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ABSTRACT

This National Science Teachers Association (NSTA) publication presents examples of science techniques and situations which provide opportunity for each child to practice the skills basic to science. The common theme in all of the techniques is that of active, personal participation to achieve individualization of instruction. It is believed that the techniques described can individualize the teaching of science skills better than would reading or talking about science. (Author/CP)

NATIONAL SCIENCE TEACHERS ASSOCIATION

how to . . .

INDIVIDUALIZE SCIENCE INSTRUCTION

in the elementary school

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In recent years, much effort has been spent on improving science teaching in the secondary school, and from this effort have come useful and challenging programs in physics, biology, chemistry, and earth science. In all of the curricula developed for the high school, there has been a definite trend away from developing factual inventories, and a movement toward the development of concepts, personal understandings, and skills related to independent inquiry.

Curriculum builders now realize that to ensure the development of the maximum science potential of each child throughout his public school education, attention must be turned to the development of better programs and teaching techniques for the elementary school. Studies now underway are producing curricula which, like those in the high school, place primary emphasis on the development of abilities which will enable children to investigate and understand science. Special consideration is being given to "honest inquiry as a basis of classroom activity, personal involvement of the teacher and children in investigation, direct reliance on observable reality, and active participation by each individual.[1] The chief emphasis of the new programs is placed, therefore, on involving each child in the activities of science, and not on the teaching of facts.

A POINT OF VIEW

One objective of this publication is to present examples of science teaching techniques and situations which provide maximum opportunity for each child to practice the skills basic to science. These techniques are the means of individualizing science instruction. The common theme in all of the techniques is that of active, personal participation on the part of the child. It is believed that the techniques described can individualize the teaching of science skills better than would talking to children about science or having the children read about science.

[1] Benjamin Nichols. *Newsletter*. Elementary Science Study, October 1964.

Individualization defined

How can teachers tailor or individualize their teaching techniques so that each child will receive the maximum opportunity to practice and thus become proficient in the use of basic science skills? Individualization of instruction can take many forms, all of which are probably familiar to the reader. Students can be grouped according to ability. Class size may be restricted. Team teaching can permit more thorough development of lesson plans and laboratory situations. A wide diversity of audiovisual aids and printed resources can be utilized to help teachers tailor their lessons to fit their classes.

The preceding suggestions do not tell the entire story. Grouped classes can be as unchallenging to the students as grouped sections. Small classes do not of themselves guarantee individualization. As stressed in this leaflet, individualization means presenting the kind of experiences in which each and every child has the opportunity to participate actively, either mentally or physically. In addition, the teacher should be concerned that the individualization takes place in the context of helping children develop the basic skills listed in the following section.

The skills

A second objective of this paper is based on the belief that the teaching of science skills necessary to explore science intelligently is more important than the teaching of isolated facts. This is not to say that elementary school science should or could exist in situations devoid of science content. Children should come away from science knowing something about the physical world in which they live. Content, however, should not be an end in itself; rather, it should be a vehicle through which skills are taught.

The rate of forgetting appears to be faster than the rate of learning. Examples of this statement

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must be apparent to all of us who teach, especially when we have "pushed through" units in science to ensure that we have at least exposed our students to the text. At the end of the year, the children have been stuffed with facts about plants, animals, machines, magnets, jets and rockets, and trips through space to the moon or Mars. It seems that our young people ought to be walking encyclopedias of pertinent (or not so pertinent) information. Yet children are able to shed these facts with guileless ease after the passage of a few weeks, to say nothing of a summer vacation.

What learnings suffer least from the erosion of time? The most lasting experiences seem to be those which stress basic science skills concerned with *how* to find out.

The following sections deal with the development in children of the following skills [2]:

1. Observing carefully
2. Grouping related objects
3. Quantifying science
4. Seeing all dimensions
5. Transmitting ideas
6. Drawing inferences
7. Making predictions
8. Setting up experiments
9. Using controls
10. Interpreting results
11. Applying concepts to unfamiliar situations

TECHNIQUES FOR DEVELOPING SCIENCE SKILLS

Observing carefully

Children live in a busy world which deluges their senses with a multiplicity of stimuli. Sights, sounds, and smells make life intriguing and worthwhile. As many children progress to adulthood, however, they never seem to achieve the ability to observe and interpret their environment to the fullest. Living things are just plants and animals; sounds are just noise or music. The ability to discriminate accurately among stimuli frequently goes undeveloped, with the result that the children only half perceive the world about them.

Experience in the skill of observing should help each child become acutely aware of the properties of things in his environment. He should be able to describe and compare objects with regard to taste, color, texture, odor, and sound. He should learn that skillful observation involves being able to describe the motion and position of objects as well as their physical appearance. He should learn to combine many of his observing skills to obtain data about an unfamiliar object or objects, or about a problem which has developed. As he becomes increasingly aware of his physical world, the caliber of the questions he asks as to why and how things are as they are will improve.

Providing children with experiences such as the following is individualization of the highest order, for no one can see what the child sees but the child himself. His success in detecting and interpreting stimuli depends on the quantity and quality of the experience he receives.

Example 1. The children are given small pieces of bread, potato, apple, gumdrop, and orange. They are asked to describe these items by seeing, tasting, feeling, and smelling. It is expected that their responses will be developed in terms of sweetness, wetness, sourness, hardness, odor, and color. Children frequently identify objects by reacting to only one stimulus. Thus all orange-colored, round objects may be described by the very young as oranges. Asking each child to identify other properties of oranges extends his range of observation and identification.

* The author is indebted in part to many current curriculum studies for ideas. See bibliography references 1, 2, 3, and 9.

Example 2. Children put their heads on their desks, or close their eyes and listen to coins being dropped. They are asked to try to identify the size or denomination of the coin. Is it a large coin, or is it a small one? They are also asked to estimate the height from which a single coin is dropped.

Example 3. Sounds common to the child's environment are recorded on tape. These could include street noises, bells, sounds of animals, and sounds of materials being struck against one another. What sounds do the children recognize? If they recognize an animal sound, is it a large animal or a small animal? Are noises near or far away? Are sounds high pitched or low pitched? Aural stimuli are important identification clues in the child's environment, although they are often not given the attention that other kinds of stimuli are accorded. The practice sessions described in examples 2 and 3 help each child develop aural acuity so that he is better able to detect finer nuances in sound stimuli.

Example 4. The children can be asked to identify squares, circles, ovals, cubes, or rectangles by being shown the actual shapes. Then they are asked to find these shapes in clouds, leaves, windows, houses, and other everyday objects.

Grouping related objects

Once children have observed that things are different, the natural tendency seems to be to group related objects. Some objects are to be eaten while others are used to play games such as "war" and "house." Grouping, or classification, is really the extension and application of the skill of observing. It helps children organize the many parts of their environment for easy use and for determining relationships between objects.

Scientists also rely heavily upon classification to help bring about order in science. The chemist makes use of the periodic chart of the elements, in which the elements are grouped into periods and families according to their physical properties. Chemists group compounds into acids, bases, and salts according to their reactions with other compounds and their chemical composition. Biologists use intricate schemes to identify the vast number of living things. In other branches of science, rocks are grouped according to texture and color, and minerals are classified according to their color, hardness, streak, crystal formation, and many other properties.

Which classification system is the best? This question has no single answer for the scientist. Any scheme is suitable as long as it meets his needs. The same criterion, therefore, should be applied to child-designed classification systems. The only unacceptable systems are those which permit overlapping where one item may fit into two different categories, or those from which some category is omitted. If a tree can be classified as a pine and an elm, then the scheme is invalid.

Perhaps most important of all is the idea that children should be able to *use* the classification scheme which they have originated. They should be able to take a strange object and, by using their key or classification system, place the object into one of the established categories.

As a result of experience in classification, the children should automatically start looking for ways to group related objects. They should be aware of the many ways in which objects differ; ways which form the basis of a system of classification. They should be able to subclassify groups of objects already classified.

Example 1. Rocks may be classified on the basis of smoothness, color, size, texture, and hardness. Each of these classifications can be conducted separately, and then combinations of these are possible. For example, all of the large rocks can be subdivided into those which are smooth or rough. All smooth rocks can be classified into rocks mostly light or mostly dark in color.

Example 2. Coins may be classified on the basis of size, value, color, design, or origin.

Example 3. Shells may be grouped on the basis of color, shape, size, and number of ridges.

Example 4. Fellow classmates may be grouped according to sex, height, weight, eye color, hair color, hair texture, and whether they do or do not wear glasses. Once the key is developed, it may be used to identify members of the class. For example, a description of a student is given in terms of the key, and someone is asked to name the student described.

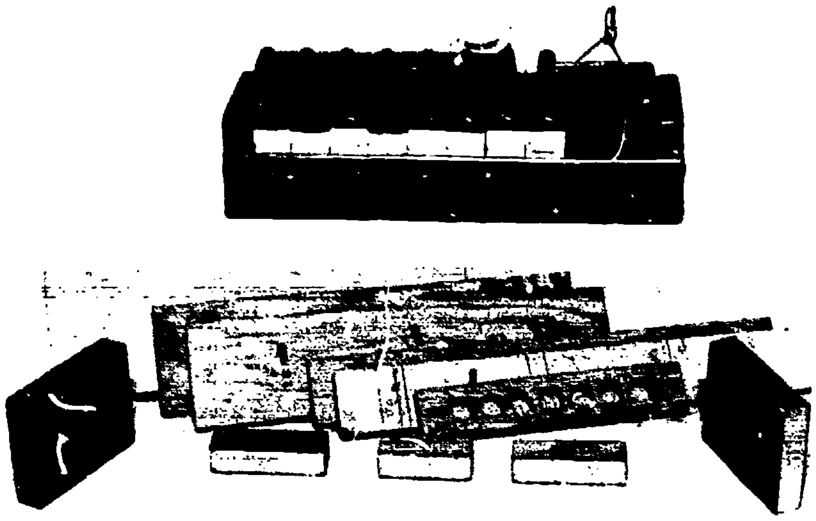
Example 5. Children may classify compounds into acids and bases. Once children are taught some general properties of acids (vinegar, lemon juice) and bases (solution of baking soda, ammonia), and indicators (litmus paper, juice from boiled red cabbage), they can group household substances according to an acid or base reaction to the particular indicator used.[3]

Example 6. Children may classify the food they eat into categories of fat, starch, sugar, and proteins by using simple, safe chemical tests. Materials necessary for Examples 5 and 6 may be assembled into a semimicro type of chemistry kit, because only small volumes of chemicals are used. Sinks and laborato· spaces are not needed. The accompanying ph · graphs show the chemistry kit unassembled and completed, and sixth-grade children at work classifying foods using the kit.[4]

[3] T. W. Munch and J. Chubbuck. "The Sixth Grade Is Ready for Chemistry Experiments." *The Instructor*, Vol. 72, April 1963.
[4] T. W. Munch. "Chemistry Kit for Intermediates." *The Science Teacher*, 29: 61-63, December 1962.

Stan Gilbert

Safe and easy-to-get chemicals assembled and stored in easily made kits provide a basic tool for individualizing science instruction.



Stan Gilbert

This chemistry kit is a simple tool which provides individualization in the practice of basic science skills for these sixth-graders.

These kits were made by the children who used the unassembled kit as a pattern. The various parts were traced onto heavy wrapping paper, and these pattern parts were transferred onto wood which the children found at home.

Quantifying science

Measuring is a vital, although sometimes unrecognized, skill which children use throughout their lives. They start early by estimating time when jumping rope, by estimating distance when leaping a puddle, and by estimating volume when they choose the largest bottle of soda for ten cents.

As children mature, they will discover that many facts in science can be verified only by *accurately* measuring objects in their environment. Further, they are led to see that instruments have been devised which permit precise measurements. Instruments help us extend our senses, and the more precise the instrument is, the further this extension reaches. Increased accuracy in instrumentation results in increased exactness of classification. Some instruments which allow us to extend our senses (and which can be easily used in the classroom) include the ruler, the meter stick, the balance, volumetric cylinders, the microscope, and the telescope.

It is best to begin the study of measurement by permitting the children to discover and use their own units of length, volume, and weight (mass). These early experiences should emphasize the arbitary nature of measuring units. (See Example 1.) The use of more precise measuring instruments, such as rulers, meter sticks, balances, and volumetric measuring devices for pints and quarts, can best be introduced a little later.

Not all measurements are limited to single units. For example, plants grow and change with time, and to describe plant growth accurately, the children should be able to relate changes in size with the passage of time. Children, cars, and falling objects move through space in definite units of time, and children should be able to measure change of position and shape with the passage of time.

Example 1. Children can measure the length of a book or a room by using a Popsicle stick. Students should see that some measurements involve only parts of the stick and that small units of measure are necessary. Perhaps they can then mark off the Popsicle stick into halves, quarters, or tenths. In contrast to this, children can easily see that small measuring tools are too short to measure long distances. Broom handles, or long straight sticks can be calibrated and used to measure a long distance.

Example 2. Children can compare weights, volumes, and lengths of unknown objects with the dimensions of known objects. A one-pound box of sugar may be used as a standard. Other objects of unknown weight are compared to the sugar. Which are heavier? Which are lighter?

Example 3. A pint bottle filled with sand or water is used as a standard. Will other bottles hold more or less sand or water?

Example 4. A ruler is used as a standard. Common objects are compared in length to the ruler. Which are longer? Which are shorter?

Example 5. Children can measure the height of plants with strips of paper. The strips are then placed on the bulletin board to show the increase of height with the passage of time. In this way the rudiments of simple graphing and the relationships between space and time can be initiated. (See also Example 2, pp. 6 and 7.)

Example 6. The number of seeds which germinate can be counted. Groups of children are given 20 seeds, which are placed on wet sand or wet paper toweling. When the seeds have germinated, the children are asked to observe how many seeds sprouted (germinated). Depending on their sophistication, the children may be able to say that 15 out of 20, or 75 percent, germinated.

Example 7. Children can count the number of tacks picked up by magnets of different sizes and strengths.

Seeing all dimensions

Many objects and processes in science (and in our everyday world) cannot be seen in their entirety, yet we must imagine how they look or what is taking place. Through a microscope, objects such as cells appear to have but two dimensions; yet cells have depth as well as length and breadth. Geologists have to visualize the position of rock strata by taking samples at several depths or by seeing cross sections of the strata at a few places on the surface of the earth. Oceanographers outline the bottom of the ocean by sound reflection patterns. Chemists and physicists construct models of the atom by observing chemical and physical reactions.

By using experiments of the kind described below, each child should come to visualize objects and shapes that are viewed from only one side. Children should be able to draw or describe how objects are arranged by observing only part of the object or when only inferential evidence is available.

Example 1. The teacher holds up a ball, a block, and a pyramid. The children are asked to draw or describe in some way how the other side of each of these objects looks.

Example 2. As plants or animals grow in the classroom, the children should be urged to describe how these organisms have changed with the passage of time. In the case of plants, what new leaves have been added? When did flowers appear? What was the effect of fertilizers on the plants? In the case of animals, when did the butterfly egg change to a larva, to the chrysalis stage, to the adult butterfly?

Example 3. Strips of different color modeling clay may be placed on top of one another. The teacher shows only a side view. The children are asked to draw a picture of the reverse side of the clay model. The teacher then presses on each end of the clay forming an upward curve in the clay. The children are asked again to draw or describe what they see.

Example 4.[5] Hold objects of various shapes in the beam of a strong light and call the children's attention to shadows they see cast on the wall or screen. Turn each object in various ways and see whether the shape of the shadow changes.

Transmitting ideas

Being able to describe ideas and observation is as important in science as it is in any other field of study. The emphasis in science is on preciseness.

Children should be helped to communicate more skillfully in three areas: oral description, written description, and graphic representation of science data. Children should be able to tell about science phenomena so that others will have a clear understanding of what has happened. Children should learn to avoid the use of such general and meaningless terms as "stuff," "things," and "junk."

Children should also be urged to write descriptions of things they have observed about science. They should be taught to write careful records of their experiences, recording any data which they collect in the process of experimenting. The old proverb that "a picture is worth 1000 words" has special significance in science. It is frequently difficult to see relationships between sets of data if the data are all left in "raw" form. Bar graphs and line graphs will help children see relationships more clearly.

Example 1. Various objects are placed on a table. One child is asked to describe one item carefully without picking it up or pointing to it, so that another child can pick out the item under consideration.

Example 2. One student is "tagged" on his back with a card naming an animal. The child must identify himself in terms of the animal. "Do I have four legs?" "Do I have hair?" "Am I a horse?"

Example 3. Dime-sized spots are applied to a balloon with a felt pen, and the balloon is blown up. The children are asked to write a description of the balloon before and during its inflation.

Example 4. Fifty seeds each of three different varieties of beans are germinated by the children. They then make a bar graph showing the percent of germination of the various varieties of seeds.

[5] Elementary School Science Project. "Astronomy: Charting the Universe." Third Edition, p. 6. University of Illinois, Urbana.

Example 5. The children make a line graph of the growth of a bean seed. The time would be shown on one axis, and the height to which the plant has grown can be shown on the other axis.

Explaining unobservable facts and events

Amazing as it may seem, scientists cannot always produce *direct* evidence for some of their most firmly held beliefs. No one has seen an atom, yet physicists describe many subnuclear particles of the atom. No one has seen electricity, yet we know how to control electrical phenomena and how to predict electrical effects. No astronomer has visited the sun, yet the scientific community accepts without a murmur the fact that approximately 66 of the elements found on the earth are also found on the sun.

How then can the scientists be sure of their scientific statements? Part of the answer lies in the word "inference." An inference is an explanation of an observed event when that explanation is not supported by direct evidence. When one makes an inference, he draws a conclusion based on indirect, but strongly circumstantial, evidence. Upon waking in the morning, a child sees that the grass and the street are wet, and he exclaims, "Oh, it rained last night!" The statement that it rained during the night is an inference. When a person is taken to the hospital in an ambulance, one may infer that the person is quite ill. A little reflection will indicate how vital a role inferential reasoning plays in our everyday life and in science. Although this form of logic can become quite sophisticated on an adult scientific level, even small children can be introduced to the skill of developing reasonable explanations for unobserved events.

Example 1. The game of "The Box" provides an interesting starting experience. The teacher puts into a box some common object unknown to the children. A clothespin, a marble, or a pencil are all good objects. The children are asked to find out what is in the box without opening it. They are permitted to shake, smell, and lift the box, but they are told nothing about its contents. The teacher lists their inferences on the board, and discusses their inferences with them. For instance, the object is not a feather, because the object is heavy and it rolls about in its container. It is also not a block because it rolls.

Example 2. A glass is filled with ice and covered with a lid, and permitted to stand for a few minutes until moisture forms on the outside. Where did the moisture come from? One inference might be that the water came through the glass. Another child might infer that the water came from the air. An important aspect of this experience is to develop a test to prove (or disprove) any inferences the children make. In the first case, the children might add food coloring to the ice water in the glass. If the moisture on the outside remains colorless, the water did not come through the glass, or the moisture came through the glass, leaving the color behind. If the moisture did not come through the glass, the only other deduction to be made is that the moisture came from the air. A variation might be to compare two beakers, one containing cold water and one warmer water.

Example 3. Variations on *Example 2* can be made by breathing on a mirror, or by passing steam over a cool, shiny pan.

Forecasting outcomes

Prediction is an important tool in the scientific world. What will the weather be tomorrow? Even the weatherman cannot always forecast weather behavior with 100 percent accuracy. Yet, weathermen and meteorologists can predict future atmospheric conditions with a great deal of accuracy by basing their forecasts on a multitude of past atmospheric patterns. Chemists can predict that by mixing an acid with an equal volume of equal strength base, a salt and water will be formed. This prediction is based on the past experiences of many chemists who have made innumerable mixtures of acids and bases and have obtained salt and water each time.

Children can and should learn to predict or forecast outcomes by using data from their own observations. *Two important points* should be made in relation to developing the ability to forecast outcomes.

1. Any prediction should be based on some observed data. Any prediction made without some factual basis is only a guess.
2. Prediction should be followed by some test to establish the validity of the prediction.

Example 1. Third-grade children are asked to list the five vegetables they like best. Similar data are gathered in one half of the other third grades, and the top five favorites are listed. On the basis of these data, the children are asked to predict what would be the five most favored vegetables in the other half of the third grades of the school. The predicted list is assembled. The check on the prediction is carried out by canvassing the remaining half of the third-grade classes.

Example 2. The children can predict what will happen to barley seeds exposed to radioactive materials. The children must first be introduced to the effects of radiation on living things by being made aware of the result of radioactive tests made in the United States on plants and animals. The students are asked to predict what will happen to seeds which have been exposed to various doses of radiation. Basing their predictions on what happened to other living things, the children might predict that the plants growing

John Dutson

These children are accumulating data to help answer the problem, "Does irradiation affect the growth of barley seeds?" These fifth-graders are measuring and recording accurately to the nearest millimeter.

John Dutson

Growing irradiated barley seeds provides experience in the practice of many of the basic skills discussed in this leaflet. Which seedlings grew from seeds receiving no radiation?

from the seeds might be stunted in growth, or that they will have mottled leaves, or that they might not grow at all. To test their predictions, seeds obtained from biological supply houses [6] are planted on wet paper towels in an empty aquarium and allowed to grow for about 10 to 12 days. The seedlings are then cut close to the seed, and the length of each seedling stem is measured. An average height is obtained for each irradiated group. Each set of seedlings is examined for mottling and other growth defects. Bar graphs are then made of the results. In this way the effects of different amounts of radiation can be compared easily. The photographs above show the seedlings after 12 days of growth, and a group of fifth-graders at work on this experience in the classroom. The quantified results and the bar graph are shown at the right.

Setting up experiments

Frequently, questions are raised, the answers to which are best obtained by doing an experiment. It is an important skill to be able to translate questions and ideas into experimental situations. What sort of experiments should the children be encouraged to perform? These guidelines should be kept in mind:

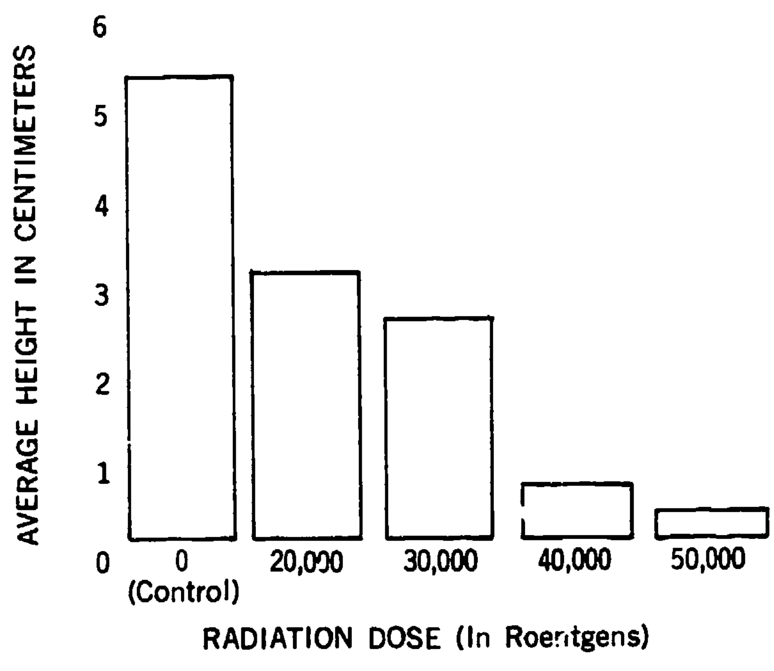
1. The experiment should be a true quest for information; not necessarily for new principles or new concepts, but certainly for information which the child cannot get easily from other sources.
2. Experiments should permit the manipulation of some variable. The student should begin to learn that he can make observations under conditions which he deliberately sets out to control and manipulate.
3. If possible, experiments should arise from questions raised by the children during classroom activities.

[6] Irradiated seeds may be obtained from the Carolina Biological Supply House, Elon College, South Carolina. The set will contain five packages of seeds irradiated with 20,000, 30,000, 40,000, and 50,000 units of radiation, respectively. There is also a control packet which has received no radiation. Each packet has enough seeds to supply a number of classes.

Growth of Irradiated Barley Seeds

Seeds	Units of Gamma Radiation				
	0 (Control)	20,000	30,000	40,000	50,000
Growth—Average height in centimeters	5.5	3.1	2.9	0.8	0.4
Number which did not grow	2	3	4	4	5

Growth of Irradiated Barley Seeds



4. Experiments should not encourage "pat" answers which can be easily found in a text, or by following simple "cookbook" types of instructions. The experiment should not be an exercise in testing some fact described in a text, or an attempt to find an answer to some paragraph or section title.

Through proper questioning, the teacher can do much to individualize instruction and foster creativity in experimental situations. Ask these kinds of stimulating questions: "How can we find a way to . . .?" "What do you predict will happen when . . .?" "What does this experiment show?" Avoid such statements as "Do this in this order." "When we do this, this will happen." "This experiment shows . . ."

Example 1. Suppose several students wish to study the effect of colored light on the growth of plants. They should grow identical plants under different colors of light while keeping all of the other variables (heat, water, soil) deliberately constant.

Example 2. Children have decided to grow pea seeds. The seeds are first germinated in sand. The teacher could ask, "What do plants need to grow?" "Will peas grow in any kind of earth or soil?" "Which soil is best?" "How can we make our plants grow faster?" "Are there things we can add to the soil to make plants grow faster?" "Are some things better than others?" The children might suggest the use of vitamins, milk, or commercial plant growth chemicals. "What kind of soil shall we use?" "How much fertilizer shall we use?" "How often shall we put water or milk on the plants?" "What controls must we use?" It is from a multitude of questions such as these that experimental situations arise.

Example 3. Children frequently bring their pets to class. One common pet is a hamster. The teacher may ask, "What foods does the hamster prefer?" "Which nesting material does the hamster like best?" "How can we find out?" From such a situation children can set up many simple experiments which will give them an opportunity to practice skills such as observing, classifying, recording, inferring, and predicting.

Using controls

Many experiments require the control of variables in the experimental environment. If possible, only one variable should be allowed to operate at a time. As a result of these types of experiences, children should come to recognize when a control is necessary, and what controls are essential.

Example 1. Consider a plant growth experiment conducted with different fertilizers. In this experiment, only the fertilizer factor is varied. Light, temperature, water, and soil conditions will be the same in all of the vessels in which the plants are grown.

Example 2. The students may be led to investigate enzymes which will digest gelatin and thus prevent it from "setting." Fresh or fresh-frozen juice of pineapple will show this effect very nicely. Samples of gelatin can be compared, some with the juice of fresh pineapple, and some without. Those without the juice are the controls. A more sophisticated experience can be designed by preparing samples of gelatin with different quantities of fruit juice. This will help to show the minimum level of protein-digesting enzymes which will prevent the gelatin from solidifying.

Interpreting results

When an experiment has been suggested and then executed, children should learn to find out what the results mean. To do this, data from the experiments will have to be recorded neatly so that they can be easily examined. The student should always be led to think about ways in which the data can be organized so that the relationships contained in the data will be clear to him or to someone else. Can the data be expressed in a chart form or organized into a graph? Can the data be condensed and tabulated so that they may be easily understood by looking at them?

Once the information is organized as much as possible, the children should be encouraged to see what it really says. Here, honesty is paramount, and the teacher should be the first to suggest that students look carefully at what they have achieved. It seems that children, and even teachers, wish to obtain rather spectacular results in all the experiments they carry out. But spectacular results are not always in evidence. Many experiments have to be repeated. Some experiments produce no positive results at all, and the experimenter finds out that he cannot come to any satisfactory interpretation of the data he has.

Example. If milk will help children grow, does it necessarily help plants grow, too? (Milk-fed plants showing greater growth than controls should be carefully compared with the controls, and the height increase interpreted with caution because the variation in height may be due to individual differences in the plants.)

Applying concepts to unfamiliar situations

Too frequently a child's understanding of a science concept is based only on a single demonstration, experiment, or illustration in a text. When the child meets the science concept expressed in a different form, he is at a loss to apply the principle involved. For example, students seem to be able to grasp the idea that air exerts pressure when they are shown the operation of a mercury barometer, but they are less able to see that air pressure pushes liquid up a soda straw. The most common student explanation is that the soda is "sucked up" in the straw.

Students should be able to transfer information they have gained to unfamiliar situations. Assume that the class has been studying air and that these concepts have been stressed: air exerts pressure, air occupies space, and air has weight. How can we be sure that the children are able to apply these concepts in situations other than those they have met previously? Pencil and paper tests might be devised. Another kind of experience, described below, involves activity on the part of children operating in small groups, and thus permits individualization in the practice of applying the familiar concepts to unfamiliar situations.

Example 1. Assume that the concept to be tested is that air exerts pressure. Simple science materials such as a paper cup and a balloon, can be assembled in a small box. In the box is placed an instruction card which directs the children to find a way to lift the cup without touching it. Four or five children can be permitted to work with the contents of the box, and they should be allowed to devise their own solutions to the question.

Example 2. Another group of students might be concerned with a simple experiment to show that air occupies space. In the box for this group are included a few safety matches, clay, a paper cup, and a jar of water big enough to accommodate the paper cup. The question on the card is "How can you put the match under water and still keep it dry?" "Why are you able to do this?"

Example 3. Still another group of students can be working to show that air has weight. In a box would be included two straws, one pin, some string, and two balloons of equal size. The instruction on the card would read, "Find a way to show that air has weight."

All of these experimental activities in applying a familiar concept to unfamiliar situations can be performed in the classroom at the same time. The findings of each of the groups are then presented to the class in a summary and discussion period.

Providing individualization through demonstrations

Presenting certain science materials to children by demonstration is often desirable. Even here, individualization of instruction can be planned so that children can be given the opportunity to develop their own abilities to give an original solution, and to be led in their thinking, rather than be told how the demonstration will proceed. *Asking the right questions during demonstrations is extremely important.* The teacher must ask, "What will happen next?" rather than, "The next thing that will happen will be . . ." "If you do this demonstration, what will you need?" rather than, "For this demonstration you will need . . ." Finally, "What can we use instead of . . .?" as a substitute for, "In this demonstration we will use . . ."

Example. A fifth-grade class is about to embark on a study of the effect of heat and cold on various substances. This demonstration is suggested as an introductory exercise *before* facts or generalizations are divulged to the class. The materials needed are the frequently used "ball and ring" and a source of intense heat, preferably a portable propane gas burner or a Bunsen burner. Explain to the class that you want them to see how heat affects things, particularly metals. Be sure that the children can see what materials are involved. Pass among the students and let them see and touch the ball and ring.

An opening question could be, "What sort of an experiment can we do with the things I have here?" This may seem like a "far out" opening gambit. Assuming that the children have never seen the demonstration before, how can they be expected to know how it operates? Probably many children will not be able to suggest an experiment. Some, however, may have had some other associations with the fact that metals expand when heated and contract when cooled. They may be able to recognize the relationships inherent in the apparatus, and they may be able to suggest something that can be done. Thus we provide individualization in that the children are challenged to the best of their ability to practice the skills of observing, inferring and predicting, and applying concepts to unfamiliar situations.

While the ball and ring are both still cold, try to put the ball through the ring. (The ball should not pass through.) Ask:

"Suppose I heated the ring, would the ball pass through? Why?"

"Suppose I heated the ball, would it pass through the ring then? Why?"

"Suppose I heated *both* the ball and the ring the same amount of time? What would happen? Why?"

"What will I have to do to get the ball to pass through the ring?"

"What would happen if I heated the ball a little and the ring a lot?"

"Suppose I heated the ring for five minutes? Would the ball pass through?"

"Suppose I heated the ring for seven minutes? Would the ball pass through more easily?"

"Suppose I heated the ring for ten minutes? Would the ball pass through still more easily?"

The last three questions, designed for the better students, provide individualization in instruction in that they present the problem of predicting the effect of continued heating on the ring. Once they have made the prediction, the children should be challenged to devise a test for determining whether continued heating causes continued expansion. In this case, the test is simple: let the children heat the ring for the suggested periods of time.

Following the demonstration, ask the children to tell or write a statement concerning what they have discovered. Be sure they do *not* overgeneralize, namely, that metals expand when heated and contract when cooled. Only iron has been used, so they cannot make definite statements regarding aluminum, copper, or brass. Ask the children what experiments can be done to permit a broad generalization to be made. (Aluminum, copper, or brass washers can be soldered onto metal rods and used instead of the iron ball and ring apparatus.)

Individualization by using small groups

The main objective of this publication has been to point out experiences in which each child can participate and develop basic skills to as great an extent as possible. This emphasis on individual involvement should not be construed to mean that individualization cannot be achieved with small-group activities.

Small-group activities, when properly supervised, afford the advantages inherent in the activities discussed in previous sections. In addition, science clubs, programed instruction, summer classes, and science fairs permit close personal contact between the student and the teacher. At the same time, they encourage close cooperation between student teams which might be working for a common solution to a problem. Small groups foster independent experimentation; they permit observation of scientists at work; and in many cases, lay the groundwork for continued participation by the scientist who originally was only an interested observer.

Science clubs

For elementary students in grades 6 to 8, a science club is a desirable way of providing individualization. Science clubs usually contain a small number of children with a more than average interest in science, and also provide a science outlet for the talented student. Activities are not bound by texts or pre-established curricula, and the members can indulge their individual interests. Science clubs, if well organized, can provide benefits not usually available in the classroom. Professional scientists and technicians can address the club on specialized topics. A small club membership permits interesting field trips. Since more adequate supervision is possible with smaller groups, the club members can be taught to use apparatus and materials not usually available to larger classes. Science clubs can provide a time and place for the development of science fair projects; projects that are truly as experimental as they can be for young people.

Science clubs should be held, if possible, in a separate workroom or area where students may safely store projects in progress. There should be adequate work tables and window benches to provide storage for experiments not designed for completion in one club meeting. There should be a sufficient number of drawers and cabinets where apparatus and various materials can be stored.

Special summer classes

Some school systems are providing special summer classes for the middle and upper elementary school children who have a special interest in science. These classes are conducted for several hours a day for a period of four to six weeks. The classes are voluntary in nature, and the students often pay a fee to help defray the cost of materials and the salary of the instructor. The classes are kept small so that a flexible program, experimental in nature, can be carried on. These summer classes should not be used as make-up sections for the less able students. The session should be structured to provide experimental situations in which the children are allowed and encouraged to define problems and to set about learning to solve them.

Programed instruction

Programed instruction is another tool which is useful for providing individualization in science teaching. Many of the facts, major understandings, and processes which children must know to understand science can be learned through self-study with programed materials. When programed materials are available, the students can proceed through them at their own rate. The more apt student, after covering the "basic" materials, can proceed with other and more advanced science activities related to the area of science being studied.

The initial flurry of interest in programed instruction has abated, but more and better programs continue to be written. A good program will have been carefully tested with children and then rewritten until the program is successful in imparting information to almost all of the students who use the materi... A good program should capture interest, intrigue and challenge the learner, and stimulate his desire to know more about the subject.

Some of the programs the author has found worthwhile are[7]:

1. How We Forecast the Weather. Grades 4-6. (300 frames)
2. The Biggest Reptiles: Alligators and Crocodiles. Grade 5. (32 frames)
3. Grouping Animals: What is a Mammal? Grades [illegible] (300 frames)
4. Experiments with Sound. Grade 6. (32 frames)
5. Photosynthesis. Grade 6. (32 frames)
6. How Scientists Think and Work. Grades 5-7. (300 frames)
7. Our Solar System. Grades 7-9. (300 frames)

Science fairs

Science fairs are not new to science teaching. In fact, they have become a rather standard yearly event throughout the nation, appearing in about the same profusion and at about the same time as the celebrated "flowers that bloom in the spring." It is unfortunate that science fairs have lost some of their luster among many who are interested in the development of science. There are several things which the originators of science fairs probably do *not* want them to be. Science fairs were not designed to house entries which are merely collections of plant and animal parts. Entries should not be merely dioramas depicting snarling monsters from the prehistoric past. Entries should not be exquisitely engineered displays of chemical or physical processes (usually built by well-intentioned adults) in which lights flash, colors change, and moving parts go "click," "snap," or "pop."

Science fairs were designed for and should be used to promote exploration of a problem for which the student has no immediate answer. The child is not expected to discover a new vitamin or explore molecular biology, but his entry should show that he has achieved some degree of skill in being able to explore a problem on his level in a scientific fashion. The entry should reflect the child's ability to use the skills discussed earlier in this paper.

Example 1. The child collects samples 12 inches square and 3 inches deep of different types of soil. Each soil sample can then be screened for different types of animals which can be classified into such large groups as insects, spiders, worms, and snails. The child can investigate such questions as "How do the kind and quantity of animals vary with different soil samples around my home?" "Is there a change in the soil and animal relationships at different times of the year?" The chart at the right presents a key to the identification of soil-animal groups together with a form on which the findings may be recorded.[8]

[7] The addresses of the publishers of these programs can be found on the bibliography page.

[8] This key and chart are adapted from: "A Study of Animals in Soil," by G. E. Grube. *Turtox News*, Volume 38, July 1960.

Key to the Identification of Soil-Animal Groups:

1. Segmented animals; animals with a series of constricted rings around the body .... See No. 2
   Non-segmented animals 7
2. Segmented animals with jointed legs or other jointed appendages 3
   Segmented animals with no jointed appendages .... Earthworms (Chaetopoda)
3. Animals with 3 pairs of legs .... Insects (Insecta)
   Animals with more than 3 pairs of legs 4
4. With 4 pairs of legs .... Spiders, Mites, Ticks (Arachnoidea)
   With many pairs of legs 5
5. With one pair of legs on almost every segment 6
   With 2 pairs of legs on most segments .... Millipedes (Diplopoda)
6. Oval shaped animals; fold body into a ball when disturbed .... Sowbugs or Pillbugs (Crustacea)
   Elongate body, not capable of folding into a ball .... Centipedes (Chilopoda)
7. Minute unsegmented worms .... Nematodes (Nematoda)
   Soft bodies, slimy animals with or without a hard coiled or spiralled shell .... Slugs (without shells) or Snails (Gastropoda)

NAME ....

DATE	Sample 1	Sample 2	Sample 3
Location from which sample was taken	....	....	....
Soil type (clay, loam, sand)	....	....	....
Ground cover	....	....	....
Weather conditions	....	....	....
Soil temperature	....	....	....
Air temperature	....	....	....
Animal groups:	**Number found:**		
Nematodes	....	....	....
Earthworms	....	....	....
Slugs and snails	....	....	....
Sowbugs	....	....	....
Centipedes	....	....	....
Millipedes	....	....	....
Spiders, mites, ticks	....	....	....
Insects	....	....	....
Unidentified	....	....	....

Example 2. Another interesting science fair entry might be achieved by examining the question, "What is the effect of a magnetic field on the growth of beans or radishes?" In this experiment a strong permanent magnet or an electromagnet can be placed at right angles to the seed bed. As the plants grow, observations may be made to determine whether the magnetic field affects the direction or the height of the plant growth. There snould, of course, be a control bed of plants with no magnetic field about it.

Summary

There are many techniques which can be used to individualize science instruction for children, and this publication has delineated many of these. There is, however, one essential "device" which no one can provide for you; this "device" is the teacher. All of the individualized outcomes discussed here will not be achieved if the teacher does not allow the child to state his views on a problem, interpret his own data, and design and carry out his own experiments. The child must be allowed freedom in the classroom to enable him to achieve a working understanding of the skills of science. When you ask a child, "How would you interpret this?" be sure you are not really asking, "Can you guess how I would interpret this?"

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