is attempting to solve. There are many instances in the history of science, however, where the scientist had no more than a general notion of what he was searching for and, as a result, all the data gathered were carefully evaluated before the specific problem to investigate was solved, or in many cases, even defined. Pasteur, for example, began his scientific career as a chemist and, as a result of attempting to solve the problem of beer and wine fermentation, was launched on an inquiry which led to the development of the new field of bacteriology. The nature of the processes of inquiry demands that situations be analyzed, investigations conducted, information evaluated, hypotheses synthesized and tested, generalizations formed and, ultimately, predictions made. Developing the ability to inquire demands that the learner have an active role in an investigation; he will not develop his powers of inquiry (the rational powers) if he assumes only a passive or listening role.

Of all man's possessions, his most valuable is the knowledge he possesses. But of all his knowledge, the most priceless and personal is that which he has discovered for himself.[2] The role of the processes of inquiry in elementary school science is to furnish a framework which can be used to lead a child to discover information *for himself*. We must not expect that a child will discover anything new to science but what he does find will be new to him. Furthermore, the very nature of the processes of inquiry demands that if the learner is to discover facts he must make observations, perform experiments, interpret data, form and test hypotheses and draw conclusions. By participating in these processes he is having experiences which will develop his intellectual abilities (his rational powers) and is accumulating information and understanding which are uniquely his. The factual information

[1] THE CENTRAL PURPOSE OF AMERICAN EDUCATION, Educational Policies Commission, NEA, 1961. The rational powers are recalling, imagining, classifying, generalizing, deducing, inferring, evaluating, synthesizing, analyzing, and comparing.

[2] Jerome Bruner, ON KNOWING, (New York: Atheneum Publishers, 1965), p. 82.

which he accumulates, however, is of secondary importance when learning by inquiry; his most important achievement is the development of an understanding of *how to inquire and make discoveries.* Inquiry, therefore, is the learning process in science because it is used by the learner to find out what it is he wishes to know. It is also an end product because by understanding how one problem is solved, the learner is in a position to better know how to solve the next problem. All of these kinds of experiences lead him to his most priceless and personal possessions—that knowledge which he has acquired for himself. Since a learner cannot acquire all the knowledge and understanding during his school years that he will need for life, *the schools must teach him how to continue to learn on his own after he leaves school.* Providing educational experiences which will teach the pupil how to learn is the school's most important responsibility. Learning science through inquiry represents a learning experience which can be used in the classroom to help the school meet this important responsibility.

THE ROLE OF THE TEACHER IN INQUIRY-CENTERED LEARNING

The successful teacher in the truly inquiry-centered classroom is inconspicuous. His role, however, is increased in importance and sensitivity as he becomes a stage setter, a giver of clues, and a questioner instead of a central figure. By involving children and himself in active inquiry he points the way toward discovery. Instead of giving conclusions, he allows the child to make them. By supplying materials and by asking questions, he assists in the progress toward discovery; in short, he creates an environment for inquiry.

It must be recognized that a child's conclusions will not necessarily be those which the teacher might draw; however, whatever the conclusion is, it must be accepted and evaluated on its own merits as substantiated by the evidence offered to support the conclusion.

Relating information is much easier than remaining quiet while a class is inquiring. The teacher must keep in mind that he is teaching the child how to learn— a process which will be valuable in all learning long after facts are forgotten.

Should the beginning teacher be uncertain of procedure in attempting this experience, he will find the teachers' guides accompanying the programs described in Chapter Two and many of the references in the Bibliography to be helpful.

TEACHING FOR BEHAVIORAL CHANGE

Using the inquiry approach, the teacher must relinquish his position as the purveyor of information and concentrate his efforts toward the development of objective reasoning. When teaching is directed toward observation, communication, measurement, and inference, the result will be a behavioral change in the child. It will be evidenced by a change in the child's relationship to himself, to his peers, and to his environment as well as by the more efficient acquisition of scientific facts as a part of his intellectual inventory.

THE ROLE OF THE CHILDREN IN INQUIRY-CENTERED LEARNING

When elementary school children learn science by inquiry, their role is an extremely important one and can be succinctly stated as being active. *The children must make the observations, do the experiments, interpret the data, and draw the conclusions.* If children report their observations and experimental results as honestly and objectively as they know how, the teacher has the responsibility to accept those reports and lead the class to examine them. The most certain way to convince children that they are expected to find only what the teacher approves is for that teacher to tell them that their results are incorrect. The data and the conclusions the children present to the teacher must be accepted by the teacher. *If these data and conclusions are not acceptable on the basis of the information available, it is the teacher's obligation to provide additional learning activities which lead children to produce results different from the first experience.* In this way the children can discover, by additional inquiries, which conclusions are acceptable.

Research with children has shown that until about seven years of age the child is in a stage of development called the "pre-operational stage."[3] During this period the child is capable of making observations and explaining those observations only in terms of his perceptions. According to Piaget, from about seven to eleven years of age the child is in the concrete operational stage of his development. During this phase he has the ability to receive information which comes from direct experimentation and observation and transform and use that information to solve problems. The third stage of a child's development is the formal operational stage. During this developmental period, the child has the ability to use hypothetical propositions. It is in this latter stage that children begin to ask, "What would happen if.....? The role of the young child (probably through the first grade) in an inquiry-centered classroom, then, is to use information he gathers to explain relationships and experiences. Observing and reporting about experiences with all types of objects is very representative of the pre-operational stage of development. The pupil's role during the concrete operational stage (from about grade two through grade five) is to take the information received from activity, organize it, and use it to answer questions and/or solve problems. In about the sixth grade, the child, although perhaps still concrete operational, may be introduced to activities which will lead him to stating and testing formal hypotheses. This will assist him in making the transition to formal operations.

There are those who believe that only the bright child can operate effectively in an inquiry-centered classroom. Psychological research[4] points out that the involvement of children in inquiry in more important for the less able than for the able. Inquiry experiences will give the less able student the opportunity to actively participate at *his* level of competence.

THE PLACE OF THE LABORATORY IN AN INQUIRY-CENTERED SCIENCE PROGRAM

For the inquiry approach to be most successful, the classroom should be organized in such a way that it becomes a laboratory in which pupils can have actual experiences with natural objects and phenomena. Each child's discoveries are his own and are a direct result of his own actions and manipulations. Thus, he experiences science firsthand.

The ideal classroom for elementary science is one which has all the necessary materials for the students to conduct their investigations. This would mean an abundance of materials for students' use and these materials should be supported by reference books and other materials. If the children in this kind of classroom are allowed and encouraged to carry on their own organized, science-oriented activities, one can expect to kindle real interest for each child in some way at some time.

3Jean Piaget, PSYCHOLOGY OF INTELLIGENCE, (Patterson, N.J.: Littlefield, Adams & Co., 1963), p. 123.

4.Jerome Bruner, THE PROCESS OF EDUCATION, (Cambridge, Mass: Harvard University Press, 1960), p. 9.

CHAPTER II

ELEMENTARY SCHOOL SCIENCE CURRICULUM MODELS

No single group can prescribe a curriculum which will fulfill the needs of every elementary school child any more than a biochemist could synthesize a drug which would cure all diseases. You, the teacher, must be the curriculum expert in your own classroom. You must make the final decisions about the experiences which the children in your classroom will have. Since the responsibility for the children is yours, we firmly believe the privilege of selecting the content and materials with which to educate them should also be yours.

Chapter One outlined the philosophy which is the foundation of a modern elementary school science program and the objectives which such a program would lead children to achieve. Perhaps you are wondering what an actual inquiry-centered curriculum would look like. In other words, what kinds of experiences would such a curriculum provide children? In this chapter, three curricular models will be described which we feel will allow you to implement the philosophy of Chapter One.

Model lessons for the programs described in this chapter will be found in the appendix.

THE SCIENCE CURRICULUM IMPROVEMENT STUDY[1] (SCIS)

In developing curricular materials for elementary school science, the SCIS personnel adhered to the basic principle that children should have experience with physical and life science each year. The distribution of the science topics throughout the elementary school years by SCIS is:

	Physical Science Units	Life Science Units
First Level	*Material Objects*	*Organisms*
Second Level	*Interaction and Systems*	*Life Cycles*
Third Level	*Subsystems and Variables*	*Populations*
Fourth Level	*Relative Position and Motion*	*Environments*
Fifth Level	*Energy Sources*	*Communities*
Sixth Level	*Models: Electric and Magnetic Interaction*	*Ecosystems*

THE FIRST LEVEL[2]

Material Objects. In this unit children study common objects and special materials and describe them by their *properties;* such properties as color, shape, texture, hardness, and weights are considered. Properties are studied by the children as they observe, manipulate, compare, and even change the form or appearance of objects. As they compare properties and recognize the differences among similarly shaped

[1]The headquarters of this project are located at the University of California, Berkeley. Dr. Robert Karplus, Professor of Physics is the Director and Dr. Chester Lawton is Director of the Life Science program.

[2]The descriptions of the twelve SCIS units included in this article have been adapted from Science Curriculum Improvement Study, SAMPLE GUIDE, Rand McNally & Company, Chicago, 1970, pp. 10-15.

pieces of aluminum, brass, lead, steel, pine, walnut, and acrylic, children assimulate the concept of *material*. Property comparison also leads children to the concept of *serial ordering*.

The pupils also investigate the properties of solid, liquid, and gaseous materials. Each child has many opportunities to apply what he has learned about material objects, their similarities and differences, the *changes* that may be brought about, and the need for observable *evidence* to support his conclusions. Near the conclusion of the unit, the children are introduced to simple experimentation. Experiments are done with floating and sinking objects, and air.

Organisms. Children become familiar with some of the requirements for life as they set out seeds and watch the growth of plants. This experience is extended when the class builds aquaria with water plants, fish, and snails. Three natural events occurring in the aquaria are observed and discussed: *birth* of guppies and appearance of snail eggs, *growth* of guppies and snails, and *death* of organisms.

When they explore the school yard, nearby park, or nature area, children discover plants and animals living outside the classroom. The pupils are led to the concept of habitat as they compare these land organisms with those living in the aquaria.

After a few weeks, the algae in some of the aquaria increase in sufficient numbers to make the water green. The children usually notice this change and sometimes ask about its cause. Through a series of experiments and observations they recognize the presence of tiny green plants called algae. Children may then find evidence that algae are eaten by *Daphnia*. When they discover that guppies feed upon Daphnia, the children can use this series of observations as the basis for understanding the concept of a *food web* depicting feeding relationships among organisms. *Detritus*, the black material accumulating on the sand in aquaria after a few weeks, is a combination of feces and dead plants and animals. Children infer, as they compare seeds grown in sand with and without detritus, that it acts as a fertilizer, enhancing plant growth.

Each experience with living organisms should increase the child's awareness of differences between living organisms and nonliving objects.

THE SECOND LEVEL

The units studied in the second year are entitled *Interaction and Systems* and *Life Cycles*. In both units the theme is changed which is observed as evidence of interaction or by the development of a plant or animal. The two units, therefore, require children to add the mental process of interpreting evidence to the observational skills they developed in the first year. As with the first year units, these two units can be taught in either order or simultaneously. Simultaneous use of the units is very convenient because during the *Life Cycles* unit there are often periods of time when the living systems are static or growth is not obvious. During these times, activities from Interaction and Systems can be profitably integrated.

Interaction and Systems. The central concept of the entire SCIS program, *interaction*, is introduced in this unit. The children's work with objects and organisms in the first year has given them the background necessary for understanding the interaction relationship. In later units, the program will emphasize the application and refinement of the interaction concept as children investigate biological, chemical, electrical, magnetic, thermal, and mechanical phenomena.

The first two parts of this unit are devoted to the interaction and systems concepts, respectively. The idea that a change may often be interpreted as evidence of interaction (for example, when photographic paper turns dark on exposure to sunlight) is explained. The remainder of the unit is divided into four parts in which the children investigate interactions and systems: pulley systems, dissolving (copper chloride, aluminum), interaction-at-a-distance (interaction without the objects touching, as in magnetism), and electric circuits. The sequence of these investigations can be altered to suit the teacher's preference. Throughout, children observe and interpret evidence of interaction.

Scientific concepts are developed in the unit, as are the children's skills in (1) manipulating experimental equipment, (2) reporting observations, and (3) recording observations during experiments.

Life Cycles. The investigation of ecosystems begun in *Organisms* is continued in *Life Cycles.* The unit, however, focuses on individual organisms, which alone show the characteristics of the phenomenon called "life." At this time the interrelationships and interdependencies within the ecosystem have secondary importance.

Each kind of plant and animal has its own life cycle. By studying the life cycles of selected plants and animals, children observe the characteristics of living organisms. Seeds are planted and their germination observed. Plants are cared for until they reach maturity, produce flowers, and form a new generation of seeds. The fruit fly, frog, and mealworm are observed while they metamorphose. As one generation of organisms produce another, children are led to consider biotic potential and the effects of reproduction and death on a population. Finally, when some of the similarities and differences between plants and animals have been considered, and children have defined the two categories on the basis of their own observations, they proceed to the more general question, "What is alive?" With each experience, a child's awareness of the differences between living and nonliving objects should increase.

THE THIRD LEVEL

Subsystems and Variables. The subsystems concept is introduced to give the children a grouping of objects intermediate between a single object and an entire system. The grains of sand in a mixture of sand, salt, and baking soda, the salt in a salt solution, the Freon in a bag interacting with water, or the arm and rivets in a whirlybird system are all examples of subsystems.

As the children experiment with solid and liquid materials they use the techniques of sifting to separate solid powders and of filtering to separate an undissolved solid from a liquid. At the same time they recognize that dissolved solids in *solutions* cannot be separated by filtering. Instead, the presence of dissolved solids may be identified by *schlieren* or by a residue that remains after the liquid evaporates. There are further experiences with liquid Freon, a material that not only evaporates quickly at room temperature, but that condenses to a liquid form when cooled with ice. The work with solutions and with Freon serves to deepen the children's awareness of the principle of conservation of matter, *even though this is not stated explicitly in the unit.* The technique of using a histogram to compare data is introduced when the children take temperature readings during the melting of ice and interpret their measurements.

In the last part of this unit, children investigate the whirlybird (a rotating propeller-like device which is powered by a taut rubber band) and discover that its operation depends on many factors they can control and on a few they cannot. The variable concept helps them to identify and investigate factors influencing the motion of the whirlybird arm, including adding weights in the form of rivets to both sides.

Populations. In this unit attention is directed toward populations of organisms rather than toward individual plants and animals. Children observe the growth, eventual leveling off, and decline of isolated populations of *Daphnia*, aphids, and fruit flies. They relate increased population sizes to reproduction and population decline to death.

The children build aquaria and terraria in which several populations live together. The aquaria contain populations of Daphnia, hydra, snails, algae, duckweed, and Anacharis. The terraria contain grass, clover, crickets, and chameleons. By observing the interacting populations in the aquaria and terraria, the children gain some understanding of the relationships among populations in nature. For example, the children observe that hydra eat *Daphnia*, with the result that the *Daphnia* population declines while the hydra population may increase. In the terraria, the children observe that crickets eat grass and clover and that when chameleons are added to the terraria they eat the crickets. Thus, the grass and clover populations are reduced, and the cricket population is eventually wiped out.

THE FOURTH LEVEL

Environments. The terraria children design and build at the beginning of the unit reflect their preconceptions regarding the needs of organisms. As a result, there is a wide disparity in the growth and survival of the organisms living in the terraria, and these differences can be correlated with variations in *environmental* factors such as temperature, amount of water, and intensity of light. The term *environment* is defined as the sum total of all the environmental factors affecting an organism.

Afterwards, the children seek to determine the responses of individual kinds of animals and plants to variations in the environmental factors. On the basis of experiments with isopods in a runway with graded temperature, the concepts of a temperature *range* and of an *optimum range* for that animal are introduced. In additional experiments, the children attempt to determine optimum ranges of other environmental factors for snails, mealworms, beans, grass, and clover. Before the unit is concluded, the children again construct terraria, but now they use their data on optimum ranges to plan a more favorable environment for their organisms.

Relative Position and Motion. In the *Relative Position and Motion* unit, activities dealing specifically with spatial relationships are introduced into the SCIS program. The investigations enchance the children's abilities to think critically, interpret evidence, and work independently. These are process objectives for the entire SCIS program. Children use *reference frames* to describe the position and motion of objects in their everyday environment.

Early in the unit, the artificial observer Mr. O serves the children as a *reference object* for describing relative position. Later they are introduced to *polar* and *rectangular coordinates* for a more exact description of *relative position and motion*. The children must apply the reference-frame concept in many activities, such as the following: (1) playing classroom games to locate objects, and solving puzzles that require matching of relative position; (2) watching the *Fun House* film in which the camera rides along with the children to record unusual relative motion; (3) drawing and interpreting flip books; and (4) orienting themselves in Yellowstone National Park with the help of maps and coordinate grids, and surveying the school playground with a simple transit. The investigations in the last part, dealing with the motion and tracks of rolling and interacting steel balls, relate the ideas and techniques developed in early parts of this unit to the matter, interactions, and energy concepts of the physical-science sequence.

THE FIFTH LEVEL

The conceptual development of the SCIS program continues as examples of energy transfer are introduced in the physical-science unit Energy Sources and of food transfer (the organic equivalent of energy) in the life-science unit

Communities. Energy Sources. During the fifth year, the pupils continue their study of matter and energy in the Energy Sources unit and also extend their skills in conducting scientific investigations. Their attention is focused on the energy transformations that accompany the interaction of matter in solid, liquid, and gaseous forms. The children's qualitative descriptions of energy transfer from a source to a receiver prepare them for later quantitative investigations of energy exchange.

The introductory investigations employing rolling spheres and paper airplanes are used to review interaction, variables, and other concepts with which the children have become familiar. These experiences and work with rotoplanes (propeller-driven rotating platforms) provide background for the invention of *energy transfer* and the identification of energy *sources and energy receivers.*

The children apply the new concepts to situations in which motion or temperature change provide evidence of energy transfer. They experiment with (1) stopper poppers, in which compressed air serves as energy source; (2) spheres rolling down ramps and colliding with a movable target, in which the rolling spheres serve as energy source; (3) the dissolving of sodium thiosulfate or magnesium sulfate, in which the water or the solid material acts as energy source; and (4) the melting of ice, in which the ice serves as energy receiver. *Communities.* In the *Communities* unit pupils investigate the food relations within a community of plants and animals. They experiment with germinating plants, discovering that food stored in cotyledons is consumed; however, another source of food, photosynthesis, supports the plants' growth.

The children observe the feeding behavior of animals in terraria containing various plants and animals. They identify the food chains and infer that photosynthesis in green plants not only supplies food for the plants but indirectly also for the animals in the community. The children count the large number of wheat seeds eaten by crickets and the few crickets eaten by a single frog. On the basis of these data, the *food pyramid* is introduced.

When an animal or plant in the terrarium dies without being eaten by another animal, the children place the dead organisms in a vial and cover it with moist soil. They observe the organism's gradual decomposition along with the appearance of mold or an unpleasant order. The children are told that organisms that satisfy their energy needs by decomposing the bodies of dead plants and animals are bacteria and molds. The transfer of food through a community is illustrated by means of a chart showing the food relations among plants, animals, bacteria, and molds. The plants are identified as *producers,* the animals as *consumers,* and the molds and bacteria as *decomposers.* The interacting producers, consumers, and decomposers in a given area constitute the community.

THE SIXTH LEVEL

The last year of the SCIS program contains both a climax and a new beginning. The study of *Ecosystems* in the life science sequence integrates all the preceding units in both physical and life sciences as the young investigators study the exchange of matter and energy between organisms and their environment. The physical science unit *Models: Electric and Magnetic Interactions* introduces the concept of the scientific model and thereby opens a new level of data interpretation and hypothesis making.

Ecosystems. Through the investigations in the *Ecosystems* unit children become aware of the roles played by oxygen, carbon dioxide, and water in the maintenance of life. When this understanding is combined with the habitat, populations, community, and other concepts introduced in the SCIS life science sequence, the term *ecosystem* acquires its full meaning.

Initially, the children review the ideas introduced in the five earlier units by building a composite terrarium-acquarium. The organisms living in the containers represent plants, plant eaters, and animal eaters--- organisms that flourish under varying environmental conditions. The *ecosystem* is defined as the system composed of a community of organisms interacting with its environment.

After they observe water droplets on the inside of the terraria-aquaria, the children clarify the role of water in an ecosystem. The *water cycle* refers to the succession of evaporation and condensation of water.

The pupils study the carbon dioxide-oxygen exchange between organisms and their environment. They test their own preconceptions about oxygen and carbon dioxide when they compare the gases formed by plants exposed to light and to the dark, by animals living in a community with plants and animals in isolation. The production and consumption of the two gases is described as the *carbon dioxide-oxygen cycle. Models: Electric and Magnetic Interaction.* The activities in the *Models* unit are directed toward increasing the children's understanding of electrical and magnetic phenomena at the levels of concrete experiences and of abstract thought.

Children review some of their work in the *Interaction and Systems* and *Subsystems and Variables* units. Next, children explore the circuits' energy sources, constructing a battery (or *electrochemical cell*) to operate light bulbs and other circuit elements. Finally, the model concept is introduced in connection with mechanical and electrical "mystery systems." The pupils must explain the systems in terms of assumed objects that cannot be seen directly.

The second part of the unit is devoted to magnetism and various models, such as the magnetic field and the magnetic poles. In Part Three the children investigate more complicated electric circuits, and the *electric current* model is introduced to unify their theories. This distinction between *series* and *parallel* electric-circuit connections can be used for predicting the operation of light bulbs and other circuit elements if a consistent model for electric current has been chosen. In the concluding activities, electric energy sources and the chemical processes related to electric current flow are considered again.

The Teaching Method. The SCIS curriculum model employs a consistent teaching strategy throughout each unit. The children are provided materials with which they are allowed to interact in their own way; they are, in other words, allowed to *explore* the materials thoroughly and completely. Since children learn most things through their own spontaneous behavior, the exploration phase of the SCIS model fits children very naturally. Spontaneous learning is limited, however, by the child's preconceptions.

There comes a time when he needs to be given a new concept which will allow him to then see the phenomenon he is observing in a new light. This input to the child is provided by the teacher who takes the ideas which the children have expressed during their explorations and provides a definition or a term for a new concept. When, for example, the children find that steel nails will be attracted to a magnet from any point in the space around that magnet, the teacher can now provide the name *magnetic field* for the space around the magnet. In other words, the teacher has *invented* a concept for the learners from the information their own explorations provided them. Sometimes a child will make the *invention* but generally the teacher provides that input to the learner's cognitive structure.

After the child has the concept of magnetic field, he can now begin to ask himself many things about it. Will the magnetic field attract pennies? How far from the magnet can a steel nail be placed and still have the magnetic field attract it? The child can now *discover* many items of information about the new conceptual invention. *Discovery* is, therefore, only a part of the teaching method used by the SCIS program.

If you carefully consider how you truly become functional with any new object, event, or situation, you find that you first learn all you can about it by involving yourself with it; in other words, you conduct an exploration. You then provide yourself some type of label for referring to the concept your explorations uncovered; you engage in invention or request someone else to do it for you. After you have developed basic and probably initial understandings regarding the new phenomenon, you try to extend those understandings by discovering all you can about the object, event, or situation from the frame of reference of the new conceptual invention. You have, in short, asked the object, event, or situation about itself, and *that is inquiry*. Discovery, therefore, contrary to much of the existing literature, is not equivalent with inquiry. Rather, *discovery is a part of the entire inquiry process.*

You might be tempted to think that the information which the SCIS units provides children would be told to them in much less time than using the units. You are, of course, correct *but* the purpose of the SCIS units is *not* to transmit information (even though the children do gather much information). Rather, the units exist to achieve the purposes stated in Chapter One. The SCIS program does not believe that transmitting scientific information to a child is educating him in that discipline; they believe, as the units demonstrate, that to educate a child in science is to provide him experiences which will permit him to learn how to learn.

ELEMENTARY SCIENCE STUDY[3] (ESS)

The Elementary Science Study presents a model for those teachers who wish to build their own curriculum from separate and diverse units involving many areas of interest. No attempt is made by ESS to direct a sequential course of science experiences. Rather, the teacher determines which areas will be investigated and builds his own program from the units offered.

All the units motivate children to explore, invent, and discover things. The major aim is to encourage children to examine the world around them and to acquire the desire, interest, and ability to continue to analyze, relate, and understand life.

PROCESS AND CONTENT

Subject areas represented in ESS include botany, zoology, astronomy, ecology, geology, chemistry, mathematics, and physics. *Elementary Science Study* is comprised of fifty-six units representing a full offering at the various grade levels.

The ESS program provides learning experiences using materials children can work with, problems they can investigate, and questions they can ask and find answers for themselves.

The Introduction in each Teacher's Guide discusses the goals and purposes of the unit. There is always rich content, but equally important to accomplishing the goals are the processes the children employ to solve problems of interest and concern. Those processes are:

Observing – Scientific observation may determine, govern, or restrict the observation, and thereby differentiate a scientific observation from a casual

[3]The headquarters of this project is located at the Educational Development Center, Newton, Mass. The material upon which this chapter is based was supplied to the Committee by Dr. Charles Oviatt, McGraw-Hill Book Company. A commercially-developed program based upon the ESS model is EXPERIENCES IN SCIENCE (EIS) published by the McGraw-Hill Book Company.

observation.
Measuring - students may engage in types of measurement not previously used in the elementary schools; for example, measurement of a microscopic field and the use of a balance.
Classifying - students develop the use of predetermined criteria.
Data processing - this may be seen as having three phases: (1) *Collecting and/or recording* - transferring observations and experiences into meaningful information. (2) *Organizing* - arranging data into usable categories. (3) *Communicating* - relating data to others through various means - charts, graphs, drawings, and reports.
Evaluation and interpretation of data - development of the ability to use data meaningfully in order to solve problems or make inferences.
Inferring - this is seen as having three aspects: (1) *Hypothesizing* - the ability to reason a solution or outcome to a future problem or event. (2) *Predicting* - the ability to use past experience or accured knowledge to forecast eventualities. (3) *Theorizing* - the ability to state well-supported generalizations about experiences and outcomes.
Manipulating equipment - self-explanatory.
Using scientific notation and terminology - self-explanatory, except that this ability should grow from a logical need and experience, and not from a teacher's desire to cram factual knowledge into a student.

The Elementary Science Study is designed to be open-ended, which means that one cannot predict exactly what material will be covered, or just what experiences will be gained as a class studies a given unit. If, in fact, objective evaluation can be a part of the teacher's evaluative effort, it must reflect precisely the events that have occurred in that particular class.

Descriptions of Representative Units

ANIMAL ACTIVITY

This unit introduces children to several techniques for observing and measuring the activity of mice, gerbils, or other small animals. Children use an exercise wheel coupled to a counter which records the number of times the wheel turns, to gather data on the activity of animals under varying conditions. They can test the effect of such factors as diet, age, size of cage, time of day, and noise on an animal's liveliness.

The student booklet, *Experiments on Animal Activity*, gives accounts of similar experiments performed by biologists investigating the activity of mammals. The case studies make good starting points for discussions and can help children to see the possible value and interest to others of their own investigations.

Grades: 4-6. Children at other grade levels have enjoyed working with activity wheels as well.
Scheduling: Animal Activity is best taught on a flexible schedule. The study generally extends over a period of two months. Since most experiments take many days to complete, only a few minutes may be needed for the unit each day. Informal work with small groups has been most effective.

Related Units: ANIMALS IN THE CLASSROOM
BEHAVIOR OF MEALWORMS
CRAYFISH
EARTHWORMS
TRACKS

ATTRIBUTE GAMES AND PROBLEMS

This unit provides an opportunity for children to deal with problems involving classification and the relationship between classes. The understandings and skills developed are useful in many areas of the curriculum-- science, social studies, mathematics, language arts, or wherever classification is used.

Children work with a variety of colored wooden and plastic shapes, sometimes developing puzzles and games of their own, sometimes attempting to find solutions to questions posed on the Problem Cards.

Grades: K-8 and beyond. The same materials are used for all levels, although in different ways, depending on the age and maturity of the children.

Scheduling: The unit lends itself nicely to informal teaching in small groups at times not necessarily scheduled. Individual children, pairs, or any number of children may engage in the activities. The teacher should make suggestions whenever the situation warrants.

Related Units: MYSTERY POWDERS
ROCKS AND CHARTS

BONES

This unit capitalizes on children's natural interest in skeletons by engaging them in activities with real bones. They can assemble a skeleton from a pile of loose bones, or even prepare a set of bones themselves. Such experiences help students to become familiar with a variety of bones, to notice the similarities and differences among them, and to experience the satisfaction (and frustration) of building skeletons. In addition, they learn many important facts about the skeletal system, and gain some sense of their own body structure and the way it functions.

Grades: 4-6

Scheduling: 10-25 lessons, depending on the number of activities undertaken.

Student Books: "Bone Picture Book" and "How to Make a Chicken Skeleton"

Film Loops: "Head and Neck" — "Knee and Elbow" — "Shoulder" — "Hand" — "Foot"

Related Units: STRUCTURES
TRACKS

BUTTERFLIES

Children can witness the complex and fascinating life cycle of an insect by raising butterflies in their classroom. While the children watch and care for their own animals, they ask many questions about them. In time they find answers to some of their questions, and begin to develop a sense for the way in which an animal lives, grows, and reproduces.

Children become very involved with their animals. They observe their appearance and behavior in great detail and they learn to care for and to protect a living thing. The excitement the butterflies engender extends naturally into many activities. Children paint butterflies, write about caterpillars, and create butterfly dances.

Butterfly cocoons can be purchased. Teachers are encouraged, however, to take their classes out to collect their own animals. Suggestions for finding and collecting caterpillars and butterflies, as well as a list of commercial suppliers, are given in the Teacher's Guide.

Grades: K-5. In the lower grades, the teacher will probably have to feed the adult butterflies. Children will be able to care for the caterpillars themselves.

Scheduling: Plan on at least six weeks within which one life cycle can be completed. The children will need at least a few minutes each day to feed their animals and to keep their cages clean.

Film: "Life Cycle of a Butterfly" (16mm, silent, 18 min., color)

Film Loops: "Black Swallowtail Butterfly: Egg-Laying, Hatching, and Larvae"
"Black Swallowtail Butterfly: Larval Molt"
"Black Swallowtail Butterfly: Preparing to Pupate (1)"
"Black Swallowtail Butterfly: Preparing to Pupate (2)"
"Black Swallowtail Butterfly: Pupal Molt"
"Black Swallowtail Butterfly: Emergence"

Student Books: "How a Moth Escapes from Its Cocoon"

Related Units: BRINE SHRIMP
BUDDING TWIGS
EARTHWORMS
EGGS & TADPOLES
CRAYFISH
POND WATER

DAYTIME ASTRONOMY

Keeping track of familiar events in the sky is a good introduction to astronomy. *Daytime Astronomy* suggests ways to help children organize their observations of familiar phenomena and changes in the sky throughout the year.

The activities are grouped into various sections. "Where is the Sun?" deals with long-range changes in the apparent motion of the sun. "Shadows and Shadow Clocks" centers around the sun's daily motion and telling time.

In "Globe Problems," children use a globe oriented outdoors in sunlight to investigate problems of time, seasons, and directions. In "The Earth and Moon: A Scale Model," children construct a scale model of the earth and moon, and use them outdoors to set up astronomical events in miniature.

Grades: 1-8. The first two sections of the unit are suitable for all grades. "Globe Problems" and "The Earth and Moon: A Scale Model" are intended for grades 6-8.

Scheduling: The unit extends throughout a year, mostly outdoors on sunny days. Most activities involve weekly or less frequent observations at periodic intervals. Some parts of the last section can be done in a few consecutive classes whenever it is convenient.

Related Units: LIGHT AND SHADOWS
OPTICS
WHERE IS THE MOON?

KITCHEN PHYSICS

This unit introduces children to some properties of common liquids-- how fast they flow through various size openings; how they fall and break up; how they heap up; are absorbed, evaporate, attract, and repel. Children measure the height of liquid columns with paper strips which can be arranged to make a graph. They collect data which they can analyze, discuss, and use to explain experimental results. They assemble and use a simple balance and then modify it for use as a tensiometer.

Grades: 6 and 7, primarily. In 8th and 9th grade, a still more quantitative approach is possible. For a selection of activities involving the properties of liquids, especially for younger children, see the unit: *Drops, Streams, and Containers.*

Scheduling: 12-20 class periods, depending upon the number of activities undertaken.

Film Loops: "Beading of a Water Column"
"Water Rise in Blotter Strips of Graded Width"
"Water Rise in Blotter Strips Exposed and Enclosed"

Related Units: DROPS, STREAMS, AND CONTAINERS
WATER FLOW

OPTICS

This unit provides materials with which students can observe and analyze many of the interesting properties of light by direct experiment. They look at light itself and its interaction with transparent objects, and with things that act as mirrors. The activities are grouped into three main sections: in the first, children explore aspects of reflection and some of the properties of shadows. They then go on to look at colored light, working with colored beams to create a variety of light-mixing effects. The third group of activities is concerned with refraction of white and colored light by liquids.

While they investigate the various optical phenomena with the equipment and raise questions about what they see, children also are exploring why the world looks the way it does to us, that is, what the properties of light have to do with our visual experience.

Grades: 4-6 and beyond.

Scheduling: Plan on ten or twelve hours to cover the activities in the Teacher's Guide. Two one-hour sessions per week has been a good arrangement.

Related Units: DAYTIME ASTRONOMY
LIGHT AND SHADOWS
MIRROR CARDS

PEAS AND PARTICLES

Peas and Particles is a unit on large numbers and estimation. Children deal with numbers informally, devising ways to estimate and approximate large amounts, sizes and distances.

At first youngsters estimate large numbers of peas, marbles, or other objects in jars. In the process, they develop a variety of counting methods which can be compared and refined. The numbers generated by their estimations can also be the basis for discussions of the usefulness of approximate numbers, and "rounding off" numbers. Later the children apply similar strategies to problems of their own choosing.

The activities give children experience with numbers and counts as we often meet them in newspapers, budgets, surveys, and other areas of everyday life rather than as exact answers to textbook problems.

Grades: 4-6 and beyond. Younger children enjoy the activity but have trouble with the arithmetic. Older groups, including adults, enjoy estimating.

Scheduling: Approximately 12-15 class periods. Some of the activities can be carried out by small groups or by individual students, but the unit is excellent for a large group and classroom discussions. Counts and estimates can be done indoors or out.

FIFTY-SIX UNITS COMPRISE THE ESS OFFERING

Following is a complete list of ESS units.

Animal Activity
Animals in the Classroom
Attribute Games and Problems
Balloons and Gases (August 1971)
Batteries and Bulbs
Batteries and Bulbs II (August 1971)
Behavior of Mealworms
Bones
Brine Shrimp
Earthworms (August 1971)
Eggs and Tadpoles
Gases and Airs
Geo Blocks
Growing Seeds
Heating and Cooling (August 1971)
Ice Cubes
Kitchen Physics
Life of Beans and Peas
Light and Shadows
Mapping (August, 1971)
Match and Measure (August 1971)
Microgardening
Mirror Cards
Mobiles
Mosquitoes (August, 1971)
Musical Instruments (August, 1971)
Mystery Powders
Optics (January, 1971)
Budding Twigs
Butterflies
Changes
Clay Boats
Colored Solutions
Crayfish
Daytime Astronomy (August 1971)
Drops, Streams, and Containers
Peas and Particles
Pendulums
Pond water
Primary Balancing
Printing
Rocks and Charts
Sand
Senior Balancing
Small Things
Sink or Float (August 1971)
Pattern Blocks
Spinning Tables (August, 1971)
Starting from Seeds (August, 1971)
Stream Tables (August, 1971)
Structures
Tangrams
Tracts (August, 1971)
Water Flow (August 1971)
Where is the Moon?
Whistles and Strings (August, 1971)

SCIENCE--A PROCESS APPROACH[4]

This program is an interdisciplinary science program in which the primary purpose is the development of skills in the process of science. The program is sequential. The order of exercises and activities is determined by hierarchies of process skills. The skills are stated as behavioral objectives. They describe what the child can be expected to do after he has carried out the activities of the exercise. Children in the primary grades will derive much more from the study of science if they learn the behaviors of scientists. Although the behaviors of scientists are complex, they have been classified into a number of process skills, some simple and some more complex. The intellectual activities of scientists are the "processes" which form the core of *Science--A Process Approach*. Children learn to do what scientists do and become highly involved in using the processes of science.

Certainly you cannot teach scientific processes without considering content. The content of science is included in *Science--A Process Approach*, but the

[4]Project Headquarters Address: American Association for the Advancement of Science, 1515 Massachusetts Ave. N.W., Washington, D. C. 20005.

emphasis is on the processes. A wide variety of science content areas are explored, content is the vehicle or means...not the end. In attaining competency in the processes of science, children will deal with such topics as plants, animals, energy, light, temperature, heat, solids, liquids, gases, life cycles, electricity, magnetic fields, falling bodies, forces, motion, the solar system, and many others.

The program provides instruction in science for the primary grades which emphasizes the development of competence in skills basic to further learning. *These processes are called observation, numbers, space-time relations, classification, measurement, communication, prediction, and inference.* The child is introduced to a variety of content in acquiring these skills -- he learns about plants, animals, rocks, weather, solutions of chemicals and the motion of objects. The content he learns is derived from familiar objects and phenomena in the world around him. The hope is that, by the end of the third grade, the child will have acquired some important fundamental process skills, a good many basic scientific concepts, and some organized knowledge about the natural world.

The exercises for the intermediate grade promote the retention and refinement of process skills by continuing to provide for a process emphasis in instruction. At this level the sequence builds upon the simpler competencies to fashion instructional exercises which are at once more complex, more comprehensive, and more like the kind of activities engaged in by a scientist when solving a problem. The various exercises deal with such integrated activities as formulating hypotheses, making operational definitions, controlling and manipulating variables, experimenting, formulating models, and interpreting data.

ORGANIZATION OF THE PROGRAM

The program is divided into parts, one part for each grade. The levels of achievement desired also function easily in a non-graded or individualized program.

The titles of a few exercises in each part are shown in figure 1 to illustrate the variety of science content in the program.

PART	LEVEL	PROCESS	TITLE OF EXERCISE
A	Kindergarten	Observing	Observing Temperature
		Observing	Observing Solids Changing to Liquids
		Classifying	Classifying Animals
B	Grade 1	Observing	Observing the Weather
		Observing	Observing Some Properties of Magnets
		Observing	Observing Color and Color Change in Plants
		Observing	Observing Mold Gardens
C	Grade 2	Measuring	Measuring Forces with Springs
		Classifying	The Solid Liquid and Gaseous States of Matter
		Communicating	Using a Sundial to Describe Shadow Changes
		Observing	Observing Animal Responses to Stimuli
		Predicting	Surveying Opinion

D	Grade 3	Predicting	Describing the Motion of a Bouncing Ball
		Measuring	Measuring Rate of Evaporation of Water
		Inferring	Loss of Water from Plants
		Measuring	Describing and Representing Forces
E	Grade 4	Controlling Variables	Liquid Movement in Materials
		Interpreting Data	Guinea Pig Learning in a Maze
		Inferring	Inferring Connection Patterns in Electric Circuits
		Classifying	Classifying Minerals
		Communicating	Force and Motion
F	Grade 5	Defining Operationally	Determining the Direction of True North
		Controlling Variables	Effect of Practice on Memorization
		Interpreting Data	Effect of Temperature on Reaction Time
		Controlling Variables	Human Reaction Time
		Interpreting Data	Moon Photos
G	Grade 6	Experimenting	Temperature and Heat
		Experimenting	The Growth of a Root
		Experimenting	Variation in Perceptual Judgments: Optical Illusions
		Experimenting	Semi-permeable Membranes
		Experimenting	Plants and Light of Different Colors
		Experimenting	Communication Among Ants

Figure 1

Each part or grade level includes--

Teaching Guides - teacher text materials made up of individual booklets, one for each exercise, and a comprehensive program description booklet.

Process Development Laboratory - the necessary classroom laboratory experiment materials supplied with a movable and flexible set of storage modules.

Behavioral Hierarchy Chart - the "skeletal structure" or educational blueprint of the program. The chart does these things:

1. Displays the skills to be taught and their sequence.
2. Shows dependencies and intradependencies of the skills.
3. Presents all the exercises in relation to the skills, provides a sequence of learning, and at the same time, defines the objectives of the exercises.
4. Accurately predicts what the child will achieve in each skill and each exercise.

The ordering in the chart implies that the acquisition of a given skill depends upon acquisition of skills at a level below it in the hierarchy. Thus the hierarchy of objectives determines the order of teaching the processes within any of the exercises.

The objectives of the Observing exercises are arranged into a hierarchy of competencies in Observing. A small part of the "Observing" hierarchy is shown in Figure 2.

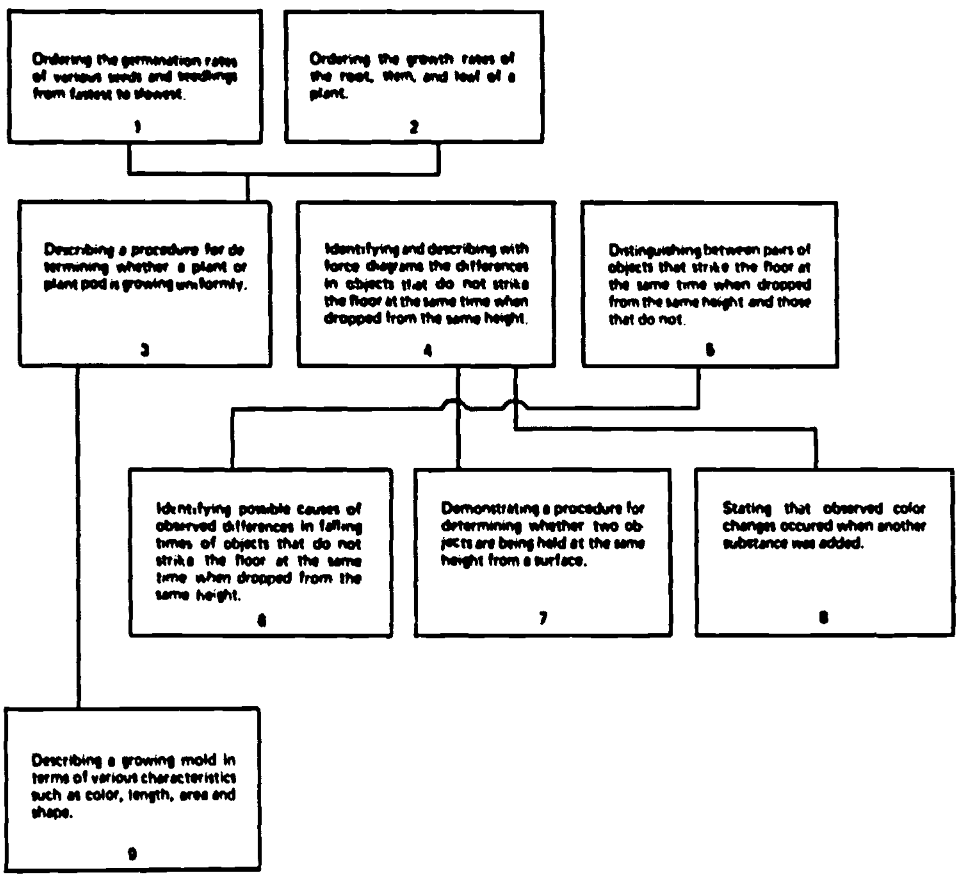

Figure 2
Hierarchy of "observing" Behavioral Objectives

The *commentary for teachers* is not part of each grade level, but must be ordered separately. The *commentary for teachers* has been written to help teachers teach *Science - A Process Approach*. It contains a short chronology of the development of the program, a statement of the broad objectives and unique features of this program, a description of the process of science and suggestions for developing them, a discussion of the various parts of exercises with samples, and a variety of background science content papers related to the process. This book should be used as a guide and as a reference by the teacher.

Student Evaluation

In the primary grades, Part A through Part D, each exercise includes an appraisal activity which the teacher uses to see how well her class has progressed in achieving the exercise objectives, and an individual competency measure to assist the teacher in determining just what an individual child is able to do. Appraisal activities are for the whole class, designed to evaluate overall class performance in a general sense. They are provided to help the teacher decide when the class has progressed sufficiently to move on to the next exercise.

Each exercise in Part E and Part F has both an individual and group competency measure. The group competency measure replaces the exercise appraisal in these parts. The individual competency measure is designed to evaluate the achievement of individual children, and the group competency measures are written tests to be administered to the class, and are designed also to test individual achievement. When a competency measure is administered to an individual, the teacher can observe just what the child is able to do. These tests also have the advantage that the child's achievement will not depend on what he is able to read. The group competency measures have the advantage of all group written tests -- they can be administered simultaneously to all children in a class. A child's achievement on the group tests will, of course, depend in part on his ability to read and there is little opportunity in a written test to test how a child handles equipment or plans and carries out an investigation.

In Part G, in which most exercises are experimenting exercises, four experimenting exercises are designated evaluation exercises.

The appraisal exercise and the competency measures provide two means of immediate appraisal to supplement the teacher's judgement and observations in the classroom. In the overall evaluation strategy of *Science - A Process Approach*, a separate technique has been developed to appraise the long-range achievement of process goals. This is the *Science Process Measure*. The *Science Process Measure* is designed to assess pupil capabilities in all the basic science processes identified by the curriculum. With the behavioral hierarchies as a guide, seven process measures have been developed for the eight basic processes, which are combined in a single test booklet. The results of the *Process Measure* provide an inventory of the individual child's achievement in the process skills. The resulting performance profile thus obtained specifies the behavior which, as yet, the child cannot demonstrate by actual performance. The overall evaluation strategy used in Science-A Process Approach is summarized in Figure 3.

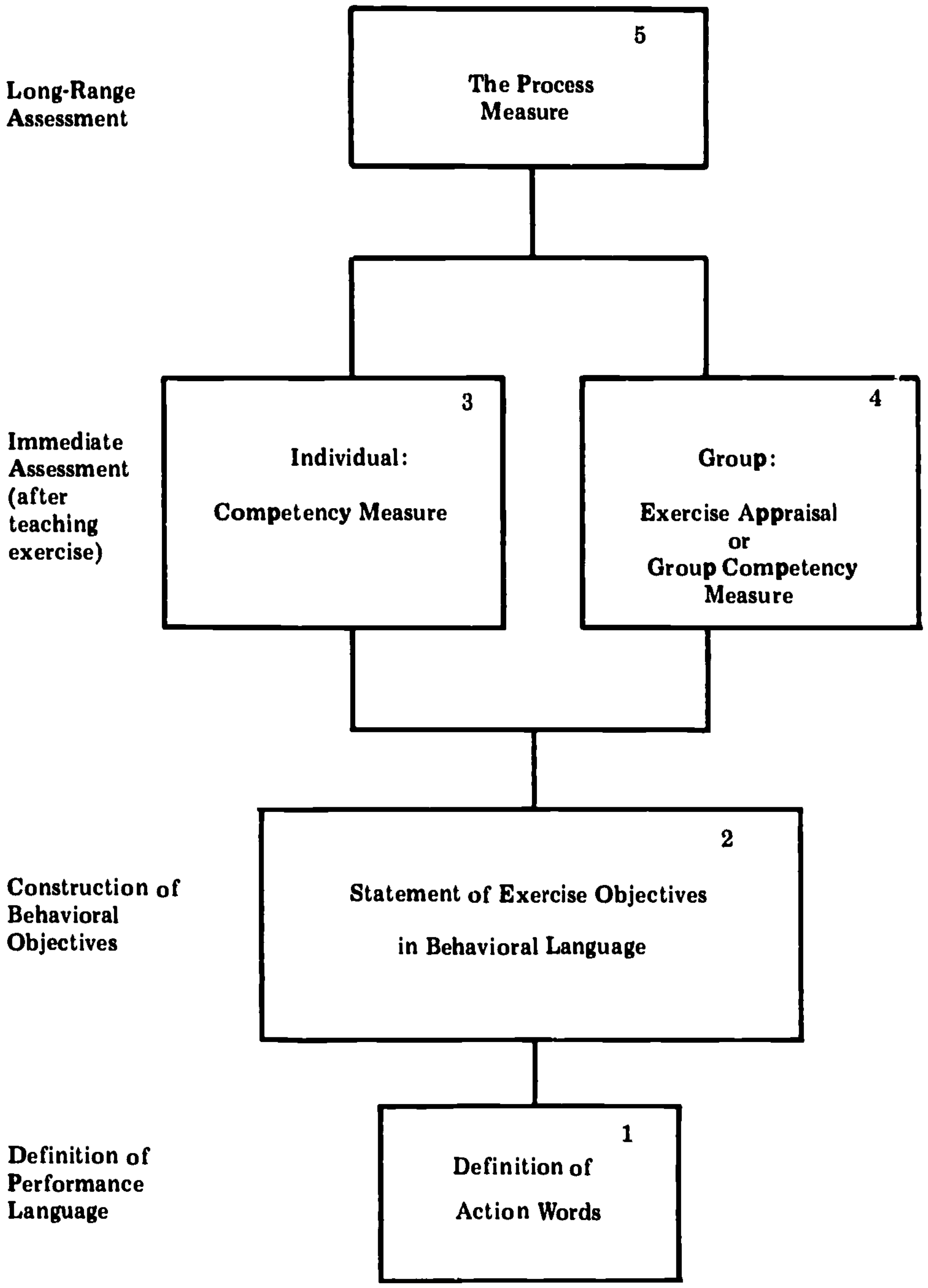

Figure 3

The Evaluation Instruments: An Overall Evaluation Strategy

THE LOCALLY DEVELOPED CURRICULUM MODEL

"Does a school system have to implement a commercially published science curriculum in order to have an inquiry science program?"

This question, which has been frequently asked by educators, should be answered with an emphatic "No". The commercial curricula materials are not absolutely necessarily a solid inquiry science program. The model presented in this section presents an alternate choice to those schools which do not wish to implement one of the existing commercial curricula.

Once the decision has been made that a locally designed curriculum is the logical approach to pursue, the local educators and consultants must decide what is to be included in the program. Of course, there is no question regarding the inclusion of those attributes which are basic to the science philosophy as presented in Chapter One. An inquiry oriented curriculum must promote those attributes which are listed below.

(1) The curriculum must be laboratory centered, that is, the learner must be engaged in experiencing the processes of science. These experiences must include the same operational processes in which the scientist is engaged. A partial compilation of these processes would include observing, classifying, measuring, experimenting, interpreting, and predicting. Thus, the learner is a scientist in this approach.

(2) The curriculum must, through the activities, reflect an understanding of the child's psychological development as presented through the theories of Jean Piaget.[5]

(3) The curriculum must aim toward the rational development of the learner based on the NEA document, *The Central Purpose of American Education.*[6]

An overview of the science curriculum based on these attributes can be illustrated with the following diagram:

Kindergarten — THE CURRICULUM — Grade 6

The Content Vehicle
Science Processes
Rational Processes

Qualitative and Concrete Activities → Quantitative and Abstract Activities

The psychological flow of the curricular activity must progress from a qualitative, concrete type toward a quantitative, abstract type which coincides with the intellectural development of the learner. Woven into this progression are experiences which require the learner's operational utilization of both rational and science processes. Local curriculum developers must select the science content area which will permit the incorporation and developmental attainment of these curricular attributes.

Another decision which the educator must make relates to the approach to the lesson activity. One approach is based on unrelated, day to day activity. This

[5]Jean Piaget, PSYCHOLOGY OF INTELLIGENCE (Patterson, N.J.: Littlefield, Adams and Company, 1963), p. 123.

[6]THE CENTRAL PURPOSE OF AMERICAN EDUCATION. (Washington D.C.: Educational Policies Commission, NEA, 1961.)

might be described as the pursual of inquiry simply for the sake of inquiry. There is no attempt to correlate individual activities.

A second approach is more complex with regard to day to day coordination. This type perhaps can be described as being more of an investigatory nature since the investigation of a single topic area might be pursued over a period of days.

The following diagrammatic presentation of student activity examples clarifies the differences between these two approaches. Remember, however, the development of all the attributes and objectives of the philosophy as listed in Chapter One can be accomplished through either approach.

	Approach I (Unrelated Activity)	Approach II (Coordinated Activity)
First Day -	Observe and record differences between a frog and a toad.	Observe and record differences between a frog and a toad.
Second Day -	Observe and classify a sack of rocks.	Determine if there are differences between how far a frog and a toad can jump.
Third Day -	Experimentally determine which kind of cloth, cotton or wool, absorbs water faster.	Determine if there are differences between how cold temperatures affect a frog and a toad.
Fourth Day -	Develop a set of data relative to different rubber balls and predict which will bounce highest.	Determine if there are differences between how a frog and a toad react to salt water.
Fifth Day -	Obtain and graph the data relative to the number of petals which a particular wild flower species has.	Observe and determine how a toad and a frog eat.

Figure 4

Types of Inquiry Approaches

The second approach is the more systematic of the two. Its very nature suggests investigatory types of activities and, consequently, the curriculum which utilizes this approach will reflect the operations basic to science. A more detailed examination of this approach will reveal how the operational utilization of some science and rational processes are achieved in the individual activities. Each activity is listed with the kind of science and rational process inclusion which one could expect. Typically, these could vary for each local system.

Model Activity In Which Child Is Engaged	Inquiry Attributes Developed by Activity
I. Observe and record physical differences between a frog and a toad.	(a) Science processes engaged are observing, recording, and measuring.
	(b) Rational processes engaged are comparing, and evaluating.
II. Determine if there are differences between how far a frog and a toad can jump.	(a) Science processes engaged are experimenting, observing, measuring, recording, and interpreting.
	(b) Rational processes engaged are comparing, deducing, evaluating, and generalizing.
III. Determine if there are differences between how cold temperatures affect a frog and a toad.	(a) Science processes engaged are experimenting, observing, measuring, recording, and interpreting.
	(b) Rational processes engaged are comparing, deducing, evaluating, and generalizing.
IV. Determine if there are differences between how a frog and a toad react to salt water.	(a) Science processes engaged are experimenting, observing, measuring, recording, and interpreting.
	(b) Rational processes engaged are comparing, deducing, evaluating, and generalizing.
V. Observe and determine how a frog and a toad eat.	(a) Science processes engaged are observing, and interpreting.
	(b) Rational processes engaged are analyzing, and comparing.

Figure 5

An Inquiry Approach

"What kind of science content is learned in the previous activities?" This is a valid question. It is obvious from the presentation which kinds of science and rational processes have been structured into the activities. Not so obvious, however, is the content which the activities present. The frog and toad have been used as the vehicles to promote the previously identified processes. Much content is learned relative to the animals' external anatomy and their behavior toward external stimulants, with all the learning coming through first-hand experiences with the toad and frog.

Another question which might be asked relates to the grade level of the previous activities. Because the processes which have been structured into the investigation are characteristic of the higher level of the learner's psychological development, the activities must be placed at the upper grade levels.

The Complete Curriculum. The total science curriculum must accommodate all learning levels from kindergarten through grade six. Obviously, this will require a great amount of time from all involved in designing the activities. The combined activities from all levels can best be presented in the form of a science curriculum guide for the local system.

This local guide, if based on the philosophy from Chapter One, can be the foundation of a solid inquiry program.

The locally designed program must never turn into the traditional "hodge-podge" approach of expecting each individual teacher to be responsible for designing the activities and obtaining the materials necessary for the program under his guidance. Administrators must be responsible for maintaining the entire program through cooperative planning with individual teachers.

The value of a local guide comes from its being designed to meet local educational needs. The curricular activities can be designed to take advantage of local resources and local educators are involved in designing their own program.

There are many programs which are promoted as being inquiry-centered. Before adopting any of these programs be certain it meets the criteria for an elementary school science program set forth in Chapter One.

CHAPTER 3

ORGANIZING AND EVALUATING A SCIENCE PROGRAM IN YOUR SCHOOL

The need for change must be recognized before any progress can be made toward an action program designed to bring the science curriculum in line with present trends and current research. The leadership for such an action program may begin with a school administrator, the classroom teacher, or an interested school patron. Once interest is aroused and the need for such a program recognized, there must be an organizational plan to assure effective curriculum change; in this plan must be the appropriate school administrator, the curriculum supervisor, the classroom teacher, the interested school patrons, and appropriate consultants.

THE PLANNING PHASE One individual must serve as the planning coordinator and provide the necessary organizational leadership to form the action group. The following discussion topics and activities are usually effective during the planning phase:

1. A study to decide on action to be taken to design an appropriate science curriculum.
    a. Exploration of education objectives
    b. Identification of needs
    c. Recognition of cultural, economic, and sociological differences
    d. Orientation to total environment with attention to geographical location.
2. A study of a science curriculum in accord with current national trends.
    a. Recognizing the teacher as the key to an effective program.
    b. Designing or choosing a science curriculum that is developmental in sequence based on levels of abstraction, rather than traditional patterns of learning based on topic sequences.
    c. Using inquiry-centered experiences as opposed to the traditional subject-centered approach.
    d. Teaching for behavioral change.
    e. Utilizing materials to meet stated educational objectives.
3. An in-service program for all involved in science curriculum planning should include:
    a. Teacher discussions
    b. Consultant visitations.
    c. Examination of current materials.
    d. Special training, usually with consultant aid, in teaching the inquiry approach.
4. Formulation of a total action program to effect science curriculum change on a continuing basis of (a) design, (b) trial, (c) evaluation, (g) revision....

Educators, in contemplating the local development of a science curriculum, must carefully weigh the advantages and disadvantages of such an endeavor. The following points are listed for consideration when determining the feasibility of a locally designed curriculum.

(1) Educators must be careful that the costs in designing the local program do not exceed those in obtaining a commercial program. Local programs can in some situations become more expensive than a good commercial program.

(2) The success of the locally designed program, as with any inquiry program, is dependent on the teachers' orientation and acceptance of the philosophy of science as inquiry. The initial development of this philosophy is probably best promoted by acquiring competent consultative assistance.

THE ROLE OF THE TEACHER

Today's elementary teacher must experiment freely in the classroom; however, modern research and current materials make it impractical for teachers to design total programs. A teacher may need to create materials and must be creative with the children utilizing all types of materials. Adaptation of materials to the teacher and the child is a normal everyday process; project-developed, for example, SCIS, materials must not be considered final answers.

Teachers who engage in in-service programs based on experimentation with new approaches and who exchange ideas with other teachers who are engaged in similar experimentation assure the child of an improved learning experience. The teacher must be involved in the same spirit of inquiry she plans for her children to experience.

THE ROLE OF THE ADMINISTRATOR

The administrator may be the superintendent, the principal or the science supervisor, depending on the school system. In any case, the responsible administrator MUST be the curriculum leader for effective change; he must accept this responsibility from the beginning. An effective developmental program that extends throughout the total school experience of young people cannot be left to chance nor even to a dedicated individual teacher's initiative. It must be planned and supervised.

The appropriate administrator must work out the lines of communication for continuous science curriculum study and revision. These lines of communication must include the teacher, the local school board, school patrons, and extend into the junior and senior high school.

It is recognized that the school curriculum must be balanced. The school administrator is responsible for a balanced curriculum in which science is neither over nor under emphasized but does become an important and integral part of the child's total educational experience. He acts as stimulator and moderator for all classroom change which is educationally significant.

THE ROLE OF SCIENCE CONSULTANTS —from outside school system

Consultants, if they are to be effective, will work with administrators and teachers to provide for the school needs as these needs are recognized by the local school district and the community.

A consultant does not dictate the approach nor the curriculum. He works closely with interested professional personnel to develop an approach which assures an appropriate transition from where the teachers are to where they desire to go. A consultant must remember that the final objective is education for continued change. The consultant should have the attitude of being a co-worker in curriculum planning and in in-service education.

Consultant services should not be for stimulation purposes on a one-time basis. *Most effective use of consultant services is over a period of time so that follow-up activities may be planned and problem areas discussed.*

In order that you might obtain help from people who have had experiences with inquiry-centered science programs, a list of consultants is available from the state science consultant. These people are all located in Oklahoma and have all had experience helping school systems implement inquiry science programs.

FOLLOW-UP EVALUATION AND REVISION

Follow-up has its value in providing the teacher with a feeling of security in the teaching of science as inquiry. The teacher shares experiences with other teachers, administrators, and consultants, and in turn, is encouraged by this interchange of ideas and experiences. *Regularly* scheduled classroom visits by the administrator, who serves as the curriculum leader, are as important as follow-up sessions. This curriculum leader should not miss an opportunity to teach during his visit as this will allow the teacher to observe inquiry-centered science from another frame of reference.

Evaluation is continuous. The criteria for evaluation should be based on the objectives of the science curriculum. Emphasis for evaluation should be placed on (1) conceptual learning, (2) behavioral change, and (3) ability to see interrelationships. It is recognized that this type of evaluation is more difficult than an objective testing of simple facts simply recalled; nonetheless, the real value of the inquiry-centered science program rests with obtaining science literacy based on a progression of learning experiences involving the previous three points of emphasis.

Revision should be continuous. Both science materials and the teaching approach should be current and pertinent to objectives.

EVALUATION OF CHILDREN IN AN INQUIRY-CENTERED ELEMENTARY SCHOOL SCIENCE PROGRAM

A question frequently asked by teachers relative to inquiry science is how to evaluate children for the understanding of the processes of science. Since the objectives and philosophy of inquiry science differs from that of more traditional science teaching, it follows that the evaluation and evaluation instruments must also be different. There is no simple solution to the problem of evaluation, whether it be traditional or process-oriented. However, the consequent discussion may be helpful in determining an evaluation program.

Evaluation is defined as the provision of information through formal means, such as criteria, measurement, and statistics, to serve as a rational basis for making judgments in a decision-making situation. The methodology of evaluation includes four functions: collection, organization, analysis, and reporting information. The teacher must be cognizant of the fact that this does not necessarily mean a summative procedure or that elaborate measuring instruments be developed. Teachers generally have tended to borrow too uncritically from the professional test writers and this leads to an inconsistancy that exists between objectives of the teacher and the evaluation procedures used.

If decisions are to be made, then explicit specifications must be stated. The purpose of the lesson, unit, course of study, or curriculum should state specifically what the learner is going to accomplish. One approach to stating objectives has been made by the use of behavioral objectives. The followir. guidelines should be used in preparing behavioral objectives.[1]

1. Identify the terminal behavior by name. We can specify the kind of behavior that will be accepted as evidence that the learner has achieved the objective.
2. Try to define the desired behavior further by describing the important conditions under which the behavior will be expected to occur.
3. Specify the criteria of acceptable performance by describing how well the learner will perform to be considered acceptable.

In dealing with inquiry oriented science programs the actions of observing,

[1]Robert F. Mager, PREPARING INSTRUCTIONAL OBJECTIVES, (Palo Alto, California: Fearon Publishers, 1962), p. 12.

measuring, classifying, predicting, data interpretation, and experimenting may serve as a basis for the objectives. Teachers should use caution in preparing objectives in order to insure that the objective does not limit the classroom activity. The objectives should be viewed as being a statement of minimal performance.

The teacher should also make use of both formative and summative evaluation. Formative evaluation is used to provide feedback at various stages during the teaching-learning process and can be used as an aid to student progress if separated from grading procedures. Summative types of evaluation are used at the end of a course, unit, or educational program.

If the primary use of evaluation is to render judgment such as pass or fail, good or poor, the child may likely respond as one who is being tried by a judge. Children learn at an early age how to beat the system. An evaluation procedure of this type used in an inquiry classroom will soon destroy the environment for inquiry to take place. Care should be taken by the teacher that the examinations made do not have damaging effects on the child's curiosity and chance to inquire.

Traditional tests which emphasize recall and memorization of facts will not adequately measure the processes of science. If multiple choice, true-false, and matching test items are utilized one should become familiar with Bloom's Taxonomy of Educational Objectives[2] and develop instruments around the following taxonomy:

Knowledge - Based on situations which emphasize remembering ideas, material, or phenomena.

Comprehension - Based on communications in which the learner is expected to know what is being communicated and to make use of it when asked specifically to do so.

Application - Based on communications in which the learner is unfamiliar. He must make the appropriate abstraction in order to use what is being communicated.

Analysis - Based on the breakdown of the material into its constituent parts and detection of the relationship which exist.

Synthesis - Based on putting together of elements and parts so as to form a whole in order to constitute a pattern no clearly observable as before.

Evaluation - Based on the making of judgments about the value of that which is being communicated. The judgment is influenced by previous knowledge and experiences.

Teachers should be encouraged to develop evaluation programs. This will require time and study. The references cited, Bloom and Mager, are recommended for developing this program.

A workable approach to evaluation is presented by John W. Renner in the following article.

EVALUATION WITHOUT TESTS:[3]
Planning Ways to Evaluate Progress

The Nineteenth-Century German chemist Justus von Liebig described the beginning of a new field of science as "...nothing more than a series of observations

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2 Benjamin Bloom, A TAXONOMY OF EDUCATIONAL OBJECTIVES, (New York: David McKay Co.,) 1956.

3 Renner, John W., "Evaluation without Tests", SCIENCE/JUNIOR HIGH SCHOOL EDITION, Advance Planning Issue. (New London, Connecticut: Croft Educational Services, 1968-69).

and experiments which had no obvious connection with one another."

Professor von Liebig was also describing how science expands, progresses, and forces man to use and develop his intellectual capabilities. He was clearly stating that two of the activities which comprise science are *observing* and *experimenting*. In addition to these, *measurement, data interpretation*, and *prediction* are also part of the fabric of science.

These five basic activities of science are all behavior oriented. If, then, a learner is provided experiences with these five activities and is evaluated in terms of how well he functions with them, teachers will have clearly demonstrated that their primary objective in teaching science is changing the learner's behavior. Behavioral change is a primary purpose of all educational experience.

LET'S AGREE

How does one evaluate how well a student has learned to observe, measure, experiment, interpret, and predict? Before answering that question, there are three points about teaching, learning, and evaluating which must be agreed upon. They are:

1. *Teaching is not telling.* Exclusive use of the lecture represents ineffective teaching.

2. *Memorization is not learning.* Asking students to memorize material is probably not developing their ability to learn.

3. *Being able to repeat is not evidence of understanding.* Recall test items probably measure very little behavioral change.

Since "tell 'em-show 'em-ask 'em" procedures do not make use of the five basic activities of science in teaching, such procedures will not allow you to determine if the activities have changed the learner's behavior. Therefore, what follows assumes that science is taught as investigation, not as fact-accumulative process.

Now let's look briefly at the five activities mentioned above to see the general approach to evaluation.

What is observation? It can be defined as looking at an event, object, or situation and being able to describe and understand what is seen. In studying science, the opportunity to develop this ability is provided in many ways. An adequate statement of the problem being investigated reflects that observation on prior experiments or on the work of others have been carefully made. Recording the results of an experiment (and not what the learner thought the results should be) is evidence of careful observation. Direct experiences in observing must be provided the learner, but the teacher must evaluate *indirectly* if the student has learned how to observe.

The same situation exists with the other four basic activities.

What is being evaluated in experimentation is whether or not a learner is willing to put together all the information he has and take a step into the unknown. How do you evaluate this type of behavioral change? A paper and pencil test, essay or objective, will not do it because there the learner need only talk about experimentation; he need not demonstrate his willingness to behave in a specific manner. What the learner *does* when meeting an experiment determines if the experiences provided have changed his behavior.

SPECIFIC CRITERIA

The following five questions can be used as criteria to determine if the five activities of science have changed student behavior.

1. Does the student state the problem being investigated clearly enough to enable him to devise an experiment for it?

If the student can imagine, design, and conduct an experiment from his statement of the problem, he has made careful observations and interpretations of other experiments or information from other sources.

2. Does the student record all the data from the investigation and not just what he thinks the data should be?

If you can say *yes* to this question, you can be sure that the student is learning to observe and measure, and that these activities are affecting his behavior.

3. In interpreting his data, does the student state only those interpretations which the data will support.

Applying this question honestly, objectively, and regularly will give you information about how the interpretation experiences you are providing are changing behavior. Not infrequently, what a student interprets from an experiment depends on what he believes the teacher will accept.

4. Were the conclusions the student drew based upon actual findings and not upon his preconceived notion of what should be found?

Here, of course, you are evaluating how observation, measurement, experimental results, and interpretation have influenced the learner.

5. Does the student approach the next investigation using the results of the last one?

In addition to being evidence of a true behavior change, an affirmative answer here is evidence that the learner has internalized the meaning of prediction. He has evidenced faith in his findings by being willing to base future actions upon them.

PRACTICAL SUGGESTIONS

How do you use the foregoing criteria? How much of a student's grade should be based on them? These questions deserve practical answers.

You need to keep records, so prepare a sheet (use the ditto machine) for each student which lists the five questions, and put the sheets together in a looseleaf notebook. Record evidences on each student as they occur. Some weeks you may have several items to enter, other weeks nothing will appear. Remember you are looking for evidence of true behavioral change or lack of it.

Is this procedure subjective? Certainly. So are other evaluation procedures. Any pencil-and-paper test is based on the teacher's subjective opinion on which questions to ask. In this new situation you must rely on your day-by-day experiences with students for information on which to make judgments.

Does this procedure require additional work? Probably. But keeping the records suggested is simply keeping an expanded grade-book. When the time to prepare the final grades arrives, the information you have on each student will make the effort worthwhile.

How much weight should your records on behavioral progress have in computing the student's final grade? Ideally, this information should determine that grade. However, in most communities, the public is not ready for such a move — parents expect schools to use fact-centered examinations and teachers to use numbers (not logic) in determining final grades.

You will note that the five evaluative criteria suggested must be applied during investigations. Since the laboratory is normally an integral part of science, fifty per cent of the final grade coming from the five criteria seems reasonable. Be sure to inform the students of the criteria you are going to use in determining this significant portion of their grades.

IN SUMMARY

The evaluation of student progress in science can be done in many ways besides paper-and-pencil tests. To utilize other methods of evaluation, the teacher must be sure of his purpose at the beginning of the year and select that content and those teaching procedures which will allow the learners to work toward the achievement of those purposes. The five basic activities of science have been suggested as constituting behavioral objectives that can be used as the basis for student evaluation.

As you teach toward changing student behavior through the activities of science, you will need to examine your teaching approach.

The following questions are referred to as checkpoints by the author.

Do you listen to students?

Listen to what students have to say about an investigation or problem and utilize their contributions in carrying forward the classroom activities. This does more than establish rapport; it tells the students that they, as well as you, have a responsibility in carrying out the learning activities. A teacher who listens tells the learners that what they have to say is a valuable part of the investigation being conducted. *Be a good listener.*

Do you accept the results which the students get in an investigation?

Too many times teachers will accept only experimental results that constitute the "right" answers. When a learner has honestly done an experiment, you have the responsibility to accept his results.

What do you do if the results are unacceptable to science? Suggest other investigations which represent different ways of solving the same problem. The second investigation will probably produce results contradictory to the first. Now the student must decide which set of results to accept, and he will see that one of the investigations (perhaps both) must be done again. If you reject his first set of results, he will put his future investigative efforts into guessing what results you will accept. *Be an acceptor.*

Do you ask questions which focus the student's attention on specific points in the investigation?

Ask many questions to find out what the students are thinking; few of the "can-you-guess-what-I'm-thinking" type. When the learner gives you an honest reply, accept it; and if that response is one which could lead him astray, ask him another question which will demand and/or allow him to refocus his attention. *Ask questions.*

Are you a guide for students during an investigation?

Ask questions, provide cues to those frustrated and/or on dead center, recommend other investigations to perform, suggest alternate ways of thinking about a problem, challenge results, and provide materials needed. *Be a guide, but do not lead by the hand.*

For a year's work, are you more concerned with the type and quality of investigations than with the number completed?

The "we-must-finish-the-book" attitude has no place in the classroom which is concerned with changing student behavior through utilizing the five basic experiences of science, (i.e., observation, experimentation, measurements, data interpretation, and prediction).[4]

[4]THE IMPROVEMENT OF SCIENCE INSTRUCTION IN OKLAHOMA, Grades 7-12. (Oklahoma City: Oklahoma State Department of Education, 1970).

CHAPTER 4

RELATIONSHIP OF SCIENCE TO TOTAL SCHOOL PROGRAM

Preceding chapters in this guide have stated that the purpose of education is to develop the rational powers and that science is a natural vehicle to foster this development. The nature of the intellectual development of the child has also been presented and the role of science in relation to the child's cognitive processes. This chapter identifies the role of science as it relates to the total school curriculum.

In recent years, curriculum projects have been developed which are based upon the principle that the disciplines themselves serve as the basis for the selection of the content. Examples of those curricula have been presented in Chapter Two. As a result of these projects, there is an emerging trend that is concerned with the total structure of the knowledge and its implications; that is, many disciplines have a common method by which the content is studied.

Phenix[1] suggests for the selection of the content of the curriculum in general four basic principles:

(1) The content of instruction should be drawn entirely from the fields of *disciplined inquiry*.

(2) From the large resources of material in any given discipline, those items should be chosen that are particularly *representative* of the field as a whole.

(3) Content should be chosen to exemplify the *methods of inquiry* and the modes of understanding in the disciplines studied.

(4) The materials chosen should arouse imagination.

In light of the foregoing principles, what is the relationship of science to the total school? Elementary school science can make a significant contribution to the education of *all* children. The role of science in the elementary school is one which encompasses the teaching of the ability to think. Due to the nature of the discipline, science becomes a natural vehicle to aid their rational development. The unifying theme is the teaching for inquiry and discovery.

Teachers have a responsibility for introducing the student to the scientific world as it exists, and any attempt to conceal its true nature from the student for the sake of expediency is unfair to science, unethical on the part of the educator, and extremely damaging to the student when he eventually and inevitably finds that he has been misled. The inquiry approach to science instruction will give the student insight into what science is.

Another important point is that scientific inquiry involves freedom of creativity, but within an orderly and logical framework. One basic value underlining creativity is independence. Whether that creative act be in science, literature, mathematics, music, or art, "a man must see, do and think things for himself."[2] If in the elementary classroom, a child is allowed this "freedom of mind,"[3] it is not

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[1]Philip Phenix, REALMS OF MEANING, (New York: McGraw-Hill Book Co., 1964) p. 10-12.

[2]Jerome Bruner, THE PROCESS OF EDUCATION, (New York: Vintage Books, Random House, 1960), p. 12.

[3]J. Bronowski, SCIENCE AND HUMAN VALUES, (New York: Harper Torchbook Series, 1956), p. 9-32.

logical that he will develop a more creative attitude? Further, if a child is allowed this freedom to inquire, he will develop a more sensitive appreciation for the values underlying a democratic society. For example, *dissent is the mark of freedom* and dissent is a value in our democratic society. But if we have dissent in society and science, we must also develop tolerance. This is to say that in this type of environment an individual should develop self discipline and a responsibility for one's actions. These values of *"freedom of mind, dissent, tolerance, and self-discipline cannot be developed in an authoritatian, dogmatic, rigid classroom.*

As teachers, we must be concerned with the total individual, and knowledge as a whole. We must teach science as a part of one's life -- socially, politically, economically, and aesthetically. It is not something taught just to develop a "brain trust," but as a part of one's life experiences. Science then, should be closely allied to the other disciplines which make up the elementary school curriculum. For example, the student should be introduced to the use of mathematics in his science studies. Mathematics should be treated as an integral part of the scientific discipline not isolated as a separate and distinct subject. The student in the elementary school should be introduced to basic statistical methods in handling data such as histograms, graphs in two dimensions, and their implications. He should deal with making measurements and interpreting these quantitative data. The teacher should capitalize upon the various relationships in terminology between the two disciplines. This is the way in which man has discovered order in nature. Historically, science methods did not progress until mathematics was used to explain the basic laws of the physical universe and to order and interpret biological data.

Communication skills may also be developed during the science program. In utilizing inquiry, the child will develop the ability to write the results of experiments, report his observations and measurements, discuss his activities with his peers and with the teacher. Many times during inquiry the child may develop a need to read about a particular phenomena and this should be encouraged. In developing the idea of classification, a child must learn to discriminate. Discrimination of symbols and words is also important in learning to read. There are many areas in which the study of science and language art skills are compatible.

It becomes necessary that a school system which adopts the inquiry approach to teaching science, continue the program through junior and senior high school. The function of elementary science in relationship to junior high science is to set the "emotional tone" for further science study. Using the inquiry approach will extend the natural curiosity of the child. The natural curiosity of the child when he enters junior high school is often depressed to the point that he will not learn and has lost interest in science. Learning early to appreciate and enjoy science and the work of scientists in this technological age will stimulate the child to wish to continue to learn science in the junior and senior high school as an integral part of his basic education.

An attitude of inquiry is basic to the nationally developed science studies in the secondary curriculum. *The elementary teacher should not be concerned with a set of content prerequisites for the secondary school program, but rather be concerned with developing attitudes of inquiry so that a child's search for knowledge may be extended.* On the other hand, secondary school teachers should understand the nature of the attitudes of the students entering their classrooms. This calls for mutual cooperation among secondary and elementary teachers to develop an articulated science program.

CHAPTER 5

RECOMMENDATIONS CONCERNING THE PREPARATION OF ELEMENTARY SCIENCE TEACHERS

There is a need for college teachers to take a critical look at the instructional procedures of their courses as well as at organization and content. If teachers are expected to teach science by the method of inquiry with real understanding, they must experience inquiry in the science courses they take. *It is impossible to accomplish this in a methods course alone.*

THE ROLE OF THE TEACHER EDUCATION INSTITUTION

The processes of scientific inquiry are as important as the concepts developed. These processes include investigating, observing and reporting results of investigation, formulating and stating hypotheses, designing and conducting investigations, the use of measuring devices, classifying materials organizing and interpreting data, and making generalizations.

The education of elementary teachers in science must be viewed as a continuous process in both pre-service and in-service. *The preparation needed in most instances differs from the typical introductory college course in both scope and emphasis.* The scope must be much broader by emphasizing the nature of scientific inquiry. The elements must be obtained by providing:

Learning experiences which lead to increased understanding, knowledge, and skills in science appropriate to the needs and intellectual level of the children;

A study of the historical development and philosophy of science;

An awareness and appreciation of the expansion of knowledge and changing emphasis in science teaching.

Student teaching experience of many kinds, especially laboratory and field experiences with children.

SPECIAL SCIENCE COURSES FOR ELEMENTARY TEACHERS

The program in science for the elementary teacher must include work from the biological, physical and earth sciences. The courses must be organized and taught using the method of inquiry. Planning these courses does not require that they be organized according to traditional disciplines. It is becoming increasingly more difficult to separate the various scientific disciplines and to separate the sciences from their social implications. There should be provision for individual and group laboratory experiments. Demonstrations performed by the instructor are not adequate substitutes for students' laboratory work. They should be utilized for illustrative techniques and to stimulate scientific thought, but opportunities must also be provided for students to develop scientific processes through designing and conducting their own laboratory investigations. Teachers tend to teach as they are taught, therefore, if science is taught by inquiry the probability of their teaching by inquiry increases. If teachers are to guide children to develop the confidence to inquire, them must first develop that confidence themselves.

PROFESSIONAL COURSES FOR ELEMENTARY TEACHERS There should be provisions for gradual induction into teaching through a planned sequence of experiences including observation of elementary school programs in science culminating in a period of full-time supervised student teaching. The professional courses specifically designed to develop skill in teaching science in the elementary schools should include:

> Systematic consideration of purposes, methods, materials, and evaluation procedures appropriate to the teaching of science;
>
> Provisions of opportunities for the development of individual creativity in conducting experiments, planning other types of learning activities, developing teaching resources, and devising demonstrative equipment and procedures;
>
> Study of the intellectual levels concept as the basis for work in the area of teaching methods and curriculum planning;

In addition to the pre-service preparation program in science for the elementary teacher, serious thought must be given to helping the teacher already on the job. In-service programs designed to facilitate the implementation of an inquiry centered science program at the local school level must be provided by the State Department of Education, colleges and universities, and local administration units. These programs must be so planned that the scientists, science educators, supervisors, and others work as a team to help the teachers understand the nature of the inquiry approach; develop the needed materials; secure suggestions for program development and implementation; adapt to local needs; and provide procedures for evaluation.

CHAPTER 6

THE USE OF EDUCATIONAL MEDIA IN SCIENCE TEACHING

The science resources of a school may be considered supplies, materials, equipment, books, audio and visual media, and adults, but the children are the most important resource of all. It is they who are learning science. They raise questions, supply ideas, suggest procedures, and describe their understandings. *This means that the various facilities for teaching science must be provided in terms of usefulness to children.* Each school must plan its science program to include the facilities, materials, and equipment that contribute to children's learning.

PLAN THE PROGRAM A planned program will include many activities and investigations that involve children in using the processes of inquiry. The sequence of the concepts and the kinds of activities will be organized in some form to accomplish set goals. One must consider the children's curiosity, their intellectual levels and their ability to operate within abstract levels.

Whatever the structure is within the planned science program, the many activities and investigations will require manipulative materials. The classroom for science should be a laboratory where children can work in small groups or alone. They need opportunities to observe, space in which to investigate, and freedom to re-arrange the room. The children also need the opportunity to experiment, test, retest, discover relationships, and discuss their findings with others. Use of the resources should assist the students to become better thinkers, better investigators and inquirers.

PRINTED MATERIALS Printed materials for teaching elementary science include a wide variety of reference books. Free materials should be reviewed carefully. Most industrial organizations employ educational consultants who prepare booklets, charts, and pamphlets. Some of these materials are valuable if properly used.

Good books can be used to improve reading skills, acquire new interests, and gain knowledge. However, books at their best cannot supply all the information teachers and children need. *A book cannot be a complete science program in itself.* Books should be used as references to supplement and add knowledge to that gained by children through their investigative activities.

RECOMMENDATION OF THE SCIENCE COMMITTEE OF THE CURRICULUM IMPROVEMENT COMMISSION There are no provisions in our present state laws in regard to textbooks whereby a local school district may officially select experimental program materials for use.

At the time our textbook laws were written, we did not have the innovative programs now available and new scientific discoveries and breakthroughs were not occuring so frequently; therefore, no provisions for including new materials were needed and none were made.

It is the feeling of this committee that provision be made in the textbook adoption law so the latest and most innovative programs may be approved for individual districts. Schools should be permitted to adopt new materials when they become commercially available instead of having to wait several years to make use of them.

The foregoing provision might be implemented by allowing only four programs to be adopted at the regular selection period and that three selections could be left open for two years so that new programs might be utilized if and when available.

Also, it is recommended that the state solicit bids for *complete programs* including the *written materials and accompanying kits* of supplies and equipment necessary to implement the program.

Printed materials provided through state funds and limited by legal adoption should not dominate and direct the science programs provided in the Public Schools of Oklahoma. As any educator knows, any book published is several years behind the knowledge acquired by the date it is published. This means that with our modern means of communications, the books available can be used for reference and inspiration only, rather than as a guide and an outline for the course. Our science programs must be constantly expanded and brought up to date through the use of the communication media and the experimental materials becoming available.

The committee further recommends that teachers and administrators solicit local support to supplement the state allocations with which to purchase the latest and most innovative materials even though these materials may not be on the state approved lists.

INSTRUCTIONAL MATERIALS

Instructional materials are complements to the teacher's presentations and to the activities of the students. Inquiry centered programs especially lend themselves to the use of instructional materials since part of the rationale includes the students' intensive interaction with materials. The supplementary instructional materials and references supporting the science programs with accompanying special equipment must be carefully evaluated so that they do not "undo" what the materials and supporting equipment have accomplished, that is, to emphasize the processes of science rather than the content.

It is the trend at this time to have a learning resources center in the elementary schools where a trained media specialist catalogs, evaluates, up-dates, and stores all the media for the school. Here tapes, slides, filmstrips, motion pictures, flat pictures, and special instructional realia are kept and filed for easy access for both students and teachers. A vital requirement in selecting this specialist is that he must understand the nature of inquiry.

Typically, the student will pursue the science in the laboratory and then expand the process by searching references, by listening to tapes, and by watching filmstrips and motion pictures. The involvement of the student with the learning materials carries the theme of the inquiry centered program and completes the cycle in communication channels.

The expanded search is a complement to the actual science experience, furthering the rationale of inquiry.

If the media is going to be effective and efficient in the inquiry method of teaching, there are certain definite criteria which must be satisfied:

1. The materials must present problems to be solved or situations to be investigated. They must be open-ended and brief to be effective within the attention span of the user.

2. The media must in some way *involve the child* actively in the learning process. If the child becomes a passive observer the complement cannot be effectively used in the inquiry learning process.

3. The media must have relevance to the topic currently being investigated in the classroom.

4. Evidence must be presented in the form of data to support any generalization drawn in the film or other device.

5. The media may be used as a *motivating* device and be concerned with asking the user "how" and "why" *not telling him* "how" and "why."

6. Materials and devices which ask questions, pose problems and suggest investigations support open-endness and student participation.

7. Materials which are easily accessible, easily interpreted and easily manipulated promote high retention and hold student interest.

Any device or material used in the classroom which only describes a place, an event, or an isolated bit of data is perhaps a good, relaxing experience for the learner, but it is doubtful if it contributes to the development of the child's ability to think.

TEACHER USE OF EDUCATIONAL MEDIA

Teachers are urged to consult with the media specialist in the elementary school learning resources center to cooperate in building a supportive science reference section where relevant and professional media can be displayed for the students to have easy access. *Science materials stored in locked storeroom help no one to learn.* If there is not a learning resources center in the elementary school -- start one. Appoint a member of the staff in the school as a media coordinator, obtain a media support commitment from your administration, and ask all the staff members to cooperate in selecting and evaluating materials to be placed *out in the open* so the student can see, feel, touch, and manipulate them.

Media at this time is coming fast and requires careful evaluation. Consultation with your colleagues and thorough media research based upon the specific objectives of the science curriculum will aid the evaluation. The objectives will eliminate irrelevant materials and *cooperation* will support selection.

Children should be given the opportunity to "discover" and not just "cover" science. A science reference book should be used as a tool to give the child information that will help him to: (1) make other discoveries on his own; (2) let him combine information gained from reference books with other information gained from personal experiences; and (3) from all of this, then form a conclusion of his own. This is the inquiry approach to problem solving that will prove more beneficial to students than just using books as such in the study of science.

It is true that the inquiry approach is time consuming. It will be criticized by some as being a "waste of time." These people are usually the ones who evaluate the effectiveness of any school program by the amount of factual information covered in a given year. They are the ones who usually feel that a child should be stuffed full of facts which can be spewed forth when called upon to do so. This type of program is one that does not represent inquiry approach. It is also true that the inquiry approach is more expensive. More equipment is needed for the child to do problem solving. It will also require more planning on the part of the teacher to make this type of teaching more effective. It will also require more work on the part of the child to achieve his objectives. The end results are most beneficial. The child learns science first hand and because of this it should have more meaning and value to him. In later years the experiences that he had in such problem solving activities should better prepare him for other problem solving experiences he is bound to encounter.

The Committee desires to emphasize that the use of inquiry is not a new or experimental method of teaching. It is the way in which a child learns. All we are asking is that the teacher recognize and utilize the basic learning process in the teaching of science. We feel that the acquisition of learning skills is more important than the acquisition of factual data in the educational process.

CHAPTER 7

INQUIRY PROGRAM MODEL LESSONS

Inquiry science programs supported by carefully prepared curricula and materials have received strong acceptance throughout the United States and some foreign nations. Support for most of the programs is obtained from government agencies and private organizations interested in the improvement of science instruction in the junior and senior high schools. The National Science Foundation has supported the major part of many program developments. For additional information concerning materials and programs contact the publishers or the project headquarters.

Model Lesson 1

OBSERVING AND MIXING LIQUIDS

SCIENCE CURRICULUM IMPROVEMENT STUDY

Children describe properties of five different liquid samples. They mix these samples and describe the properties they observe. They watch the changes that occur in mixtures of liquids over a period of time.

The children's experiences with liquids are extended as they observe and describe the properties of different liquids added to the class collection.

TEACHING SUGGESTIONS

In this chapter the children's experience with material objects is extended to liquids. The children will carefully observe a group of liquids. (You should encourage them to describe the properties of each one as well as the similarities and differences between several of them.) Next, the children will mix the liquids together to observe the effects generated. The experiences of mixing liquids will provoke a great deal of discussion.

Take advantage of the opportunity for furthering your pupils' language development. Conventionally, we think of a specific sample of liquid (water in a glass or juice in a container) as an object, while we do not usually refer to water or juice as objects.

Observing the liquids. Give each team of four children a set of five liquids in vials. (The caps should *not* be removed.) After the children have manipulated the vials and observed the liquids within, ask them to compare the liquids, describing some obvious properties. Encourage students to name properties that others have not yet thought of. Ask teams to group their liquids by property and to describe the grouping. Suggest that others question these arrangements.

Mixing the liquids. For the conclusion of this session give each child a clear plastic plate, which should be placed on his cardboard tray. The children should *carefully* pour a few drops of each liquid in different places on the plastic plate. (The team members will share the contents of their vials). Give them opportunities to feel and smell the liquids instead of merely looking at them. The children can use their fingers to spread and mix the liquids if they wish. Discuss the fact that each sample apparently consists of only one material. Finally, the children can walk around the room to observe each other's trays.

Setting some liquids aside. Most of the used plastic plates can be washed and saved, but you should set aside some plates containing both unmixed and mixed liquids. Leave these uncovered somewhere in the classroom where they can be observed for several days. Encourage the children to predict what will happen to each liquid sample, and record their predictions on a chart. Later, compare the predictions to the observations; the observed changes can stimulate further discussion about the properties of the liquids.

Similarities and differences in liquids. During the next session, again distribute a set of five vials to each group of four children. Ask the children to think of similarities and differences among the liquids. They may talk about these properties before holding a class discussion.

Mixing liquids in the quart jar. Following the discussion, show the children (who can be gathered in a wide circle for better observation) the five large jars of liquids. The class may want to mix liquids again. As your students refer to the previous spreading-around of liquids, you can explore their ideas of what happens when liquids are mixed. Then bring out the two quart jars, and pour into each enough of the liquid contained in a large jar so as to form layers about 1 inch thick. Let the children observe the combined liquids before you use the dowel to vigorously mix the contents of one jar. The children should describe any change in appearance caused by the stirring. Encourage them to compare the stirred and unstirred jars. Finally, place both quart jars aside where they can be observed for a week or two.

Setting up a "Liquid Museum". Explain that the remaining liquids in the large jars will provide the beginning of a museum. Show a chart on which you will record all the liquids in the quart jars and the date when each is added. Ask the children to bring from home labeled samples of liquids, which the class will add to the museum. Each child should obtain his parents' permission before bringing a liquid to school. Suggest that the children bring their liquid samples in baby food or other small jars.

Explain that the children will continue to observe a mixture of many liquids in the quart jars, since each child who brings in a liquid will pour some of it into each jar. (The rest of the sample should be added to the museum). The contents of one quart jar should be stirred with the dowel; those of the other quart jar should not be stirred at any time.

As you continue to add liquids, hold occasional class discussions on the enlarging mixtures. The children should note the smells, colors, number of layers, and other properties. Encourage them to compare jars.

Safety note. It is difficult to foresee what your pupils will bring for the museum because of the great variety of liquids found in homes. It is possible that certain liquids should not be mixed with others that are already in the jar. If you are in doubt about a liquid, consult its commercial label to learn what precautions you should take before working with it. If you are still concerned, do not use it.

Using the student manual. Each child has an opportunity to record his own observations of the liquids in the unstirred jars. This record may be used in addition to class chart. The children should color the drawings to show how the jar of liquids looked on a particular day. You should help them indicate the date on each drawing. The unstirred jar has been chosen for the record since the appearance of the stirred one is different immediately after stirring and again a few minutes later. Since liquids are being added from time to time, the level in the jar will change. By reviewing their records you can determine whether the children are sensitive to these changes and record them accurately. At the end you may discuss this increase in volume with the children.

Optional Activity. The "mystery liquid" provided in the kit is a methyl cellulose solution. On initial observation, it seems to be very similar to the mineral oil; many of the children will think it is an oil. However, it mixes with water and does not separate as does the mineral oil. Your pupils will find this unexpected behavior interesting. Use the mystery liquid at almost any point during the chapter. You may distribute small amounts of it and let children experiment as they wish. In another approach, give it to some or all of the children, and ask them to decide which liquids have similar or different properties. You can also add some methyl cellulose to the quart jars of liquid.

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Model Lesson 2

BRINE SHRIMP IN SALT WATER

SCIENCE CURRICULUM IMPROVEMENT STUDY

Your students experiment with brine shrimp eggs in different amounts of salt in water. They compare their findings on a class chart and determine the salt concentration in which most shrimp eggs hatch. This activity is intended to help the children realize that there are environmental factors other than those they have investigated so far.

Background information. Natural substances, composed of chemical elements and their compounds, are basic constituents of any environment. The survival of all organisms is greatly influenced by the concentration of chemicals in their environment. A particular chemical can have both short- and long- term effects on an organism, depending on how much of it is present. Short-term effects are usually due to either a drastic lack or an over-abundance of a substance, and they most often result in the death of the organism.

Long-term effects are less obvious to the observer. They may be due to a chemical's being present in less than optimum concentration, for example, the unhealthy appearance of plants grown in soil that lacks nutrients, and the disease *rickets* in humans, which is due to a deficiency of vitamin D. The responses of organisms to chemicals in the environment are more difficult for children to investigate than are the same organisms' responses to other environmental factors. The brine shrimp experiment will call your students' attention to the presence of chemicals in the environment.

Teaching suggestions. You might begin by explaining to the children that there are factors in an environment other than light, temperature, and water to which organisms respond. Natural substances composed of chemicals are among these. Tell the children that they will have an opportunity to work with a new organism (brine shrimp) and to investigate its response to a chemical (salt). Show the children the brine shrimp eggs and explain that these eggs hatch in salt water. Tell them also that the amount of salt in the water may affect hatching, and ask for suggestions on how to determine the salt concentration that produces the most shrimp. Give your students the opportunity to plan the experiment.

The experiment. We have outlined one way such an experiment could be conducted; feel free to modify it according to the children's suggestions. Distribute the materials (except the colored dots) to teams of four. The teams should squirt six droppers of water into each vial, following this with a *very small* pinch of brine shrimp eggs (enough to fill the small end of a flat toothpick).

The groups should add different amounts of salt to the vials so there is a range in the salt concentration. A level spoonful can be considered 1 unit of salt. The children can provide a range by adding 0, 1, 2, 3, and 4 units to their vials.

Each vial should be labeled with the number of salt units it contains, the date, and the initials of the team members. The contents of each vial should then be stirred gently so the salt dissolves.

The members of each team should place their five vials in a stand and place the vial stands away from direct sunlight and excessive heat.

Recording the results. Let the children observe the developing brine shrimp during the next four to seven days. When some hatching is reported in most of the vials, let the class devise a chart. A possible method for recording hatching is described and illustrated below.

Give each team five dots (points to be placed on graph). The teams should observe the vials and determine whether *most, some,* or *none* of the eggs hatched in each. After evaluating the hatching success in a certain vial, one team member should place a dot on the class chart in the appropriate space. If most of the eggs hatched in the vial containing 1 unit of salt, a child would place a dot inside the "most/1 unit" section. See Figure 1.

HATCHED:					
Most					
Some					
None					
	0	1	2	3	4

UNITS OF SALT:

Figure 1

Class Chart: Brine Shrimp in Salt Water

Discussion. Discuss the results of the experiments with the class. Do these results indicate an optimum range of salt concentration for brine shrimp eggs? Your students may infer from the data that the specific amount of salt in the water does not seem to be critical and that eggs hatch in a wide range of salt concentrations. Ask the children to suggest in what type of environment they might find brine shrimp.

Other factors. You might ask the children to name natural substances to which humans respond; pollen and dust are probably among the substances to which some of your pupils are allergic. This may lead to discussion of chemical pollutants in our environment. (In a later SCIS unit, children will investigate how pollutants effect the environment and the community).

Children might also consider other environmental factors to which organisms respond, such as noise or the influence of another organism. Ideas from this discussion may lead to optional experiments children can design, using the organisms in the kit.

Cleanup. The vials should be rinsed and returned to the kit for later use. If there is an aquarium in your classroom, the brine shrimp may be added to it as food for the fish.

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Model Lesson 3

BEHAVIOR OF MEALWORMS

ELEMENTARY SCIENCE STUDY

Students begin their study of mealworms with a casual examination of the insect's normal activities. Questions arise from these observations and are investigated experimentally. "What is the most effective way to make a mealworm move backwards?" Such problems as these provide effective opportunities for children to examine the structure and behavior of mealworms by observation and experimentation.

When studying mealworms, students engage directly in scientific investigations. They answer questions for themselves by making observations. Statistical analysis is required to determine the regularity of specific types of responses. Students design and construct simple apparatus to test various hypotheses. By performing controlled experiments, they seek explanations for observed behaviors.

Much of what students discover while experimenting with mealworms is applicable to the study of animals behavior in general. *Children learn to ask a mealworm questions by altering its environment.* The answers come from interpreting the responses to these changes. When doing their experiments, students quickly become aware of a difficulty which confronted all animal researchers — that of adequately controlling the many variables. After studying *Behavior of Mealworms*, children may find that they do not know very much at all about a mealworm, which at first seemed so simple.

Mealworms seem particularly appropriate for study because they exhibit definite and consistent behavior. In addition, they are readily available and easily maintained.

Below is a description of activities which have worked well with trial classes. The direction of the unit to some extent should depend upon the orientation given it by the students.

Some suggestions are available for teachers who plan to use mealworms. They include a description of the life cycle of the insects, the method of caring for the insects at school, a list of necessary materials, and hints for teaching the unit.

Activity 1 — *What Can Be Found Out About Mealworms by Watching Them?*

The initial assignment for students is to have them make cursory observations of mealworm behavior. They experiment at home and answer on paper the questions: "What did you do?" and "What did you find out?" Some might be motivated by the challenge of seeing who can discover the most. For the students who are uncertain, a few ideas from other students of what they plan to do might be helpful.

Mealworms are distributed "cafeteria style." Each child receives a handful of bran and five mealworms stapled in a wax-paper sandwich bag.

The discussion which follows the investigation at the home might begin with the question. "Who found out something which no one else did?" The experiments performed are varied and often appear illogical as seen from this sampling:

1. I put him on an ice cube and he doesn't like cold.
2. I placed it on its back.
3. I dropped vinegar on the tail and he didn't like it.
4. I held a pen in front of it.
5. I put him between piles of sugar and salt.
6. I bounced him around on a sheet of plastic.
7. I shined a flashlight on him and he crawled away.

If the children wish to draw conclusions from their observations, they should be made to realize that the evidence upon which the inferences are based is quite inconclusive.

These undirected activities provide a background for the more refined observations and experiments on a mealworm behavior which now follow.

Activity 2 — *How Can Mealworms Be Made to Back Up?*

From the previous discussion will come some mention of mealworms backing up in certain situations. These observations can be capitalized upon in this lesson with the question of what things cause the organism to react in this unusual manner. At home, the students are to try to make their mealworms move backwards by as many different methods as they can devise.

The procedures which caused the desired effect can be listed on the board on the following day. The question can be raised of which way is the best for making a mealworm move backwards. "Which method would you select to force the mealworm to back up the greatest number of times?"

Guesses can be heard, but there will probably be little agreement. Now the problem is, "How can this be found out?" Students may need help to see that quantitative results obtained by counting will best answer the question.

Four or five representative techniques which elicited the backing response are selected for further study. Students perform each at home, recording on a chart the total trials and the number of times backing occurs. Class totals can be tabulated efficiently by listing the categories at separate places on the chalkboard. The students all go to the board and write their figures in the appropriate column.

The summary from one class is illustrated below:

What was done	Times tried	Times not backwards	Times backwards	Rank from Best to Worst
Flashlight ½" away	106	58	48	3
Match ½" away	95	28	67	1
Drop of Water on head	90	21	39	5
Wood stick in front	110	63	47	4
Blow on Head with straw	119	60	59	2

If percentage has been studied previously by the class, it will be of practical value here.

Activity 3 — *How Do Mealworms "Explore" a Box?*

Individual test boxes are needed for this and future experiments. Suggestions for the design and construction of such a box can be discussed. A shoe box, cigar box, or another cardboard or wood container of similar size is suitable. Glass and metal enclosures are not desirable because mealworms cannot walk normally on these smooth materials. A ring of Scotch tape stuck around the top of the box makes a slippery surface which prevents the mealworm from escaping.

A transition to the exercise using the test box can be made by asking the question: "Do mealworms ever move backwards in the box for no apparent reason?" The box is used first at home when watching for instances of unexplainable backward motion and then brought to school for additional use.

The discussion of the mealworms' behavior in the test boxes brings out many interesting observations. Disagreement will arise, or if not, can be easily encouraged about where a mealworm travels in his "exploration" of the box. "Does he spend most of his time following an edge?" "How much is most?" "Where does he climb more, up the sides or up the cracks where two sides meet?" "How much of the time is he stopped?"

The students may experience difficulty in deciding for themselves that time can be used as a measure to sharpen up their observations. If this cannot be resolved through discussion, they will have to be told. A metronome vibrating at approximately one tick per second is a good time-keeping device which permits uninterrupted observations. Students make as many measurements as feasible in class and record their results in seconds on their charts.

The particular types of "exploratory" behavior to be examined should be chosen as much as possible by the pupils. Charts developed by two different classes are included below for comparison. The figures shown are class totals.

Time Moving	Ticks	Time Stopped	Ticks
in middle	7,068	in middle	5,107
along edges	14,802	along edges	7,138
in angles	2,099	in angles	2,271
climbing corners	4,597	climbing corners	2,262
climbing sides	6,254	climbing sides	2,835

Activity	Total Time in Seconds
stopped	929
on bottom	4,751
along edges	11,380
up sides	3,435
up edges	3,670
in corners	1,323

Some clarification of what distinguishes the middle of the box from the edge may be necessary. It was decided by one class that to be along an edge a mealworm must be no farther away than one mealworm width. Every other place on the bottom was called the middle.

After the students have studied their results they can make more definite statements about "exploration." Relative amounts of time spent still or in motion and in various parts of the box may be expressed in fractions or percents.

Activity 4 — *How Does a Mealworm Sense the Presence of a Wall So That He Can Follow It?*

After the exploration study, students are well aware of the tendency of mealworms to follow walls. A question which follows naturally from this observation relates to the way in which the mealworm does this.

Various possibilities to explain the organisms' perception of an obstruction are considered. Should the students lack ideas, they might first think about ways they would have of walking along the wall in the school room. One way would be to use one's eyes, as might a mealworm. But suppose the person were blind? The arm or body could be dragged along the wall. What could a mealworm use to do this?

A detailed anatomical examination of a mealworm at this time might reveal some tactile structures. Magnification of the insect could be accomplished with hand lenses, a binocular microscope, or photographic enlargements. Any of these will be adequate to show the presence of the pointed antennae, the hooks on the end of each leg, and the fine hairs on the legs and underside of the body. One or more of these structures could serve as a touch-sensing device.

What experiments could be done to help determine which of these possibilities might be correct? To test sight, the mealworm could be blinded by coating its head with nail polish or black paint. The use of the legs or antennae of a mealworm following a wall could be examined carefully with a magnifying glass. The idea of building test walls can be introduced by the teacher if it does not evolve naturally.

What kind of "mealworm walls" could be made to test the alternative explanations for wall-following? A plastic or glass wall, which might not be seen, could indicate the visual acuteness of the animal. To keep the mealworm's protruding feet from touching, a wall could be made with an overhang. A very low wall would allow only the feet to come in contact with the vertical surface. What would the mealworm do if the wall he was following ended?

With the foregoing thoughts in mind, construction of the test walls is carried out in school. Wood strips, cardboard, wire, plastic, saws, and glue are made available. The walls can be built inside the test boxes or on separate pieces of cardboard.

Magnifying hand lenses might aid the investigation. Students can answer the original question on wall-following techniques in writing by describing their observations.

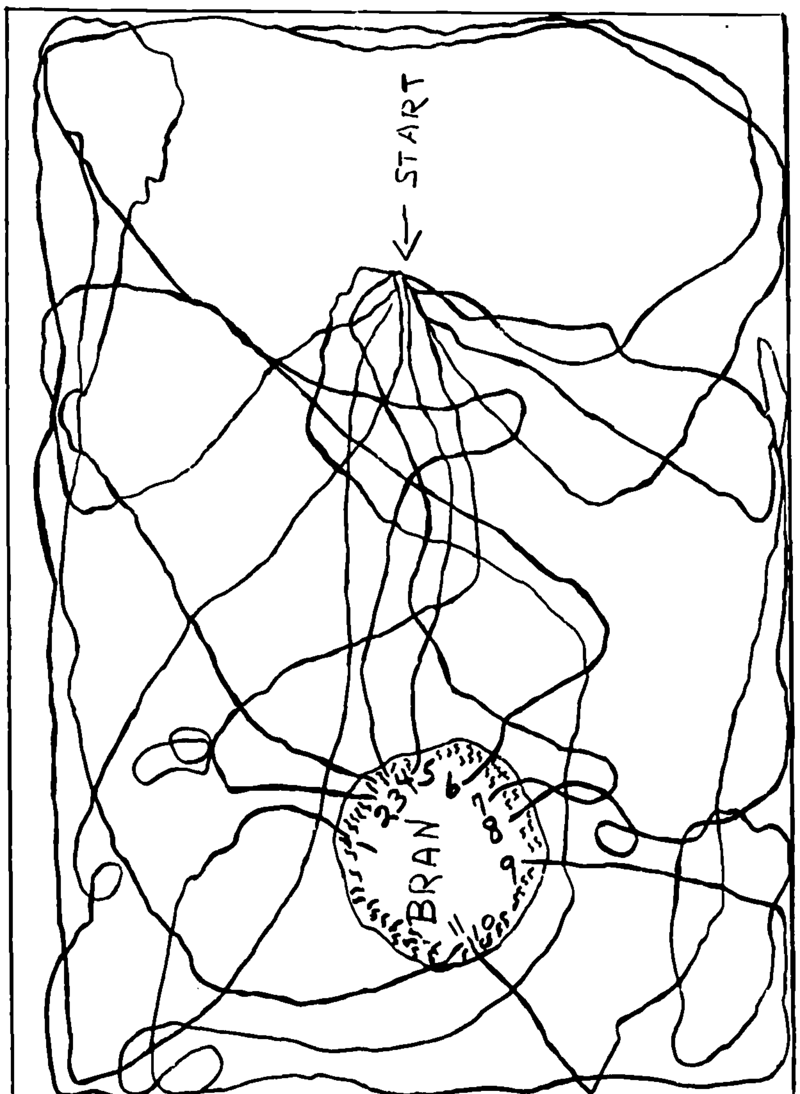
Activity 5 — *How Does a Mealworm Find Bran?*

The class is shown a shoe box with a pile of bran at one end. About twenty mealworms are placed in the other end and the box is left uncovered until the next day. By then, most or all of the mealworms should be in the bran. Then pose the question, "How do they find the bran?" Discussion might bring out some possibilities as sight, smell, or just chance.

"How could we find out if they find it because they sense it (by sight or smell) or just because they happen to bump into it?" A useful procedure is to trace the mealworm's path by following him with a pencil line as he moves along. A random direction of movement is normally observed at first. But as he wanders closer to the bran, is a distance reached where his motion becomes more directed? If so, at this distance it would appear that the organism can somehow detect the presence of bran.

To obtain uniformity and thereby permit better comparison of results, a paper is duplicated on which is indicated a circle for the bran and a starting point for the mealworm. A one-inch wall of thin metal, plastic, or other smooth material is placed around the perimeter of the paper to confine the organisms' activities. Even a ruler could be held along the edge of the paper nearest the mealworm.

Each pupil can trace the path of his mealworm a few times on the special form. See the Sample Form. A composite of the paths drawn by all the students can be made by transferring them with carbon paper or by eye onto a master sheet. This can be duplicated or shown through an opaque projector. The probable conclusion to be drawn is that the mealworms' discovery of bran is by chance alone.



Activity 5. *Sample Form for mealworm finding the bran.*

Activity 6 — *Why Does a Mealworm Stay Under the Bran?*

This question follows easily from the former but is considerably harder to solve. This is mainly because the number of variables is so great that it is impossible to control them sufficiently. This may be the most valuable lesson to be learned from the exercise.

Some possible explanations for this behavior, as offered by the pupils, might be that mealworms remain in the bran because it affords food, darkness, weight on back, quietness, and pleasant odor. Of these, the first three are most suitable for further study and are treated separately in some detail.

The other possibilities might be disposed of by a discussion to show why they are probably not causing the behavior being examined. Loud noises have no apparent effect on a mealworm. Even so, it would seem doubtful that a little bit of bran could reduce noise noticeably. A quick check will show that bran has little or no smell, at least to humans.

1. Does the Mealworm Stay Under the Bran Because of its Touching its Back?
   "What materials could be used to test this idea?" Something is needed into which a mealworm can crawl, but which will not provide darkness or food. "What could be used?" The student can offer suggestions, and the thought of shredded cellophane, or similar transparent flakes might be given. A piece of such material is provided for each student to cut up for experimentation in his test box. There may be other ideas which should be discussed and tried out if they seem suitable.
2. Does a Mealworm Stay Under the Bran Because of Darkness?
   "How could this be found out?" Many ways will probably be suggested and can be carried out. Among the most convincing is to see if mealworms collect in bran when the whole box is dark. Students should be encouraged to demonstrate during the discussions any special equipment which they may have made to help solve the problem. Also, appropriate charts should be designed and used for recording data.
3. Do Mealworms Eat Bran?
   A few flakes of bran can be placed in a tiny closed box, like a match box, with a mealworm. If the bran disappears, it has probably been eaten. Repeating this procedure with other foods could indicate the mealworm's acceptance of these also.

Model Lesson 4

GROWING SEEDS

ELEMENTARY SCIENCE STUDY

Growing Seeds gives children an opportunity to get acquainted with science as early as the first grade--an opportunity to discover for themselves something of the way to find answers to their own questions about the world. At first they gather and bring in small objects that they think might be seeds. They become absorbed in asking questions and devising ways to find their own answers.

What's inside a seed?
Does a seed have a bottom and a top?
How can you be sure this is a seed?

The teacher contributes to this questioning by giving the children some additional objects, most of which are seeds but a few of which are not.

Among the objects children are given is a cinnamon candy drop. Its inclusion has caused some controversy among teachers in the trial classes. Some teachers think it silly and distracting; others are delighted when the children recognize the candy, laugh, and eat it!

That's not a seed, it's candy.
How do you know?
Well, plant it!

Whether or not the cinnamon candy drop is used in your lesson is a matter of personal style, but the thought it evokes is essential: Couldn't there be some funny kind of cinnamon candy drop that would sprout? How do you know?

After the children have planted the objects and watched the seeds sprout, they follow the growth of one plant. Every day each child cuts or marks a strip of paper to represent the size of his plant. Later he pastes his strips on a larger sheet of paper to make a picture of the plant's growth. From these pictures the children begin to see the answers to questions they could not answer earlier.

Of course, not all your children will devise a picture. However, when children devise pictures for themselves, out of their own needs, they are taking a first step in science. By working out their own techniques for answering their own questions, they understand better why the techniques are useful and how they can be applied to other situations.

It is a good sign of learning when children say: *Let's try it. Let's plant it. Let's grow it.* When they seek the test of direct information, they are engaging at their own level in a kind of science: They are evolving a belief in their own ability to answer questions.

Activity 1 — *What are These?*

MATERIALS

From the kit:
envelopes
paper plates
"seeds": morning glory seeds, popping corn, beet seeds, radish seeds, yellow-eyed beans, dried peas, red kidney beans, gravel, charcoal granules, vermiculite, cinnamon candy drops, mung beans, grass seed, corn seeds. Do not use the ear of corn in Part One.

You could add or substitute other "seeds": acorns, lima beans, poppy seeds, grapefruit seeds, candy bits, pea shooter peas, Cocoa Puffs, birdseed, cloves, lentils

PREPARATION

Fill one envelope for each child with one of each kind of "seed." At the same time you may wish to prepare the envelopes for the second lesson, "Planting day."

PROCEDURE

One or two days before you plan to begin, ask the children to bring to school anything which they think might be a seed. What they bring will depend a great deal on their experience. Some children bring packages of seeds sold for gardens. Some bring apple seeds, prune pits, nuts. Some bring seeds from trees, bushes, and weeds in their neighborhood. As they bring in their "seeds," the children tend to have no doubts at all about the fact that these *are* seeds they are bringing. Occasionally this will be because they have already planted seeds like them, and have grown plants. More often it is because they have been told that these are seeds.

When they have started to bring in their seeds, you can make your contribution to the collection by giving each child the small envelope containing a variety of seeds you have prepared for them, to compare with their own.

The children usually recognize one or two of these little objects — the candy for instance — and they may think you are trying to fool them. This raises just enough question in their minds that they may start wondering about some of the other objects and about some of the things they have brought themselves. *How can you tell whether something is a seed or not?* You will hear a strange variety of ideas expressed.

Welcome all responses whether they are questions or statements about differences, likenesses, color, or texture or whether they are ideas about what makes a seed a seed. Some of their criteria for claiming that an object is or is not a seed may be dubious ones:

This can't be a seed; it's too hard.
This is a seed because it's bumpy.
Seeds aren't round.
Seeds aren't flaky. This can't be a seed.

On the other hand, some child may point out more helpful criteria such as, *There's a little mark,* as he notices the scar on a kidney bean.

The children themselves will be highly critical of one another's reasons. Try to promote such critical interplay among them whenever possible. From time to time, you will need to take part in their discussions yourself. Try to point out inconsistencies in their arguments. If a child says that an object is a seed because it's bumpy, you could point to a bumpy object in his pile of things that he thinks are *not* seeds; if he says that something can't be a seed because it's too shiny, show him a shiny object in his "seed" pile.

Hold back on definitive responses such as, *You are right* or *You are wrong.* It won't be difficult if you remember that during the coming weeks you will have a chance to watch the children do many things to their "seeds." On their own they are going to discover the need to change some of their earlier notions.

Twenty or twenty-five minutes of these preliminary comparisons and discussions will lead to some thinking and many good observations. The class as a whole will then be ready to consider better ways to find out whether their objects are seeds. Before long, many will be eager to try planting them in soil, to see if any of them grow.

As one of the ideas about what to do to the little objects, someone may suggest: *Open them up.* If this is not volunteered, it might be wise to interject this idea yourself, because it raises the important question: *What is inside a seed?* Since most of the seeds are hard, opening them will be a difficult operation at this point. But let the children attempt anything reasonable. They can take their envelopes home and follow up on the problem, since you can supply more of these objects for the children to plant at school.

Encourage them to bring to school anything else they think might be a seed.

Activity 2 — *Planting Day*

MATERIALS

From the kit:
the "seeds"
one envelope for each kind of "seed"
1 clear plastic container for each pair of children
1 plastic sheet

You will need to supply:
large cardboard box
cellophane tape
soil
watering pitchers
newspapers or paper towels (to keep desks clean)

PREPARATION

Line one cardboard box with a sheet of plastic, as shown in the photographs. Put soil in it to a depth of about three inches.

Put 10 or 15 of the same kind of "seed" into an envelope. Use as many envelopes as you have varieties of "seeds."

Plant several extra small boxes (clear plastic containers) with red kidney beans for the children to dig up and examine, or for replacing lost seeds.

PROCEDURE

By drawing lines in the soil, divide the large box into small plots — one for each kind of "seed." Assign two or three children to each of the envelopes, and let them take turns planting the contents of their envelopes in one of the plots.

How will the children remember which kind of "seed" they have planted in each plot? One of our trial classes came up with a neat solution: they attached a "seed" to a stick with transparent tape and stood the stick in the plot.

While the children are taking turns planting in the big box, distribute the small plastic boxes to pairs of children. In these boxes each pair of children can plant whatever they wish — seeds they have brought, seeds left over from the first class, more seeds from the class supply.

As long as the children include soil, seeds, and some water, let them do the planting without too much formal instruction. They will make mistakes, but they will learn from them.

Activity 3 — *What Are the Planted Things Doing?*

MATERIALS

From the kit:
red kidney beans and dried peas — about one cup of each

PROCEDURE

After planting day, set aside a few minutes a day for watering, tending the boxes, seeing what changes are taking place in the sprouting seeds. Most of the children will be aware of the need to water the newly planted objects, but when nothing appears to be happening, they may need some subtle reminding and encouragement from you.

They may also become impatient for their things to start growing. Take advantage of this waiting period by suggesting that they dig up a few of the planted objects to examine them. If some children feel protective and do not want to dig into their boxes, don't force the issue — although you might remind them that the objects can be replanted. In any case, do continue to arouse their curiosity.

What do you suppose the things you planted look like now?
Do you suppose they look the same as when you planted them?
Do you think anything is happening to them?

After discussing questions like these for a while, the children will want to find out more, and they may be willing to dig up at least one or two "seeds." If you planted kidney beans in several extra boxes during the second day, some of these can be dug up for examination. When they do this, the children will probably notice that some of the objects are larger and softer and easier to open than before.

Direct their attention to some of the more significant changes by asking for comments on the softness and on the role played by the soil or the water.

You can help the children follow through some of their ideas of what makes the objects softer or bigger by giving them a few of the dried peas and beans to experiment with.

Activity 4 — *What is Inside a Seed?*

MATERIALS

You will need to supply:
paper towels or newspapers for each child
soaked beans and peas—six or eight per child

PREPARATION

Twenty-four hours before the class meets, put dried peas and beans into a container; cover with water, and let them soak. If you soak them much longer than this, they will start to rot. Schedule at least 30 minutes for this lesson.

PROCEDURE

As you give each child six or eight soaked peas and beans, suggest that he look at them carefully. Questions such as these will guide the examination:

What are they like now?
Are they larger than they were before?
Can you open them?
What do you see inside the pea when it comes apart?

Encourage the children to comment on what they see and to pose further questions. You will begin to hear remarks like these:

The outside skin pops off.
There are two pieces inside.

Sustain their interest in looking and in talking about what they see. They will be impressed by the differences between the peas and beans and excited over the size of the little plant in the beans. They may want to dig up some more of the planted things and compare them.

Activity 5 — *Are the Planted Things Changing?*

Bring the children's attention back to the planted objects with questions that arouse their curiosity about what is happening inside the boxes. Have them dig up, open, compare, replant their objects. If some are still reluctant to dig into the boxes they have planted, offer them the extra boxes of seeds you planted earlier. (Groups of three or four can be assigned to work with one box.) As you go from desk to desk, raise more questions about the things the children point out to you.

Yes, I see that little wormy thing. What do you suppose it is?
Is it growing?
What do you think it will grow into?

Most children think of their own questions:

What happens if you plant it right at the bottom of the box?
What happens if you plant it on the top of the soil?
Is there a tiny plant already inside the seed?
Is grass the only thing that keeps growing after you cut it off?
If you plant a half a seed, will you grow half a plant?

These questions all suggest good things to do, Let the children plant more seeds in paper cups or milk cartons to see if they can find out the answers to their own questions.

During the next few days as the children continue to dig up, open, compare, and replant, they will find out many exciting things about seed germination and the sprouting of plants.

Activity 6 — *Continuing to Watch*

Take a few minutes to let the children sum up their findings on which of the objects so far have shown signs of being seeds:

How many appear to be sprouting?
What about the ones that haven't sprouted yet?
Are they exactly the same as when they were planted?
Which plants came from which kinds of seeds?
Can you still find the seed, once the plant has started to grow?

Do the children think all seeds sprout in about the same length of time? How long do they think they should wait to see if the objects they have planted will sprout?

Some children like to transplant bigger plants into a pot or box where they will have more room to grow.

Model Lesson 5

OBSERVING TEMPERATURE

SCIENCE — A PROCESS APPROACH

OBJECTIVES

At the end of this exercise the child should be able to

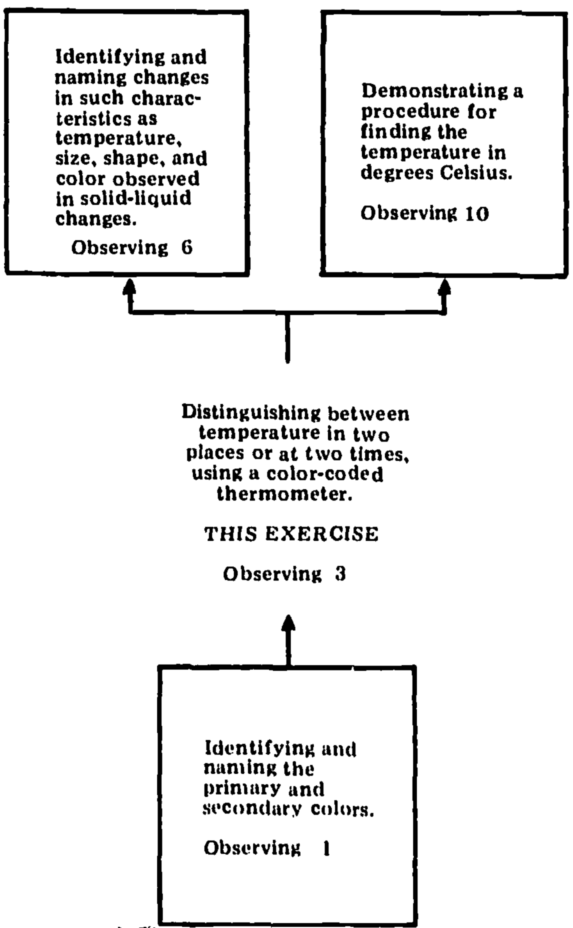
1. *DISTINGUISH* between two very different temperatures without the aid of a thermometer.

2. *IDENTIFY* and *NAME* temperature ranges using codes on a thermometer.

3. *DISTINGUISH* between the temperature in one place and that in another, using a coded thermometer.

4. *DISTINGUISH* between the temperature at one time of day and that at another, using a coded thermometer.

SEQUENCE



RATIONALE

It is important for young children to learn to use their senses in as precise a way as is possible for them. It is also important for them to learn that they can use instruments to extend their senses and to make observations more precisely.

In this exercise, they will compare coded temperature ranges rather than quantitative readings of thermometers. The children should associate a higher thread (column) in the thermometer with a warmer temperature.

Celsius (C) and Fahrenheit (F) are arbitrary scales which are used to express temperature precisely. The Celsius scale was formerly called *centigrade*. Use the numerical temperature only for sufficiently mature children.

Children may describe objects as "feeling" warm or cool even though the objects may be at the same temperature. A piece of metal at room temperature may feel cooler than a piece of wood. This difference is due to the different thermal conductivities of the objects, that is, the rate at which *heat* is conducted away from the hand and through the object. It is probably better not to try to explain at this time the different sensations of "coolness" given by the different objects.

The activities described here are written for the color-coded thermometer. If you use a different code, you will need to make an appropriate adaptation of the instructions. In geographic regions where temperatures change little, other kinds of adaptations may also be necessary.

RED

YELLOW

GREEN

BLUE

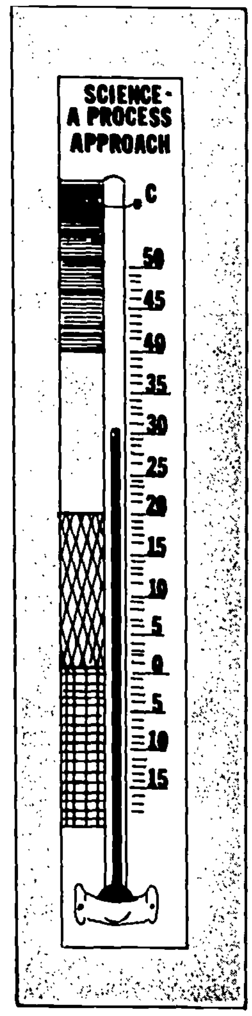


Figure 1

This exercise has been placed early in the sequence so that weather observing can be carried on throughout the rest of the year. If you feel that the children in your class are not mature enough to carry out the suggested activities at this point, postpone the exercise for several months.

VOCABULARY

thermometer	lower	cold
temperature	earlier	up
warmer	cool	down
cooler	later	rise
higher	hot	fall

RELATED MATERIALS

Listed below are the materials required to conduct this exercise.

Some items cannot be supplied at all or are not supplied by Xerox in the Standard Kit. These are designated as NS. Note, however, that many items so designated are supplied in the Comprehensive Kit. A separate list of these items is included with the comprehensive materials.

Items too large for the Exercise Drawers will be found in the Teacher Drawer and are designated as TD.

Hot plate, 1 (NS)
Metal dishpan or bucket, 1 (NS)
Glass containers, 4 (NS)
Celsius thermometers, 4 (see Figure 1 and accompanying instructions)*
Construction paper, 4 sheets: 1 red, 1 blue, 1 green, and 1 yellow (NS)
Ice (NS)
Salt (NS)
Large calendar, 1 (NS)
Adjustable ribbon chart for recording high and low temperatures, 1 (TD)**
Charts for recording clouds, wind, and precipitation (Optional), 30 (NS)
Device for recording cloud cover (as in Figure 4, Optional), 1 (NS)
Fruit juice or milk for each child to taste (NS)
Drinking cups, 30 (NS)
1 bottle each; red food coloring and blue food coloring (NS)

*Cover one side of the scale on the thermometers with opaque white tape which you can then mark at appropriate divisions and label with a suitable code. Use waterproof material for marking so that the whole thermometer is immersible in water.

For a color code, you might use red, yellow, green, and blue. (See Figure 1.) Other symbols are also suitable, such as letters or picture symbols. For example, you might use a boy in swimming trunks for the scale above 30 degrees Celsius, ice skates for the scale below zero degrees Celsius, and so on. Some children already familiar enough with numerals that they will want to use the gross divisions of the scale.

**You can make a chart of suitable size on a piece of cardboard about 30 x 40 cm, using two pieces of red ribbon and two pieces of white ribbon, each about 45 cm long. Draw the two outline thermometers on the cardboard, and color or mark the areas with the code desired. Cut slots through the cardboard at the top and bottom of the drawings of the thermometers. Attach a red and a white piece of ribbon together with tape, or by sewing or stapling. Slip the ends of the ribbon through the slots, and tie them together loosely on the back of the cardboard. (See Figure 2.)

INSTRUCTIONAL PROCEDURE

Introduction

You may introduce the topic of temperature in connection with other classroom activities. If the temperature of the outdoor air is cooler than that of the indoor air, the discussion might center around what the children wore to school today. Ask such questions as these: What would you have worn if it had not been so cold? What would you have worn if the air had been cooler? How did you decide what to wear?

Alternatively, you might ask, When you are filling the bathtub, how do you decide when the water "feels" just right? Explore the various methods suggested, which will probably include such activities as "testing" with a toe, a hand, or an elbow. Ask, What do these "test" tell you? (The water is too hot or too cold.) What do you do if it is too hot? (Add some cold water until it is *cooler* than it was to begin with.) Continue the discussion until the children begin to describe the difference of the "feel" of the water in terms of *cooler than* or *warmer than*. Ask, Does cool mean the same to everyone?

One teacher likes to introduce this exercise by asking, What do you think of when I say "temperature"? Some of the questions listed above might follow logically from responses to this opening question.

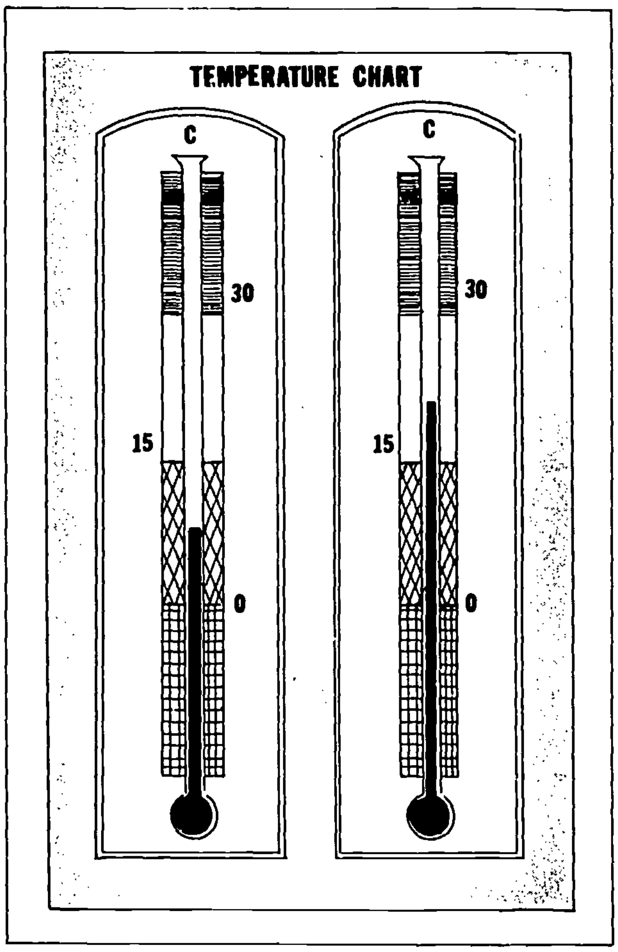


Figure 2

Activity 1

Devise a plan to provide two areas in the classroom when the air temperature will be different. This might be done by opening a window, by using an oven turned low, or by covering an electric plate with an inverted metal dishpan or bucket and turning the heat low. Keep the source of heat as inconspicuous to the children as possible.

Ask about four children at a time to extend their arms out from their sides so that one hand will be in the heated or cooled area and the other not. Tell them to wait until all have felt the two areas before they discuss their observations. Unless the differences are great, some of the children may not detect a difference, or they will not agree about which area is the warmer.

Show the class two similar glass containers with equal amounts of water in them except that the water in one is at room temperature and in the other about 10 degrees (Celsius) warmer or cooler. Ask the children what they observe. They may say that the containers and contents look alike. Have one child at a time put one hand in one container and the other hand in the other container, and ask him to describe any differences. The response should be in terms of *warmer than* and *cooler than*. Ask the children how they might show in some other way that the water in one glass is warmer than that in the other. If no one suggests using a thermometer, bring out one of the coded thermometers and tell the children that it measures temperature and is called a *thermometer*.

Activity 2

Put four large containers of water at different temperatures in front of the children. To help present the coding device, wrap or mark the containers with colored construction paper matching the color code on the thermometer scale, or with white paper which has other identification. The water in the red container should be moderately hot; in the yellow container, warm; in the green container, cool; and in the blue container, cold. You will need an ice and salt mixture in the blue container in order to register a "blue" temperature.

Put the coded thermometer into each container in turn so that the colored liquid in the thermometer will move conspicuously. Be sure each child sees a change in the position of the top of the red column. Describe what you are doing, and ask different children to describe what they see. Ask, When does the red line go up? (When the thermometer is in the hot water.) When does it go down? (When the thermometer is in the cold water.) Why have I put these marks (color tabs or other symbols) on the thermometer? (When the red line is up to the red part of the thermometer scale, the water is hot like the water in the red container; if the red line is only up to the yellow part of the thermometer scale, the water is warm—like the water in the yellow container. And so on for the cool water in the green container and the cold water in the blue container.) Say, Would this work in air as well as in water? Let's see about that tomorrow.

Activity 3

Ask a child to look at the thermometer and tell you whether the temperature is in the red, yellow, green, or blue area. Tell the children that when they do this, they are "reading the thermometer." If the red line is alongside the yellow part of the thermometer scale, for example, the temperature of the room is "yellow." (See Figure 3)

Ask the children what color they think they would read on the thermometer if it were placed outdoors. Put the thermometer out of doors and note the reading on the code. Select a colored piece of paper or square to match the color code corresponding to the temperature reading, and paste it over the proper date numeral on a large calendar. Repeat this activity daily at the same time of day. Let the children take turns reading the thermometer and selecting and pasting the appropriate colored paper on the calendar. If a large calendar is not available, fasten the colored squares in the form of a calendar to the bulletin board, and put the date on each colored square.

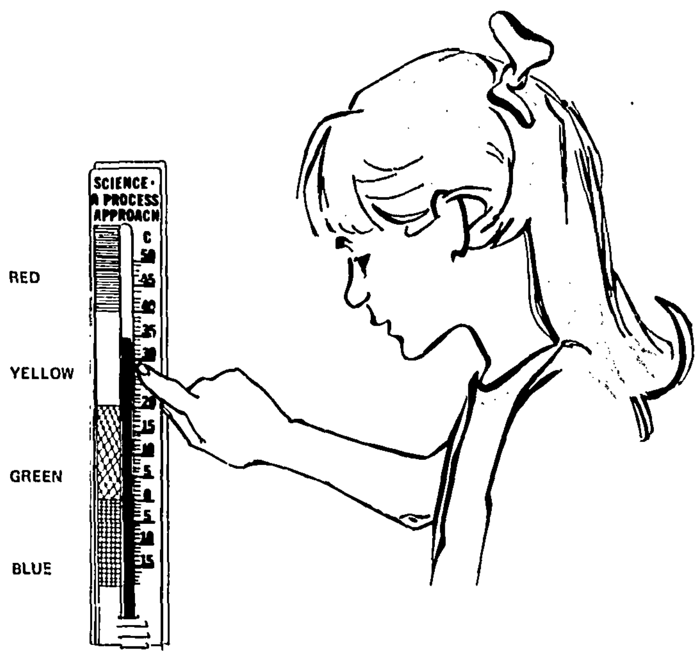


Figure 3

Activity 4

(Temperature readings in this activity are to be made out-of-doors.)

When the children arrive for school, ask one or more of them to read the thermometer. Show the children the ribbon chart and demonstrate how you adjust the ribbon to match a thermometer reading. Ask a child to set the ribbon on one of the ribbon scales to correspond to the reading the children have just made. Choose a time as much later in the day as possible (a time which can be used daily), and again read the thermometer and set the second ribbon thermometer. Discuss the change in temperature. Be sure that the children say, "It is warmer than it was this morning" or, "It is cooler than it was this noon." The lower the red ribbon, of course, the cooler it is.

Activity 5 (Optional)

The children may be interested in pursuing the study of weather conditions other than temperature. If so, a record of cloud cover or wind, or precipitation, or all of them may be kept. The illustration below shows one device for comparing cloud cover from day to day. (See Figure 4)

GENERALIZING EXPERIENCE

Give each child a small cup of fruit juice or milk which is about 10 degrees (Celsius) colder than room temperature. Suggest that they drink the juice if they wish. Then ask, Is it cold or hot? How hot or how cold? Is it cooler or warmer than water from the drinking fountain? How can we find out? Use a thermometer to find the temperature of the water from the drinking fountain and of the fruit juice.

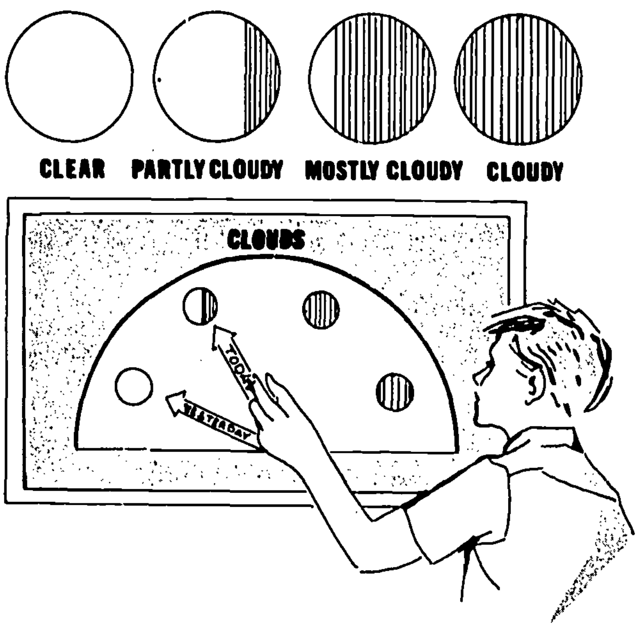


Figure 4

APPRAISAL

Put an incandescent desk lamp on a desk and turn it on. The bulb should be close enough to make a noticeable difference in the temperature of the desk top. Ask the children to feel the desk in various places and determine where it is "warmer" and where it is "cooler." Someone will probably suggest placing a thermometer in various places on the desk and taking the reading. If not, ask the question, How can we find out?

Ask them to use the thermometer to find where it is "warmer" and where it is "cooler." Determine whether or not their findings with the thermometer agree with their findings when they used their hands.

Have the children put the thermometer in the warmest place and note the temperature. Then turn the light off. After about five minutes, ask them to look at the thermometer again. Ask, **Is this place warmer or cooler than it was when the lamp was on?**

COMPETENCY MEASURE

(Individual score sheets for each pupil are in the Teacher Drawer.)

Show each child three clear containers of water. Color the water in two of the containers with food coloring so that one contains blue water and the other, red. Let the blue colored water be the warmest, the uncolored water be of intermediate temperature, and the red colored water the coolest. The difference in temperature between the warmest and the coolest should be at least 20 degrees Celsius.

TASK 1 (OBJECTIVE 1): Have the child place one finger in the blue water and one finger in the red water. Ask him, Which is warmer? Put one check in the acceptable column if he says that the blue water is warmer.

TASK 2 (OBJECTIVE 2): Ask, **What besides a finger can be used to find out which water is warmer, the red water or the uncolored water?** Give one check in the

acceptable column if he suggests that we use a thermometer.
TASK 3 (OBJECTIVE 3): Put one thermometer in the uncolored water and one in the red water. After about half a minute, say to the child, Look at the thermometers and tell me which water is warmer. Give one check in the acceptable column if he states that the uncolored water is warmer.
TASK 4 (OBJECTIVE 4): Allow the two containers from the third task to stand with their thermometers for at least two hours. At a convenient time, say to the child, Find out whether or not there is now a difference in temperature between the containers. There may or may not be a difference that can be detected. Give one check in the acceptable column if he gives the answer indicated by the thermometers.

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Model Lesson 6

LOSS OF MOISTURE FROM POTATOES

SCIENCE — A PROCESS APPROACH

Objectives

At the completion of this exercise the child should be able to:

1. identify environmental conditions that may affect the moisture content of a fruit or vegetable.

2. demonstrate that the moisture content of a fruit or vegetable may be controlled by changing environmental conditions.

3. identify greatest surface area as a means of obtaining the shortest evaporation time for a fixed volume.

4. construct and demonstrate a test of the inference that the change in mass of a cut portion of a fruit or vegetable can be explained by a change in moisture content.

Rationale

This exercise introduces the children to the process of controlling variables in an experiment. The experiments which should be done by the children will be relatively simple to plan and carry out. A principal concern is with conditions under which evaporation of moisture is speeded up or slowed down. The children identify these conditions (variables) and plan experiments to test their influence on evaporation of moisture from potatoes.

One variable is manipulated at a time while several other variables must be held constant or not allowed to change during the test period. In the first two activities it is important that variables such as sizes and shapes of the pieces of potato be kept as constant as possible (controlled). The variable to be manipulated is the environment. In Activity 3, on the other hand, the environment (air, temperature, and movement) should be kept constant, and the sizes of the pieces should be varied.

The rate of evaporation of moisture from potatoes will be affected by the relative humidity, but this is not a variable that can be measured or controlled easily by the children. Even though the relative humidity may change during the experiment, all of the samples exposed to the air will experience the same change, so in a sense this variable is controlled. Unless the children ask about the effect of relative humidity on the rate of evaporation of moisture, it is suggested that humidity not be mentioned. If they do ask about humidity, you may tell them that the rate of evaporation of moisture increases as relative humidity decreases, and decreases as relative humidity increases.

Note: In setting up for Originating the Problem some preparation must be done several hours before the lesson.

Vocabulary

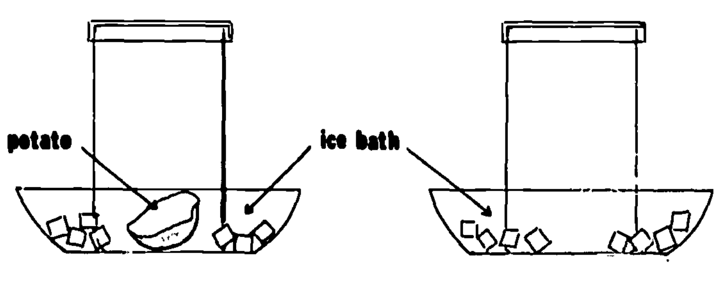
Evaporate, evaporation, environment.

Materials

Fifteen white or sweet potatoes of uniform size and shape, and two other large potatoes
- Containers with lids (such as small jars)
- One dozen apples
- Two identical plastic or glass bowls
- Equal-arm balances and gram weights (masses)
- Knives--one for each group of children
- Tags, indelible pencils, or felt pens--one for each group of children
- Plastic sandwich wrap
- Aluminum foil
- Petroleum jelly (small container)
- One dozen paper plates
- Graph paper--four sheets for each child

Originating the Problem

Obtain two identical small jars (glass or clear plastic) with lids. Place a piece of freshly cut potato in one of the jars. Cover each jar tightly and place both in an ice bath (see diagram) or on top of a cooler.



Within five minutes the children should be able to see drops of moisture collect on the inside of the jar which contains the potato. Ask: Where does the moisture (water) come from? If some of the children answer that the moisture comes from the air inside the jar, have them observe the empty jar. Point out that this jar was subjected to the same conditions as was the other. If the moisture came from the air, both jars would show the same amount of moisture. This may lead the children to infer that the moisture may have come from the potato or from both the air inside the jar and the potato.

Cut a large potato into four pieces and show the pieces to the children. Ask them what they notice about the potato. They will probably talk about its size, shape, color, smoothness, and moistness. Show them a similar potato that has been cut into four pieces and allowed to be on the table for several hours. Ask the children: What is different about the two potatoes? They will probably mention differences in color and moistness of the cut surfaces. They may mention difference in moisture content. As these answers are discussed, ask the children what effect loss of moisture might have on the piece of cut potato. The children may suggest that loss of moisture results in loss of weight, but if necessary ask questions which will bring out this suggestion.

Ask the children how they could measure the loss of moisture of the potato. (By weighing the potato before evaporation and then again after it is believed that some evaporation has taken place.) State that in their experiments they may use weighing to measure the amount of evaporation.

Instructional Procedure

Activity 1--Speeding up Evaporation

Ask the children to suggest different environmental conditions that might speed up the rate of evaporation from cut potatoes. List the conditions on the chalkboard as they are given. This list might include putting the cut potatoes in:

1. open air (on a plate or saucer)
2. open air near fan
3. open air under lamp
4. open air near window
5. open air in direct sunlight

NOTE: Accept all suggestions even those which describe conditions that might lead to a decrease in evaporation rate. Let the children discover for themselves.

Tell the children to test the conditions they have suggested. Have them work in groups of four or five. Tell them to cut cubes of potato about 2 cm on each edge and quickly mark each piece with an identification tag or by a numeral written on one face of the cube with felt pen or indelible pencil.

Next tell the children to measure the mass in grams of each potato piece. Have them do this for five consecutive days at about the same time each day. The mass of the identification tag may be subtracted from each reading or included each time. Have them put the moist potato on wax paper to protect the balance pan and remind them to wipe the paper each time. You might ask why they should do this.

This activity is concerned principally with conditions under which evaporation of moisture from potato pieces is speeded up. The manipulated variable is the environment. The groups test different environmental conditions while other variables such as temperature, size, and shape of the potato cubes are held the same (constant) for all groups.

Urge the children to keep careful records. Following is a suggested chart for data keeping.

Environmental Conditions	Mass in Grams				
	Day 1	Day 2	Day 3	Day 4	Day 5
1. Put in open air (on plate)					
2. Put in open air near fan					
and so on.					

Encourage the groups to compare results. Ask them to graph the data over the five-day period. Time (Day 1, Day 2, and so on) should be shown on the horizontal scale and the mass of the cube of potato on the vertical scale. The children should construct a graph for each of the environmental conditions. Then you might make a composite graph on the chalkboard, putting curves for the different conditions on a single grid. If some of the better pupils can make the composite graph, ask them to do it. Comparisons will be more dramatic in the composite graph.

Activity 2--Delaying or Preventing Evaporation

In this activity the procedures are similar to those in Activity 1, and for this reason the two activities may be taught simultaneously if the teacher prefers. Here the emphasis is on the effectiveness of various ways of preventing evaporation.

Ask the class to suggest ways in which the evaporation of water from a potato may be prevented or slowed. Write the children's suggestions on the chalkboard. A list similar to the following would be satisfactory.

1. Wrap in plastic.
2. Wrap in paper toweling.
3. Wrap in cloth.
4. Cover with petroleum jelly.
5. Wrap in aluminum foil.

Provide materials so the children can work in groups with several of the experiments suggested by the list. The groups doing suggestion 4 should be cautioned not to put the potato cube coated with petroleum jelly directly on the balance pan. Have them place the potato on a piece of wax paper or plastic wrap. Use the same piece of paper each time. The mass of the paper or wrap should be included in every measure.

Activity 3--Evaporation and Surface Area

Select four or more potatoes of approximately the same size, shape, and mass. Place them on the table in clear view of the children. Cut one of the potatoes into two pieces, another into four pieces, another into eight pieces, and so on. Leave one uncut. Ask the children to predict which potato will lose moisture most rapidly. List all of their predictions on the chalkboard. The children may agree that the one that is cut into the most parts will lose moisture most rapidly.

Now ask the children to suggest other ways of cutting the potatoes into two, four, and eight pieces. Let them agree on which way to cut in order to obtain as large a cut surface as possible. Then give each group four potatoes; one into two, the second into four, and the third into eight pieces. The fourth should be left uncut.

Next have them choose the environmental conditions in Activity 1 in which the evaporation was the most rapid and ask the children to plan and carry out an experiment using these conditions. Suggest that they record results for three consecutive days. They should record their results on an appropriate chart suggested by them. The following is one example of a table.

Potato	Mass in Grams		
	Day 1	Day 2	Day 3
1. Uncut			
2. Cut into 2 pieces			
3. Cut into 4 pieces			
4. Cut into 8 pieces			

Ask them to graph the data for all the potatoes. Again prepare a composite graph on a single grid. Time should be shown on the horizontal scale and mass on the vertical scale.

Let the children interpret the data on their graphs. Encourage them to compare results. Ask how the variables in this experiment are different from those in the earlier experiments. This time all the potatoes are subjected to the same environmental conditions but they differ in size and shape. The environment is, therefore, held constant. The size and shape of the potatoes are the manipulated variables.

Based on the discussions and the observed trend in the graph, ask the children to predict and estimate (extrapolate) the mass of the potatoes of the fifth day. Tell them to add two more columns to their data sheet for days 4 and 5. Have them write down their estimates for day 5. Tell the children not to touch their potatoes on the fourth day. The teacher should, however, take the measurements when the children are out of the room. On the fifth day have them measure the mass of their potatoes to determine how close their approximations are. Now have them estimate (interpolate) the values for day 4. Then tell them the actual data and have them compare it with their estimates.

Activity 4--Inferences Suggested by the Investigations

Write on the chalkboard the inferences that the children may make from the various experiments in this exercise, discussing with them the evidence they have found on which to base their inferences. Call attention to the inferences for which they have more reliable evidence and to those for which they have less reliable evidence. The children's suggestions might include:

Potatoes contain water.

Potatoes lose mass because of evaporation of water if they are cut and the cut surfaces are exposed to the air.

Environmental conditions affect the rate of evaporation of water from potatoes.

The evaporation is more rapid as more cut surface is exposed.

A fan or lamp increases the rate of evaporation.

Little evaporation takes place if the potato is wrapped in plastic or aluminum foil or if the surface is covered with petroleum jelly.

Appraisal

Ask the children, working in groups of four or five, to plan and carry out an experiment to determine the loss of mass of an apple caused by evaporation of water. Encourage the groups to compete in trying to set up an experiment in which the apple will lose the most mass in 24 hours. Agreements should be reached before the experiments are started on what variables are to be controlled and which ones should be manipulated. The controlled variables should be the same for all groups.

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Model Lesson 7

CARBON DIOXIDE

EXPERIENCES IN SCIENCE

UNDERSTANDINGS

1. Although a gas may be colorless, odorless, and tasteless, it is possible to devise a test to determine it presence.
2. When baking soda and vinegar are combined, carbon dioxide is released.
3. When carbon dioxide is added to limewater, a milky white precipitate is formed.
4. When carbon dioxide is added to a blue or green-colored solution of bromthymol blue, the liquid turns yellow.

EQUIPMENT

For each group of 4 students:
- generator tank and cover (4 oz)
- plastic tube
- work tray
- mixing container (collecting tank-24 oz)
- 4 test cups and covers
- 2 pieces of newspaper (3" x 4")
- wood splint

For entire class:
- baking soda
- limewater
- vinegar
- bromthymol blue
- stock supply of water
- waste pail
- matches
- mixing container (collecting tank) and cover
- 3 plastic spoons
- covered pint jar

For preparation of stock supply water:
- test cup
- bromthymol blue solution
- sodium bicarbonate
- sodium biphosphate
- large bowl or pot
- well-rinsed milk containers (sufficient for storing 3 quarts of water)

PREPARATION

Preparing the stock supply of water

Test the acidity or alkalinity of the tap water as follows: Fill a test cup halfway with tap water. Add 3 drops of bromthymol blue, shake and observe the color of the liquid. If the color is green or bluish-green, tap water can be used throughout this unit without special treatment.

If the color is more yellow or blue than green or bluish-green, prepare 3 quarts of water which should be used whenever stock supply water is specified. Use a large bowl or pot for mixing.

If the color is on the yellow side, add 1 pinch of sodium bicarbonate to the 3 quarts of water. Stir or shake and then test ½ cup of the water. If necessary repeat, 1 pinch at a time, until the color reaches green.

If the color is on the blue side, repeat the above procedure, but add sodium biphosphate instead of sodium bicarbonate.

Store the stock supply water in clean, well-rinsed, covered containers, such as those used for milk.

Preparing the limewater

Start making the limewater at least 1 day before it is needed.

1. Fill a mixing container (collecting tank) to the ridge with tap water. Add the entire packet of calcium hydroxide ($Ca(OH)_2$) to the water. Cover the container and shake it. Allow it to stand overnight.

2. The next day, carefully pour the clear limewater into a clean pint jar. Cap and store for class use. Discard the sediment in the bottom of the container and rinse the container.

You may wish to use limewater in the Enrichment experiences in Lesson 6.

Preparing the newspaper

Cut newspaper into 24 pieces, 3" by 4". Save eight pieces for use in Lesson 5.

Special Note: Divide the class into groups of four.

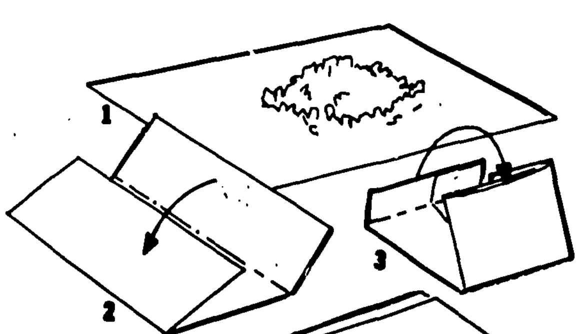
PROCEDURES

Read and discuss: The students read the first two paragraphs on page 2 and discuss them. They become familiar with using the chemical formula CO_2.

Special Note: CO_2 stands for 1 atom of carbon and 2 atoms of oxygen combined to form 1 molecule of carbon dioxide. It is not necessary for the students to discuss the molecular structure of carbon dioxide at this time.

The students read the rest of the text on pages 2 and 3. They discuss it so that they are sure how to proceed.

Activity: Each group obtains a work tray, generator tank and cover, plastic tube, piece of newspaper, four test cups and covers, and a collecting tank.



Special Note: The students should always work over a tray so that they do not allow any materials to spill onto their desks.

One student in each group pushes one end of the plastic tube through the hole in the generator tank cover. He works from the outside of the cover. There should be about ½" of tubing on the inside of the cover.

Another student takes the piece of newspaper to the class supply of baking soda and places 1 spoonful of baking soda in the center of the paper. He folds the paper around the baking soda.

Carbon dioxide

Carbon dioxide is a gas which is involved in the life processes of plants and animals. The chemical formula for carbon dioxide is CO_2. Because carbon dioxide is colorless, odorless, and tasteless, a special test is necessary to prove that it is present.

Carbon dioxide is released when vinegar is added to baking soda. You will use the carbon dioxide you prepare to learn two tests for carbon dioxide. For these tests, you will need limewater and bromthymol blue.

How to prepare carbon dioxide

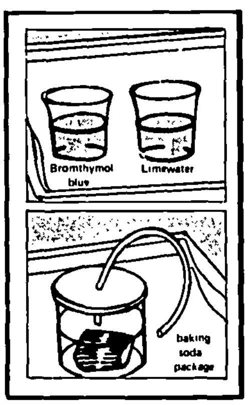
Push one end of a plastic tube through the hole in the cover of a generator tank.

Cut or tear a rectangle of paper so that the length of one side is about three inches and the length of the other side is about four inches.

Place one spoonful of baking soda in the center of the paper. Fold the paper around the baking soda to make a package.

Fill a test cup with vinegar. Pour the vinegar into the generator tank. Then fill the test cup with water, and pour the water into the generator tank also.

2



Fill a clean test cup halfway with limewater.

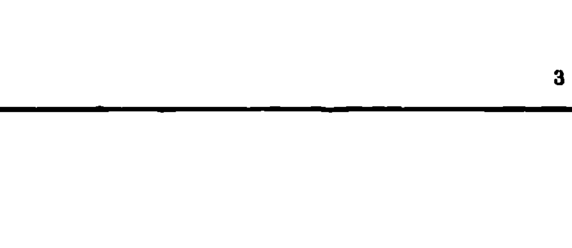
Fill another clean test cup halfway with water from the stock supply. Add six drops of bromthymol blue. What color is the liquid now?

When you are ready to use the carbon dioxide, put the paper package of baking soda into the generator tank.

Quickly cover the generator tank. Let the gas form for about one minute before you use it. This will give the carbon dioxide time to force the air out of the generator tank.

Limewater test for CO_2

Put the end of the tube into the test cup that contains limewater.



Describe what happens.

3

Each student has a test cup with vinegar from the class supply. He pours the vinegar into the generator tank. Then he fills the test cup with water and pours the water into the generator tank also.

The fourth student fills a test cup halfway with limewater from the class supply. He fills another test cup halfway with water from the stock supply and adds 6 drops of bromthymol blue to the water.

Observe and record: Each student examines the test cup containing the water and bromthymol blue and records the color in the space provided on page 3.

Activity, observe, and record: One student in each group manipulates the cover of the generator while another student drops the baking soda package into the mixture of vinegar and water. A third student puts the end of the plastic tube into the test cup containing limewater. When all the students have observed what happens to the limewater, the fourth student puts the end of the tube into the test cup containing bromthymol blue and lets the gas bubble through until there is no further change observable. All the students observe what happens.

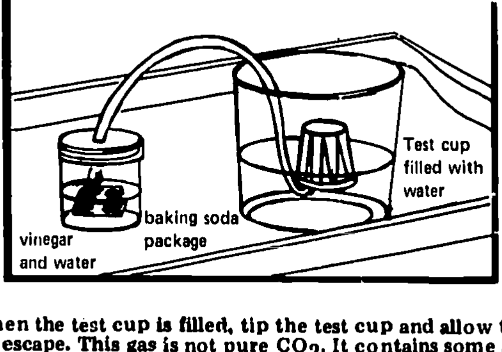
Bromthymol blue and CO_2

Put the end of the tube from the generator tank in the test cup containing bromthymol blue. Let the gas bubble through until there is no further change. What color is the liquid now?

How to collect CO_2

Fill a collecting tank halfway with water. Put a test cup into the water. When the test cup is filled with water, turn it upside down in the water. Be sure there are no air bubbles in the test cup.

Start making CO_2. Wait one minute after the gas begins to form. Hold the test cup so that it remains upside down. Put the end of the plastic tube into the test cup.



When the test cup is filled, tip the test cup and allow the gas to escape. This gas is not pure CO_2. It contains some air from the generator tank.

4

The students record their observations of carbon dioxide and limewater on page 3 and their observations of carbon dioxide and bromthymol blue on page 4.

Discuss: The students discuss their experiences. They should agree that the limewater was clear when they started, but that as the carbon dioxide bubbled into it, the limewater became cloudy (or chalky or milky).

The students should also agree that the bromthymol blue was bluish-green to begin with and that it turned yellow as the carbon dioxide bubbled into it.

Special Note: Bromthymol blue is an indicator which can be used to determine the alkalinity or acidity of a liquid. Any acid or alkali will affect the color. Acids cause the liquid to turn yellow while alkalis cause it to turn blue. When carbon dioxide is added to water, it combines with the water to form carbonic acid. It is the carbonic acid which causes the bromthymol blue to turn from bluish-green to yellow.

Activity: The students pour the contents of the various containers into the waste pail. They clean and store their equipment.

Fill the test cup with water again, and collect gas from the tube. When the test cup is filled with CO_2, put a cover on it while the test cup is still upside down in the water. Then remove the test cup from the water. Be sure the cover fits tightly.

Collect two more test cups of CO_2 the same way.

Describe what happened in the test cup. ______________

____

____

____

____

____

You have collected the CO_2 over water. Why do you think gases are often collected over water? ______________

____

____

____

____

____

____

5

Special Note: The lesson should be interrupted at this point.

Read and discuss: The students read the instructions on page 4 for collecting carbon dioxide. They discuss the instructions so that all the students understand that there should not be any air bubbles in the test cup of water because then they would not have pure carbon dioxide. There would also be some air in the test cup. The students should also realize that they cannot begin collecting the carbon dioxide immediately because there is air in the tube and generator tank. They must discard the first cupful of gas. After that time, the air in the tank and tube should have been pushed out.

Activity: Each group obtains a generator tank and cover, a plastic tube, four test cups and covers, a collecting tank, and a piece of newspaper. They proceed as they did on page 2 and set up the generator.

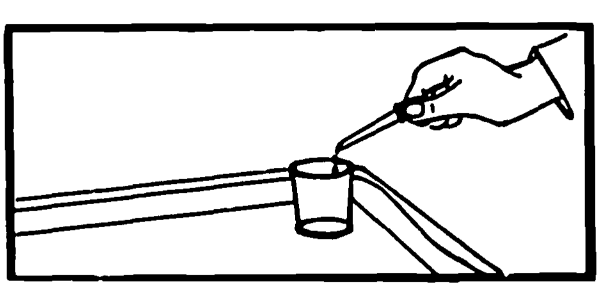
One student fills the collecting tank halfway with water. He puts a clean test cup into the water and lets it fill. Then he inverts it, making sure that there are no air bubbles. Another student holds the end of the tube from the generator under

Test the gas collected

Uncover one test cup of CO_2 and quickly pour a little limewater into it. Cover the test cup again, and shake it. What happens to the limewater?

Put one drop of bromthymol blue into the second test cup of CO_2. Cover the test cup again and shake it. Describe what happens.

Your teacher will light a splint and then blow out the flame. What happens when the glowing splint is pushed into the third test cup of CO_2?



the water and pushes the tube up into the test cup. He allows the test cup to fill with gas and then removes the test cup from the water to allow the gas to escape.

Another student uses the same test cup and proceeding as above, collects another cupful of gas. He covers the test cup while it is still upside down in the water. Each of the other two students in the group collects a test cupful of gas and covers it in the same way.

Think about and record: Each student describes what happened in the test cup as the gas was collected. He writes his description in the space provided on page 5.

The students think about the question at the bottom of page 5 and write their answers.

Discuss: The students discuss their answers. They should agree that as they collected the gas, gas bubbles rose up into the test cup and forced the water out into the collecting tank. When the test cup was filled with gas, the gas began to bubble out through the water in the collecting tank.

The students should agree that two reasons for collecting a gas over water are: (1) there is no gas in the test cup to begin with so you can collect a pure gas, and (2) you can tell when the test cup is filled with the desired gas because it bubbles out into the tank.

Activity, observe, and record: One student in each group pours a little limewater from the class supply into one of the test cups of carbon dioxide. He works quickly so that the cover is removed for as brief a time as possible in order that the carbon dioxide will not escape. He re-covers the test cup and brings it back to his group. He shakes it to mix the limewater with the carbon dioxide. All the students observe what happens and record their observations at the top of page 6.

Another student puts 1 drop of bromthymol blue solution from the class supply into another test cup of carbon dioxide. He returns to his group, and the students observe what happens. They record their observations in the middle of page 6.

The teacher lights a splint and then blows out the flame. She plunges the glowing splint into the carbon dioxide in the third test cup. The students observe and record what happens. She repeats this for each group.

Discuss: The students should agree that when limewater was added to the carbon dioxide, the limewater turned milky. When bromthymol blue solution was added, the bromthymol blue turned yellow. When the glowing splint was plunged into the carbon dioxide in the test cup, the glow was extinguished.

LIGHT, ELODEA, AND CARBON DIOXIDE

Understanding

1. A water plant gives off carbon dioxide when it is in a dark place.
2. A water plant uses carbon dioxide in the presence of light.

Equipment

For every 4 students:
- 2 covered test cups with *Elodea* (from Lesson 4)
- 2 covered test cups without *Elodea* (from Lesson 4)
- generator tank and cover
- plastic tube
- piece of newspaper (3" x 4")
- work tray
- piece of white paper

For entire class:
- waste pail
- 2 test cups
- 4 black bags
- felt pens (as many as are available)
- plastic spoon
- baking soda
- stock supply of water (½ pint)
- vinegar

Procedures

Read and discuss: The students read the text on page 11 and discuss the instructions.

Special Note: Assign two pairs of students to work together. Since there are not sufficient empty test cups available for each group to have its own cup for measuring the vinegar and the water for the CO_2 generators, place one test cup alongside the vinegar and one alongside the stock supply of water for use by the entire class.

Activity: Each group labels one of its test cups with *Elodea* "A" and the other test cup with *Elodea* "C." The students label the other two test cups "B" and "D."

Each group generates CO_2 as they did in Lesson 2. The students bring the generator to the class supply of vinegar and water and use the test cups there for measuring the correct amounts.

The students bubble CO_2 from the generator into each of their test cups until there is no further change in color.

Observe, record, and discuss: Each group places a piece of white paper behind the four test cups. Each student observes the color in each cup and records the colors in the second column in the chart on page 13. The students should agree that the liquid in all the cups is yellow.

Activity: The students place test cups A and B in the brightest part of the classroom. They put test cups C and D in black bags.

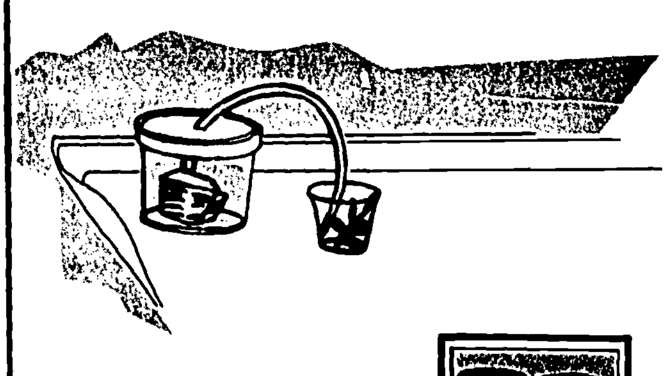
Special Note: You may wish to move test cups A and B from one windowsill to another during the day to follow the sunlight.

The lesson should be interrupted at this point.

Light, *Elodea*, and carbon dioxide

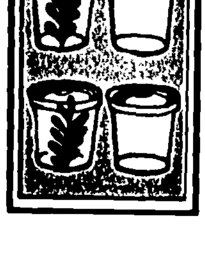
Find out if light has any effect on the amount of carbon dioxide in a test cup containing *Elodea*.

Use two of the test cups with *Elodea* and two of the control test cups which were prepared in the last experiment. Open the test cups. Generate CO_2 and allow the gas to bubble into each test cup until no further change of color occurs in the liquid. Cover the test cups again tightly.



Label the test cups as follows:
A—Test cup with *Elodea*
B—Control test cup
Test cups A and B will be kept in the light

C—Test cup with *Elodea*
D—Control test cup
Test cups C and D will be kept in the dark



11

Observe and record: The following day, the students observe all the test cups again. They record the colors of the liquids in column 3 of the chart on page 13. In column 4, they record whether they think there is more, less, or the same amount of CO_2 in each liquid.

Discuss: The students should agree that only the liquid in test cup A changed color; it became green. Therefore, they assume that there is less CO_2 in the liquid test cup A than there was the day before.

Special Note: Some students may note that the liquid in cup C appears to be more yellow, and therefore they may conclude that there is more CO_2 in the liquid in cup C than there was on the previous day. This is possible since test cup C was kept in the dark and the plant gave up CO_2 to the liquid as it respired.

Activity: The students reverse the positions of the test cups. They place cups C and D in direct sunlight and A and B into black bags.

Place a piece of white paper behind all four test cups, and examine them. Compare the colors of the liquids in the test cups. Record the color of the liquid in each test cup in the second column of the chart on page 13.

Place test cups A and B in direct sunlight. Put test cups C and D in a black bag. Leave them overnight.

The next day compare the colors of the liquids in the test cups again. Record your observations in the third column.

In the fourth column, describe what you think has happened to the amount of CO_2 in each test cup. Is there more CO_2? Is there less CO_2? Is there the same amount of CO_2?

Now place test cups A and B in the black bag. Keep test cups C and D in direct sunlight. Leave them overnight.

The next day use the fifth column to record your observations of the colors of the liquids. In the last column, record what you think has happened to the amount of CO_2, in each test cup.

12

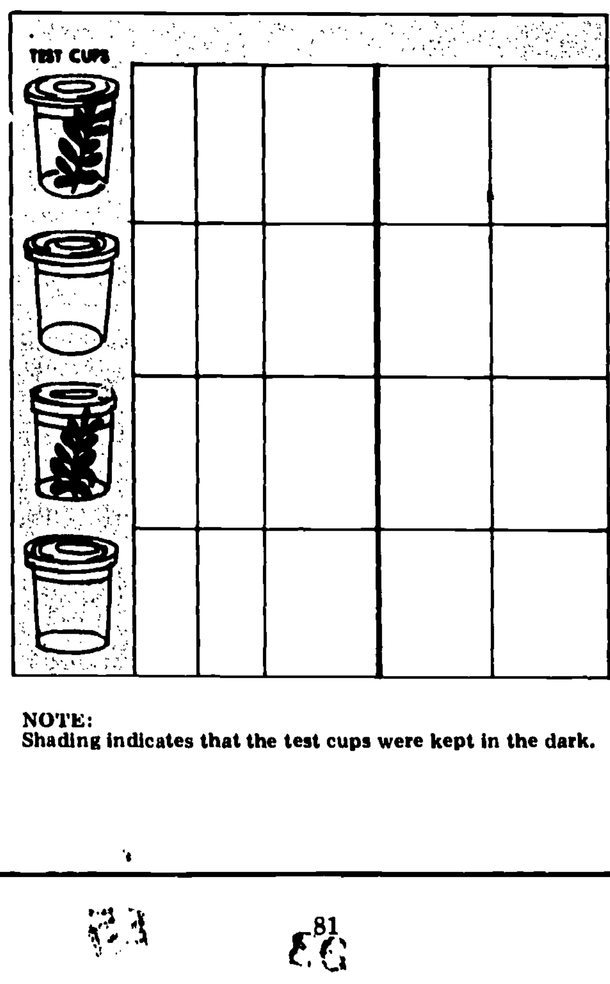
Special Note: The lesson should be interrupted at this point.

Observe and record: The following day, the students observe all the test cups again and record their observations in the last two columns of the chart on page 13.

Discuss: The students should agree that now only the liquid in cup C is green. They assume that there is more CO_2 in the liquid in cup A and less CO_2 in the liquid in cup C than there was on the previous day.

Think about and record: The students think about the problems posed on page 14 and they write their answers.

Discuss: The students should agree that there was less CO_2 in cup A after the first day because the *Elodea* used some of the CO_2 when the cup was kept in the light. They should assume that there was less CO_2 in cup C after the second day for the same reasons. The students should conclude that the CO_2 was used by the *Elodea*



NOTE:
Shading indicates that the test cups were kept in the dark.

13

plant because the only difference between the contents of the test cups was the presence or absence of that plant. They should also conclude that the *Elodea* used the CO_2 when light was present. When there was no light, the *Elodea* did not use the CO_2.

Enrichment: The students can place all the test cups in the light to find out how long it takes for the liquid in all the test cups containing *Elodea* to become the same color.

The students can also determine that the liquid in the test cups without *Elodea* does not change color, even with extended exposure to light.

Activity: The students pour the contents of all the test cups into the waste pail. They clean and store the equipment.

CO_2 was bubbled into the test cups. Was there less CO_2 in any of the test cups after the first day? ________ If so, in which test cups? ________ Explain why you think you obtained these results. ________

Was there less CO_2 in any of the test cups after the second day? ________ If so, in which test cups? ________ Explain why you think you obtained these results. ________

When the liquid in a test cup turned blue, there was less CO_2 in the liquid. Where do you think the CO_2 went? ________

Explain why you think this was so. ________

How did light seem to affect the amount of CO_2 in the liquid containing *Elodea*? ________

14

A CHEMICAL REACTION

EXPERIENCES IN SCIENCE

Understandings

1. Change in temperature can be a sign of chemical change.
2. Formation of a precipitate is a sign of chemical change.
3. When zinc is placed in a solution of copper sulfate, a chemical change takes place.

Equipment

For every 2 students:
- work tray
- test cup and cover
- zinc strip (1" x 2")
- ¼ spoonful of copper sulfate crystals
- paper towel
- piece of paper

For entire class:
- 3 mixing containers of copper sulfate solution
- waste pail
- spoon
- 3 thermometers

Preparation

Beforehand, fill two test cups with copper sulfate crystals to be used for examination by the students and in Lesson 5. Divide the remaining crystals equally among three 24-oz mixing containers. Fill each container almost to the top with water. Put a cover on each container and shake it to dissolve the crystals. The 72 oz of copper sulfate solution will be sufficient for the entire unit.

Procedures

Activity, observe, and record: The students work in pairs. Each pair obtains ¼ spoonful of crystals of copper sulfate on a piece of paper, a strip of zinc, and half a test cupful (½ oz) of water from the class supply. Five pairs of students share a thermometer. The students examine the copper sulfate crystals and the water, and each student records his own observations on page 2.

They dissolve the copper sulfate in the water, and describe the copper sulfate solution in the spaces provided at the bottom of page 2.

Each student examines the zinc and describes it at the top of page 3.

The students immerse the zinc in the copper sulfate solution. They record the temperature and the color of the contents of the test cup at the bottom of page 3. The students may have to bend the zinc a little so that they can fit the cover on the

A chemical reaction

One sign of chemical reaction is a change in temperature. A change in temperature always involves energy. When you mix certain chemicals, the mixture gets hot. When you mix certain other chemicals, the mixture gets cold.

Find out if a temperature change occurs when you add zinc to copper sulfate solution. Work on a tray.

Put ¼ spoonful of copper sulfate on a piece of paper. Examine the copper sulfate and describe its properties.

Phase (solid, liquid, or gas) ______________________

Shape ______________________

Odor ______________________

Temperature ________ Celsius, Color ______________________

Texture ______________________

Fill a test cup halfway with water. Describe the properties of the water.

Phase (solid, liquid, or gas) ______________________

Odor ______________________

Temperature ________ Celsius, Color ______________________

Put the copper sulfate into the water. Put a cover on the test cup and shake it to dissolve the copper sulfate. Examine the solution and describe its properties.

Phase (solid, liquid, or gas) ______________________

Odor ______________________

Temperature________ Celsius, Color______________________ test cup. They shake the cup occasionally. After 2 minutes, they observe and record the temperature and color again.

Each student examines the zinc, copper sulfate solution, and precipitate, and describes them in the spaces provided on page 4.

Think about and record: Each student thinks about the last five questions on page 4. He reviews his record and answers the questions.

Discuss: The students should agree that they observed a chemical change. There was a slight elevation of temperature when the zinc was placed in the copper sulfate solution. The zinc turned black and became warmer. The copper sulfate solution became lighter blue and a precipitate was formed in it. The students should conclude that the precipitate probably is copper since its color is the color of the copper they know, and since copper is a component of copper sulfate. Since the students observed a temperature change, they can conclude that energy was involved in the chemical change.

Examine a piece of zinc and describe its properties.

Phase (solid, liquid, gas) ______________________

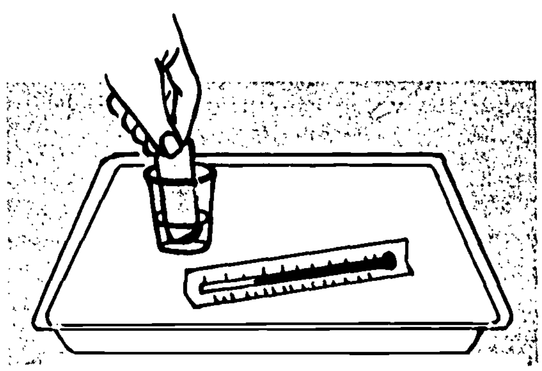
Shape ______________________

Odor ______________________

Temperature ________ Celsius, Color ______________

Texture

Put the zinc into the copper sulfate solution



Record the temperature and the color of the mixture of zinc and copper sulfate solution when you start. Put the cover on the test cup. Shake the cup occasionally. After two minutes, record the temperature and color of the contents of the test cup again.

Time	Temperature	Color
When you start	°C	
After 2 minutes	°C	

3

Special Note: The students can compare the precipitate with the copper nail or copper sheet supplied with this unit.

Activity: The students clean and dry the zinc strips with paper towels. They pour the copper sulfate solution into the waste pail and clean the test cups. They store their equipment.

Special Note: Each pair of students can obtain a container, either a bag or a box, for storing equipment and thus minimize the distribution process for each lesson.

Remove the zinc from the test cup.

Describe any changes you see in the piece of zinc. ________

____

____

Describe any changes you see in the copper sulfate solution.

____

____

Look at the new material formed in the test cup. Take some of it out of the cup and place it on your tray. Describe its properties.

Phase (solid, liquid, or gas) ________________

Odor ________________

Temperature ________ Celsius, Color ________________

Texture ________________

The new material is not zinc or copper sulfate. What do you think it is? ________________

____

Did temperature change occur when the zinc was placed in the copper sulfate solution? ________________

Did a chemical change occur? ________________

What is your evidence? ________________

____

____

Was energy involved in the changes that occurred? ________

4

ELECTRICITY FROM CHEMICALS

Understanding

Electricity can be produced when a chemical change takes place.

Equipment

For every 2 students:
- test cup and cover
- copper nail
- zinc nail
- iron nail
- aluminum nail
- work tray
- paper towel
- 2 hook-up wires
- galvanometer

For entire class:
- copper sulfate solution
- waste pail
- steel wool (for cleaning nails)

Procedures

Special Note: If the nails become too heavily coated, the cell will not operate

Electricity from chemicals

A flashlight battery is an electrical cell. It is sometimes called a "dry cell." You can use copper sulfate and two metals to make an electrical cell. It will be a wet cell.

1

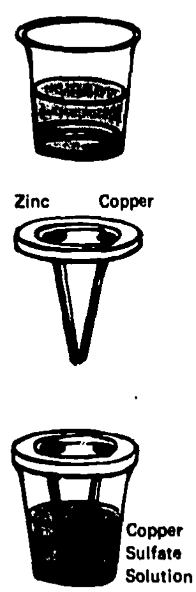
Fill a test cup half-way with copper sulfate solution.

2

Push a zinc nail and a copper nail all the way through the cover of the cup. Put the nails on either side of the center ridge.

3

Put the cover on the cup.



You have made a zinc-copper wet cell.

7

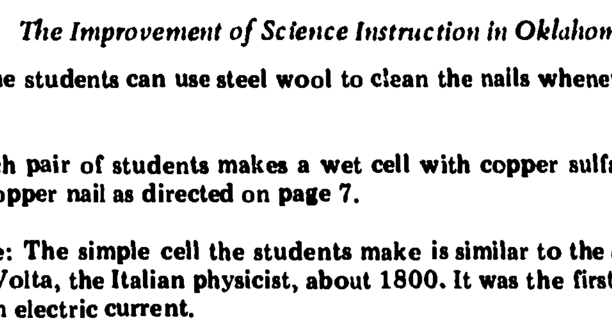
properly. The students can use steel wool to clean the nails whenever they can see a coating.

Activity: Each pair of students makes a wet cell with copper sulfate solution and a zinc and a copper nail as directed on page 7.

Special Note: The simple cell the students make is similar to the one developed by Alessandro Volta, the Italian physicist, about 1800. It was the first known means of producing an electric current.

Observe and record: The students test their wet cells by attaching them to a galvanometer. They attach the bare ends of the hook-up wires to the ends of the galvanometer wire. The students fasten the other end of one of the hook-up wires to the head of one of the nails. They touch the bare end of the other hook-up wire to the head of the other nail. They observe what happens to the galvanometer and record their observations in the first set of spaces on page 8. They reverse the connections and record their new observations at the bottom of page 8.

Test the zinc-copper wet cell with your galvanometer. Fasten one hook-up wire to one end of the galvanometer wire. Fasten the other hook up wire to the other end of the galvanometer wire. Then fasten the bare end of the first hook-up wire to the head of the zinc nail. Touch the bare end of the other hook-up wire to the head of the copper nail.

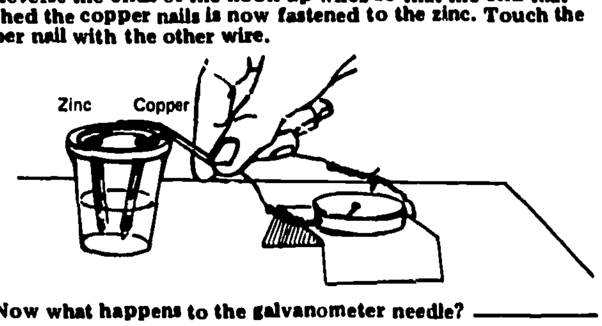


What happens to the galvanometer needle? ______________

____

____

Reverse the ends of the hook-up wires so that the end that touched the copper nails is now fastened to the zinc. Touch the copper nail with the other wire.



Now what happens to the galvanometer needle? ______________

____

____

8

Special Note: It is advisable for the students to wipe each nail immediately whenever they take it out of the solution so that the nails will not become too heavily coated.

Discuss: The students should agree that in each case, the galvanometer needle moved. Therefore, an electric current was passing through its wire. The students all should have observed that when they reversed the connections, the needle moved in the opposite direction. The students should compare this with what happened when they reversed the connections to the flashlight battery on page 6.

Observe and record: Each pair of students makes three galvanometer readings with the zinc-copper wet cell. Then the students test various combinations of nails in their wet cell as specified on pages 9 and 10. They record their observations in the spaces provided.

Special Note: To make it easier to read the numbers on the compass dial, instruct the students always to start a trial with the blue tip of the needle at 0^{o} (north). The

Make three readings using the zinc-copper wet cell.

Metals used in the cell: zinc and copper

Does the galvanometer needle swing? ____________________

If so, how much does it swing each time?
Trial 1: ______ Trial 2: ______ Trial 3: ____________

Remove the nails from the copper sulfate solution as soon as you have finished working with your cell. Wipe them with a paper towel.

Try using other metals in the copper sulfate solution. Test each cell you make with the galvanometer. Try to measure the electricity produced by each cell. Make three readings of each cell for more reliable results.

Whenever you have finished using a nail, wipe it with a paper towel.

Metals used in the cell: zinc and aluminum

Does the galvanometer needle swing? ____________________

If so, how much does it swing each time?

Trial 1: ______ Trial 2: ______ Trial 3: ____________

Is this more or less than the swing caused by the zinc-copper cell?

9

students should wait until the needle comes to rest before taking a reading. Since the direction in which the needle swings depends on how the galvanometer is connected to the wet cell (which end of the galvanometer wire is attached to which nail), advise the students that if the needle swings counterclockwise (toward the west), they must deduct their reading from 360 to get the number of the swing. For example, if the needle swings counterclockwise and comes to rest at 240, they subtract 240 from 360 and record 120 for that trial. If the needle swings clockwise (toward the east), the students can record the number without subtracting.

If a pair of students is having difficulty getting a reading using the zinc and copper nails, check the following:

1. Are the nails coated? Do they need to be cleaned?
2. Are the nails all the way down in the copper sulfate solution?
3. Are the hook-up wires fastened securely around the nail heads?
4. Are the hook-up wires fastened securely to the ends of the galvanometer wire?
5. Is the compass needle stuck?

It will not be unusual for the students to have difficulty getting readings with

Metals used in the cell: zinc and iron

Does the galvanometer needle swing? ____________

If so, how much does it swing each time? ____________

Trial 1: ______ Trial 2: ______ Trial 3: ______
Is this more or less than the swing caused by the copper-zinc cell?

____

Metals used in the cell: iron and copper

Does the galvanometer needle swing? ____________

If so, how much does it swing each time? ____________

Trial 1: ______ Trial 2: ______ Trial 3: ______
Is this more or less than the swing caused by the copper-zinc cell?

____

Metals used in the cell: iron and aluminum

Does the galvanometer needle swing? ____________

If so, how much does it swing each time? ____________

Trial 1: ______ Trial 2: ______ Trial 3: ______
Is this more or less than the swing caused by the copper-zinc cell?

____

Metals used in the cell: aluminum and copper

Does the galvanometer needle swing;

If so, how much does it swing each time?

Trial 1: Trial 2: Trial 3:

Is this more or less than the swing caused by the copper-zinc cell?

10

the iron and aluminum, iron and copper, and aluminum and copper, since these produce such a small current.

Activity: The students clean and dry all their nails. They put the cover on their test cup of copper sulfate solution. They store their equipment.

Special Note: The lesson should be interrupted at the end of page 10.

Think about and record: The students review the trials they recorded on pages 9 and 10. They approximate an average for each set of trials. Then they arrange the pairs of nails on the chart on page 11, listing the pair with the smallest swing at the bottom.

Discuss: The students compare their results. A chart can be made on the chalkboard, and the approximate averages obtained by each pair of students can be listed for each pair of nails.

List the pairs of metals in order, beginning with the pair which moves the needle the shortest distance.

Compare your chart with those of the other students in the class. Did everyone get about the same results? ____________

Think about this

The boy in the picture is lifting a weight. He is doing work. Your wet cells made the galvanometer needle move.

Can electrical energy do work? ____________________

Why do you think so? ____________________

____

____

11

Special Note: The exact numerical values the students will get will vary with the concentration of the copper sulfate solution, and the amount of coating on the nails. It is not likely that many pairs of students will get identical results, but the locations of the pairs of nails on their charts should be similar.

The students should conclude that iron and aluminum, iron and copper, and aluminum and copper produce relatively small electric currents. The other three sets of nails produce currents of about the same strength, with zinc and copper producing the greatest current.

Think about, record, and discuss: The students think about the problem at the bottom of page 11 and write their answers. The students should conclude that electrical energy can do work because it made the compass needle move, and that is considered work.

Special Note: The lesson can be interrupted at the end of page 11.

Find out what happens when 2 nails of the same metal are used.

Metal used in the cell: copper

Does the galvanometer needle swing? ____________________

If so, how much does it swing each time?

Trial 1: ________ **Trial 2:** ________ **Trial 3:** ____________
Is this more or less than the swing caused by the copper-zinc cell?

Metal used in the cell; aluminum

Does the galvanometer needle swing? ____________________

If so, how much does it swing each time?

Trial 1: ________ **Trial 2:** ________ **Trial 3:** ____________
Is this more or less than the swing caused by the copper-zinc cell?

Metal used in the cell: iron

Does the galvanometer needle swing? ____________________

If so, how much does it swing each time?

Trial 1: ________ **Trial 2:** ________ **Trial 3:** ____________
Is this more or less than the swing caused by the copper-zinc cell?

What have you found out about the metals used in wet cells?

____

____

12

Activity, observe, and record: The students set up their wet cells. Each pair of students shares its nails with another pair so that they can all test their cells using two nails of the same material.

Special Note: Since the nails do not have to be tested in any special order, one pair of students can test copper, while the other pair is testing aluminum, and so on.

The students record their observations for each trial on page 12.

Discuss: The students should reach two conclusions as a result of their experiences in this lesson:

1. They must use two different metals in order to produce electricity with their wet cells.
2. Some combinations of metals produce more electricity than others.

Activity: The students clean and dry all their nails. They discard the copper sulfate solution and clean and dry the test cups. They store their equipment.

Experiences in Science - E.I.S. - Statement of Philosophy

EXPERIENCES IN SCIENCE provides a set of systematically planned experiences that enable students to build understandings of some of the fundamental principles of science.

The EXPERIENCES IN SICENCE structure includes content from several fields of science.

EXPERIENCES IN SCIENCE fosters conceptual learning by stressing the processes of science, not as opposed to content but as essential to learning and understanding.

The Recortexts enable the students to plan investigations, to observe, to measure, to contrast and compare, and to classify, organize, quantify, infer, predict, and verify predictions.

EXPERIENCES IN SCIENCE recasts the role of the teacher who now becomes a catalyst of learning, a guide in the process of investigating.

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