The Goals in Elementary School Science

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Sometimes there seems to be little connection between what we say our goals are and what happens in our classrooms. If our goals are really to be guides they must be carefully conceived, exact, and realistic. They must be blueprints for actions that will result in changes in behaviors. We must also consider them in terms of individual children. Not all children achieve them in the same way nor to the same degree at the same pace.

In considering the goals for any subject-matter area in the elementary school, it is important to look first at the objectives for the total elementary-school program. The goals of the elementary school have been stated in many places in many ways. Without going into details and technicalities, we can sum up these objectives this way: The goal is to help children gain the ideals, understandings, and skills essential to becoming well-rounded, full-functioning adults. How is science an essential part of this development?

First, what is involved in reaching this broad general purpose of the elementary school? Certainly we must teach the skills of reading, writing, and arithmetic for they are essential equipment for enjoyment, for gaining information, and for communication. Add the ability to use one's hands to make them do what one wants them to do, and the skill of seeing things around you and seeing them accurately. Include the skill of listening intelligently and of speaking effectively, so that we can express our ideas coherently and accurately. And the skill of sensing problems and solving them in a scientific way, so that the results are dependable. This involves being open-minded, fair, careful in arriving at conclusions, accurate, and free of prejudice and superstition.

The National Science Teachers Association [1] has summarized the general goals of all education as: "learning how to learn, how to attack new problems, how to acquire new knowledge-using rational processes-building competence in basic skills- developing intellectual and vocational competence-exploring values in new experiences-understanding concepts and generalizations-learning to live harmoniously within the biosphere."

This leads us to add that attending school for six or eight years, from nine o'clock to three, is supposed to accomplish still more. Classroom experiences should provide many occasions to identify and understand social procedures and problems, to make hypotheses and have opportunities to carry them out through working together. Children need to check results, to say to each other: "How well did we do this?" "Was our plan good?" "What would have made it better?"

While they are working together, they should be developing social sensitivity to the needs of one another and of the group. They should be learning cooperation, democratic procedure, and group planning; they can learn these things only through using them every day and seeing how they operate.

The school environment should be a place conducive to developing the physical and mental health of children. Among other things, this means that the schoolroom should be a cheerful place, alive with purposeful industry, where children have successful experiences and develop good feelings about themselves. It should be a place of real achievement, where children learn to work diligently and to take pride in accomplishment. It should be a place where children are free to say: "I don't understand." "I think so and so." "I want to ask a question." A place where children feel secure and at home, where they belong, where they can live happily, a place from which pupils often go home tired at the end of the day, having engaged in hard work that has real purpose. It should be a place where pupils stretch their minds through challenging mental activities, just as they stretch their muscles at recess. The opinion of so many that "We are underestimating the capacity of many of our elementary school pupils" is not just idle musing.

Furthermore, the elementary school, if it is to achieve our purposes, ought also to be a place where children learn to develop wholesome interests for their leisure time. Because of school there ought to be less of "Mother, there's nothing to do!" on rainy Saturdays and summer days. There ought to be numerous interesting things children want to do at home because they have experienced pleasure and satisfaction in doing them at school.

The elementary school must be a place where children acquire useful knowledge. And we do not mind running the risk of repetition by saying: "Let's stop being slightly apologetic when we say we expect children to learn some meaningful knowledge that is important to them." We shall discuss this in more detail later on.

Science, or any other subject in school, is included in the curriculum because it can contribute something to the goals of the entire school experience. We have just listed some general goals for this total experience. Now let us see how science can be geared to them.

OUR INTENTIONS FOR ELEMENTARY SCHOOL SCIENCE [2]

Our goals should speak with a loud clear voice. They should be specific and exact. They should direct us and answer the questions why and how. They should indicate our expectations and describe, as far as possible, how these expectations are to be realized and how we can tell if they are reached.

It is helpful to think of our objectives in the light of what behaviors or performances may result. We may describe such objectives as behavioral or performance objectives, which may be classified according to what we expect from children as the result of achieving these objectives. There are those that are chiefly concerned with teaching and understanding concepts and generalizations in science in other words the knowledge and understandings which we hope that children will assimilate. But we also hope that they will develop certain attitudes, interests, appreciations, and values (see later discussion) and that they will develop manipulative and other skills as a result of their science learning experiences. We must then formulate goals involving all of these areas. It is quite obvious that some of these goals are easier to state in specific terms than others.

The objectives concerning subject matter have traditionally received the most attention. Since achievement here is more easily and exactly measured, they are more easily stated in exact terms. In contrast, objectives concerned with stimulating interest, developing appreciation and values, and developing process skills are harder to measure with any degree of objective accuracy. Since we consider them to be of such great importance we continue to focus our attention on them.

The use of "action" words is important in making our objectives more specific and in suggesting ways of achieving and evaluating this achievement. Since we are looking for behaviors, we can concentrate on: a result of participation in certain specifically indicated experiences (observations, experiments, experiences, manipulations, and soon); we expect children to be able to identify, demonstrate, use, state, analyze and compare, predict, list, define, state a rule, and so forth. Such action words (illustrations will follow throughout this chapter and others) indicate in a more precise manner what we expect to achieve. Such objectives accompany and direct our procedures for each science experience with children. Let us now examine some of the general and specific goals for teaching science in the elementary school.

CONCEPTS AND GENERALIZATIONS

There is no question that the subject matter of science is important. We do need persons in our society who are well informed about the world in which they live An informed person is likely to be an interesting one, we would probably agree. But let us not consider a person educated in science just because he can tell us how many legs a cricket has, that a certain pair of pliers is an example of a first-class lever, what a tufted titmouse looks like, or the definition of chemical change. Such items are important when children learn how to put them together into meaningful ideas.

We must teach ideas in context, in relation to broad concepts. The distance to the moon, for example, is meaningful when it helps us understand why a radar beam bounced on the moon from the earth takes about three seconds for the round trip. When we say that children should learn science subject matter we mean that they should be able to formulate concepts and generalizations useful in interpreting the world in which they live. And we keep in mind that what we learn is important, just as how we learn it is important. This leads us to a summary statement of one of the general objectives for teaching science: To help children to learn and understand some generalizations or "big meanings" that they can use in solving problems in their environment.

To make this goal more meaningful and useful to us we must break it into parts that are more precise, linked more closely to what we expect children to do about it and how, and, if possible, how much we expect from them.

The following description of a classroom experience will help to make these ideas more concrete. We shall first describe the experience, and then examine it for its possibilities for developing behaviors and performances. While the experience obviously intends to do more than deal with the aspect of attaining science knowledge, we will concentrate chiefly on that phase of the lesson, leaving the other objectives until later where we discuss them in greater detail.

Children are working with a problem about what heating and cooling does to matter - solids, liquids, and gases. A question has arisen: Why does running hot water over the metal lid of a glass jar make it easier to unscrew? In investigating this problem (we will have more to say about methods of investigation in the next section) some children suggest that: "The hot water washes away some sticky food between the cover and the jar. (Incidentally, this may be a factor.) Other children suggest that: "The heat does something to the metal cap itself, makes it looser in some way." Children suggest other hypotheses to explain what happens.

They decide to use several clean empty jars (to test the sticky-food hypotheses) with the caps screwed on tight. They again find that a cap held in hot water turns more easily. Someone suggests: "Let's hold a lid in cold water." They find that in this jar the lid seems even tighter than before. Why? It is proposed that heating makes the metal lid get larger - expand - and pull away from the glass. Cooling does the opposite. Is it really true that heating a metal can make it larger? How about other solids? How about liquids and gases? Children propose a series of experiments involving predictions, hypotheses, tests, and observations, as well as some research reading. The children arrive at some generalizations: Solids, liquids, and gases expand when they are heated and contract when they are cooled. Not all of them expand equally. Such generalizations come as a result of many experiences; they are put together gradually; they are not memorized from printed material; they are not caught by slight exposure as children catch mumps.

Now what can the children do with this information? They examine a thermometer to see that it works by expansion and contraction of a liquid mercury or alcohol with changes in temperature. They observe how sidewalks and pavements and metal bridges are constructed to allow for expansion caused by an increase in temperature. They use their discoveries to interpret things they see.

Now let us examine these experiences from the standpoint of some of the specific objectives concerning both subject matter and performance. Our thinking goes along this path: As a result of investigating in different ways (experiences, experiments, environmental observations, discussions, and exploratory reading) the children should be able to gather data (information) from the experiences in which they have participated, describe what happens when hot and cold water are applied to various solids under different conditions, demonstrate these happenings when provided with the essential materials, and construct a generalized statement that describes the results of heating and cooling of certain solids under specified conditions. These are examples of the behaviors we expect and concentrate on.

Concepts and generalizations are an economical way of organizing vast amounts of information. Scientists use concepts in their research; teachers and children can use them to facilitate learning. To know that the fluid in a thermometer "rises" when the temperature is higher is useful but limited; to know that heating a substance makes it expand is to have the key for the understanding of many phenomena.

PROCESSES OF DISCOVERY

Another closely related major objective for the study of science is, to help pupils to grow in ability to use science processes. This is a general statement of our objective. As we proceed we shall indicate behavioral aspects that make it more specific.

A science class should be a place to ask questions as well as to answer them. It is probably true, unfortunately, that we as teachers are in the habit of giving greater recognition to the pupils who know the answers than to those who ask thoughtful questions. The thinking child says: "If that is true, why...?" Or "I understand that but why. . . ?" Science is problem seeking as well as problem solving.

We begin then to give more and more attention to helping children formulate problems. These problems may arise because of children s experiences: "Miss Brown "last night. I saw the moon come up. It was big and the color of oranges. How come?" Problems may result from children's reading: "Mr. Jacobs, it says here that sunlight is made of all different colors. How can that be?" Problems may arise on trips as a spillover from the investigations of other problems, from current events, and from many other sources. An important role for the teacher is to plan situations which provoke children to pose problems.

Problems and questions trigger the process of investigating and may result in discovery. Here is a bird's-eye view of the processes of discovery and what they involve.

Observing: A fundamental process which in a sense underlies many of the other processes. What does it involve? It is quite possible to look but not actually to see. We all do this. Real observation requires thoughtful looking. It is closely linked will being able to describe what is observed. "What can we discover by looking closely?' "Try to tell what you see." These are both approaches in stimulating children to use and sharpen their powers of observation. Observations should lead to exactness. How much? How many? How long? Children should come to understand that there is a difference between observing and inferring.

Communicating: When we urge children to tell what they observe, we are stimulating the use of a skill that is fundamental to our everyday living. Children and adults are frequently heard to say: "I know what it is, but I can't tell it." Learning to communicate orally; in writing; through the use of diagrams, graphs, and in other ways is an integral part of processes that help discovery and understanding in science [3].

Hypothesizing: Having made careful observations and discussed the observations, we encourage children to formulate possible explanations. In the illustration of the experiences with heating materials children proposed various possible explanations about why the placing of the metal-capped can under hot water made it easier to open. Formulating hypotheses is one of the early steps in the process of discovery. An "educated guess," a possible prediction for our purposes is like an hypothesis.

Experimenting: The term experimenting has often been used loosely to mean following directions from the text or showing something that is already known or playing with petty apparatus. When it is used as a process to discover something that is not known to the child, to test an hypothesis, to attempt to solve a real problem, it becomes a scientific endeavor. As in the other processes, there are many degrees of sophistication in experimenting. These and other aspects of experimenting are discussed in the next chapter.

Measuring: Exactness is fundamental to many of the processes of discovering. How much, how many, how often, and so on are important. Learning to use the tools of measuring, to record the results in some graphic form, and thus to have available some quantitative basis for predictions or generalizations or hypothesis is an integral part of many science experiences and experiments.

Classifying: Learning to group things in light of their characteristics is an important process of discovery. If you think about this you will realize that this process is often used in everyday life. For example, it is often a step in identifying. As a result of careful observation children identify likenesses and differences; they compare and contrast and from these data attempt to classify objects and living things.

For example, in an aquarium it is helpful to classify things according to living and nonliving. The living things may be further classified as plants and animals; the nonliving things into solids, liquids, and gases.

We see that classifying often gives meaning to things and situations. In its simplest form it may require using only one or a few characteristics; in the multistage classification several characteristics are used.

Generalizing: As has been indicated earlier and is illustrated throughout the book, children and the rest of us find it difficult to remember thousands of facts. However, assembling these facts, realizing the relationships, grouping them into a meaningful whole constitutes an important aspect of the process of discovering. Refer again to the experiences children had with the heating and cooling of materials and it becomes obvious that the generalizations arrived at come as the result of these many experiences, observations, and experiments. How complex the generalizations are depends on the maturity of the children, the materials and experiences available, and on other factors which we will discuss and illustrate in detail in many places later on.

Predicting: (See also hypothesizing.) To be able to make reasonable predictions on the basis of available data is an important process. When we examine the processes used by scientists we see that predictions, and the hypotheses relating to them, are of vast importance in the seeking of scientific knowledge. If our teaching is related to our stated objectives children will find many opportunities to predict possible outcomes. As they learn to observe, examine, contrast, compare, and use the other processes they also learn to react to such questions as: "What do you think will happen if…?" "If we tried this again would the same thing happen?" "In the same way?"

There is no intended implication in the foregoing that the order in which these processes are presented is the order children must follow; that they all must be present in any investigation; nor that the processes of discovery are limited only to these.

It is implicit in our review of processes that children will express their understanding of them in terms of their behavior. Thus children will be able to: formulate some hypotheses for testing, devise experiments to gather information, and communicate their ideas.

Here, for example, is an actual experience from a sixth-grade class that illustrates how a teacher and children work when the goal is to combine the process with the subject matter, when the emphasis is on the processes of discovery as well as other objectives. It should be remembered that even though these examples are from actual classrooms, all children do not react the same and so in other situations the experiences may turn in many other directions.

New classrooms are being added to the school building and construction is going on just outside the window. Children watch at recess with their noses pressed to the glass. They see men with pulleys lift wheelbarrows full of bricks; steam shovels at work; construction elevators being built; and all sorts of machines cutting, digging, pulling, and pushing. It is the chief topic of conversation. The teacher watches, too. The children raise questions: "How can a man lift a big hunk of the cement sidewalk with an iron bar?" "How can a man lift a hundred bricks by pulling down on a pulley rope with one hand?" These and other problems are raised, stated carefully, and recorded. The teacher says: "I'd like to know how these machines work, too." And she adds some of her own problems to the list. As the study proceeds, other questions and problems are added.

Then, because she has an eye on the goals of improving ability to use science processes to discover she says: "Now these are good problems. How shall we solve them?" And the pupils after some discussion say: "We can experiment. We can look in science and library books. We can ask the workmen. We can ask other people who know. We might watch the machines more closely. We might find a motion picture that will help us." After these possibilities are considered, the pupils select the problem about the use of the iron bar and the piece of sidewalk.

To help pupils see how experiences may be used as a process, the teacher brings into the classroom some bricks and a board from the construction scene. She says to her class: Can anyone in this class lift me? After a quick survey everyone gives up and she says: Can anyone in our class use these bricks and this board to lift me?

Several suggestions are made. Pupils discuss the suggestions and make some hypotheses and predictions about them. One suggestion is to place a brick on the floor and lay the board across it at about a midpoint. Several pupils indicate the belief that this is the situation they had observed outdoors. One student stands on one end of the board and asks the teacher to stand on the other. This does not produce the desired results, so the pupils suggest other hypotheses for testing. "Use more bricks to give more height." "Don't put them in the middle; leave more length of board on one side of the bricks than the other." "What would happen if we moved the bricks closer to Miss Wright?" These possibilities are tested. Children begin to sense a relationship between the distance the push moves to the distance the weight lifts. They suggest measuring to see what the relationship is. The measuring results in further trials.

This brief description of the beginning experience serves to illustrate a problem that originated from the environment and resulted in meaningful investigations. Pupils suggested hypotheses. They were given an opportunity to predict outcomes. They tried out their hypotheses. They revised their plans. They measured. They gathered mathematical data. They began to see relationships. They were using some of the processes of discovery that may eventually lead to making some generalizations regarding the function of levers. They began to see the relevancy of these materials to their own lives.

But all discoveries cannot be made through direct experiences, experimentation, and observation. Other learning methods are also important. As the study proceeds, children gather reading materials to find out more about levers and how they work and are used. In so doing they use language-arts, skills to locate materials by the use of an index, table of contents, or card catalogue. They plan an interview with the construction foreman to ask questions about machines and how they work. This calls for making an outline of their findings and for presenting a well-organized, clear oral report to the class. They locate pictures that can be arranged in sequence to show some of the ways in which machines are helpful. They find a motion picture that will help to clear up their ideas about how machines work. They devise other ways to gather information, test it, and apply it to their problems about machines. In all of these activities the children proceed on their own as far as possible. The teacher suggests possibilities when necessary and when children's experiences are limited.

These pupils are discovering more about how to state their problems carefully; they are learning how to collect appropriate materials to solve the problems. They test their findings and record them in brief sentences. Later, in discussing her work with the pupils, Miss Wright says: "The study of machines seemed very successful because the children wanted to solve the problems. They were interested in setting up ways to find out. It turned out to be an open-ended experience that grew and developed as we went along.

They learned something about using the processes of discovery and so did I. I learned that sometimes simple materials are most useful, the near-at-hand problems raised by the children can be very important; and I came to know that the pupils liked solving problems that are their own."

As we examine the possible behavioral outcomes from such activities, experiment and observations we intend that pupils will demonstrate growth in being able to identify and state specific problems, construct some inferences from observation propose and attempt to test hypotheses, describe their findings, and so on.

Learning how to use processes of discovery is one of our important goals. How does this fit into our general elementary-school plan for children? Certainly our success in living with one another is increased if we are skillful in solving our daily problems, knowing what is pertinent, reliable information; learning how to apply it; knowing how to check the validity of results.

Pupils need help in seeing how the processes of discovery in science are like processes of discovery in other areas. They may never make this connection unless it is called to their attention. The teacher may frequently say: "You remember how we found some of the answers when we worked on the problems about machines? How can we use what we learned there to help us find the answers to this new problem in our social studies?" The new problem may be: "How can we organize a good safer patrol for our school?" Such problems as this help pupils to transfer lessons in using processes to their everyday living.

SCIENTIFIC ATTITUDES

In general terms we say that the experiences in science should help children develop and use scientific attitudes. We have been saying this for years, but we need to do more about it. The development of scientific attitudes, like the development of processes of discovery, come about only through conscious effort. First, to achieve this important objective we must understand what it means and we must think of it in terms of the behaviors and performances we expect from children. Then, we must teach so that children cannot get along without using scientific ways of thinking. Here are some of the characteristics that a scientifically-minded person possesses:

He is open-minded, willing to change his mind in the face of reliable evidence; and he respects another's point of view.

He looks at a matter from many sides before he draws a conclusion. He does not jump to conclusions or decide on the basis of one observation; he deliberates and examines until he is as sure as he can be.

He goes to reliable sources for his evidence. He challenges sources to make sure that they are reliable.

He is not superstitious; he realizes that nothing happens without some cause.

He is curious. He is careful and accurate in his observations.

It is these characteristics that we are trying to help children develop through science experiences. But it is possible to work with science apparatus, read source books, respond in science classes, set up exhibits for science clubs, and do a lot of other things without making any use of scientific attitudes. This happens every day in some of our science classes, because teachers do not actually try to see that scientific attitudes are emphasized and set up their objectives in terms of expected performances. Every time children attempt to experiment, whenever they use other processes of discovery, whenever they read, take a field trip, see a motion picture, communicate their findings to the class, identify a problem to solve, their scientific attitudes ought to be showing. It should become a real part of their thinking equipment. There should be much of "Hey, wait a minute!" "Let's try that again." "How do you know that's true?" "I've changed my mind since I read what scientists say." "Where did you find that answer?" "You may be right, but tell me more about where you found your information." "I think our hypothesis should be revised." These remarks and similar ones should often be heard in our science classes as well as in social studies, arithmetic classes, and other places where children are working together and using processes of discovery.

Now let us be specific. In a fourth-grade class the pupils have been studying plants and how they grow. They have experimented and found that plants need water. Someone asks: "What happens to the water?" The children set up some hypotheses about the course of the water through the plant. The teacher asks: "What can we do so that we can see where the water does go?" "Color the water so we can see it," is a logical suggestion. So pupils take a stalk of celery, cut off the bottom of the stem with a sharp knife, and set the stem in a jar of water colored with red ink. They predict possible results. Later they examine the stalk, cut it open to observe the channels, and note the colored veins in the leaves which show where the water went. Someone then remarks: "I've read that some of the water goes off from the leaf into the air." The teacher asks: "Could you suggest a way to find out whether this is true?" A student suggests that they put something over a plant to catch any water that might come from the leaf. Pupils invert a quart jar over a small geranium plant. They do this and the next day notice that there are tiny droplets of water collected on the inside of the jar. "What does this show?" the teacher asks. The children seem to concur that it shows the geranium leaves give off water. "But," the teacher asks, "could the water have come from somewhere else?" (unless one of the children happily asks this question first). The water might have come from the soil in which the plant was growing or from the air around the leaf; the pupils have not investigated all the possibilities. They have not controlled all the variables.

The teacher invites them to reconsider because she believes in the importance of helping pupils to think more scientifically. As a result someone suggests: "Maybe some of the water is coming from the soil. We ought to cover the soil with plastic wrap, then maybe the water couldn't get out of the soil." "Let's try it and see." The experiment is reassembled in its improved form (testing a variable). Again the water condenses on the inside of the jar, and the pupils are about to be satisfied with the results, when a student says: "Maybe the moisture is coming from the air in the jar. It could be, you know." Indeed, it could. The teacher comments favorably on this kind of thinking: "How can we find out?"

Someone suggests using two sets of equipment exactly alike except that only one jar is over a growing plant; the other contains soil covered with plastic wrap and air. " Then if the jar with the plant has water on it and the other one doesn't, we'll know that the water really came from the plant" (formulating hypotheses; controlling variables).

The group performs similar experiments and does additional "research" reading before the pupils finally decide that the leaves of plants give water off into the air. The teacher intends to see that the scientific attitude is kept in mind. She helps the children plan so that they can see the results of making and using careful observations and controls.

Does it take more time to experiment in this way? Yes, it does, but how better can you spend time than in helping children be more careful and accurate in their judgments? Frequently in experimenting the subject matter learned may be of less importance than the methods used and the attitudes acquired. These methods of observing, questioning, checking details, inferring, testing, and withholding judgment should be called into play whenever experimenting takes place, whether the experiments come from a basic textbook, a supplementary science book, or are originated by the children.

Whenever children read there is plenty of opportunity for the application of scientific thinking. When young children ask: "Is that really a true story?" there is opportunity for them to get acquainted with the differences between factual material and fiction and to learn that one is used for the purpose of finding answers or getting information and the other more usually for entertainment and enjoyment.

The pupils' discovery of mistakes (or what appear to be mistakes) in books or other printed material may be a landmark in the development of their scientific attitudes. To realize that a statement's appearance in print is no guarantee of its accuracy may be an eye opener to a child who is being introduced to reliability as a criterion for selecting material to read for gathering information. One book, for example, may state that the earth has only one satellite; another may say the earth has only one natural satellite, although it has many man-made ones. Here is an opportunity for communication and discussion. Children come to appreciate the importance of using up-to-date material for reference work. They come to know that such words as "known and "natural" are extremely important, as are such phrases as scientists think, It is generally believed, It may be true that, some people say, and evidence seems to indicate that. This same attitude should permeate our activities in social studies and other areas of learning in the elementary school.

The following letter written by an eight-year-old to an author is an illustration of challenging the accuracy of information:

Dear ______________________

You wrote a book called the Pet Show, didn't you? One of the stories in it is called the "Guinea Pigs at the Show." One sentence says, "They can run about when they are only a few days old."

This is not true.

They can run about the day they are born.

Yours truly,
Mary Lou ______________________
P.S. I raise them

Here, obviously, is a pupil who is learning to evaluate some of her reading and to relate it to her own experience. Some adult, either at home or at school, may have urged her to write to the author to find out why her experiences and the book did not seem to agree. Through such an experience the child learns something about how books are written, how limited experience may sometimes be misleading, how scientific observations may differ from a child's observations, and how different statements of fact may only seem to be in disagreement.

Children's reports of horsehairs turning to snakes and other superstitions should be subjected to investigation and checking to develop scientific attitudes. Statements such as the following are often made by children and grown-ups too: "You can't believe the weatherman!" "Animals can tell if the winter is to be very cold." "You can tell your future by the stars." These remarks offer excellent opportunities for the use of scientific investigation and checking. They involve finding the answers to such questions as: "Who says so?" "How can we find out the facts?" "Why do some people say these things?"

We have given only a few examples of situations that can help children to develop scientific attitudes. Other ideas for accomplishing this important purpose will be presented as .we go on.

Stating objectives in behavioral form makes them specific and helps us to come closer to being able to evaluate them. Attitudes are hard to assess, but they do regulate behavior. When we are more specific in saying: As a result of these experiences and experiments children should exhibit an attitude of withholding judgment and develop a tendency to challenge information sources," our teaching focus becomes sharper.

INTEREST AND APPRECIATION

In general terms learning in science is supposed to create in children an interest in and an appreciation for the world in which they live. The attitudes which we have just discussed are closely related to interest and appreciation. They, too, are difficult to achieve and hard to measure. Let us examine a background situation to clarify the idea.

Just now, as this is being written, the evening sky is flaming with a hundred hues. The clouds five miles away, made of countless droplets of water, are reflecting some of this light through the window. The window glass itself was made by heating sand to which chemicals have been added, and the result offers protection from the weather. Growing almost into the window, vine leaves glisten green in the light of late afternoon. In leaves such as these the food for the world is being made. The leaf is a wonderful manufacturing plant where water, lately fallen from the sky as rain, comes up from the roots in the ground and meets with carbon dioxide from the air. In the green leaf, in the presence of sunlight, food is manufactured from this water and carbon dioxide. All living things depend on this process. In the world about us there are, indeed, great things to wonder about: How can sunlight be changed to brilliant colors at sunset? How are clouds formed? How is glass made? How do plants manufacture food? How did the world itself come to be, and how has it changed through the ages? Some wise person has said: "He who can no longer pause to wonder is as good as dead."

Young children deserve to find in schools a nurturing influence for their natural curiosity about the world. They deserve also to have this curiosity extended to new fields about which they have never wondered because they did not know they exist. They deserve the opportunity to come to appreciate, through understanding, the wonders of the world to be "at home" in the world. Exactly how this appreciation is to be developed, we still have much to learn. Experience seems to show that children do not gain it through listening to sentimental gushing from an adult. Perhaps it comes about when adults provide opportunities for children to discover for themselves. We can provide opportunities to observe firsthand, to feel, to see, to use the senses so that satisfying experiences will result. Perhaps through knowledge thus gained, through satisfying experiences, each child may develop for himself an appreciation that fits his person. Certainly there can be great thrills in discovery, great satisfaction through contact with natural objects and phenomena.

As these paragraphs were being written the colors disappeared from the west. Twilight is here and soon night will come. Our side of the earth is turning from the sun; darkness comes. Elsewhere the dark side of the earth is turning toward the sun and day is coming. In a few weeks the leaves will drop from the vine outside the window; the days will grow colder; autumn will be here, then winter, then spring, and summer. Here is the cycle of the seasons. There is also the cycle that water follows as it disappears from the surface of the earth and appears again, falling from the sky as rain; the cycle of seeds from tiny cells to adult plant and the production of seeds again. These and similar phenomena are what we have in mind when we think of providing opportunities to increase children's interest and develop their appreciations, which in turn will lead to growing comprehension and insight. As in the case of the other objectives discussed, this one is realized only if we intend it to be and plan learning experiences for children accordingly. We hope to bring about changes in behaviors and think of our results in terms of showing evidence of a broadening interest through asking more searching questions, bringing to class, examples that show increased curiosity, selecting science books of a more diversified content.

Let's remember that children are individuals and differ in ability, background, interests, and many other characteristics; you cannot expect all of them to be equally interested in any one topic or subject. The best a teacher can do is to make it possible for children to explore their present interests, discover new ones, and derive satisfaction from pursuing them. Above all, let us try to keep interest alive, not kill it by forcing children to go further than their interests and abilities will carry them. It is just as important to know where and when to stop the study of a problem in science as when to start it.

Remember that children will in their later school experience have other opportunities to study science; consequently it is not necessary for them to exhaust the subject in the elementary school. Even if it were to be their last school contact with scientific material, there is still nothing to be gained by running it into the ground. The vast majority of pupils will find satisfaction in science as they do in their other school subjects, with interest spurts and lags, depending on the specific problems being considered. Some-we hope relatively few-will have but a passive interest in science, and during science classes their minds may be far away. It is when the minds of most of the pupils are elsewhere during science study that we should show real concern. It is then that we should examine critically the content and techniques of teaching.

RESPONSIBLE, INTELLIGENT CITIZENSHIP

Knowledge of science concepts; understanding of science processes; and the development of attitudes, interests, and appreciation are all of little avail if we produce adults who are unable or unwilling to use these in helping to solve the serious problems which face the world today. We are only beginning to realize how serious some of these problems are. The interest in ecology and the state of our environment came with an almost explosive suddenness revealing many urgent problems: general deterioration of the environment, the exhaustion of our natural resources, over-population, drug addiction, illiteracy, ignorance and prejudice, threat of nuclear war, poverty, urban decay, crisis in transportation.

While the production of responsible, intelligent citizens is a general goal for all education, it is obvious that science education has some very significant concepts and methods to contribute. The science experiences in the elementary school lay the groundwork for these contributions when we involve children now in projects in their schools and communities. With these projects children have the satisfaction of knowing that what they do makes a difference. Problems such as the following may trigger worthwhile projects.

What can we do about the lot next to our school which is filled with papers and rubbish?

Where does the soot on our playground come from? What can be done about this?

How can the environment of our school and community be improved?

While we cannot overestimate the importance of helping children to develop into responsible intelligent citizens, we accomplish little when we superimpose adult views on them. As with the other aims we have discussed, the interests, drives, capacities and the developmental levels of children must be understood and respected. Nor should we be deceived by children's verbal performance in the use of ecological terms. We must continue to search for evidence that the behaviors of students have changed that they have established certain desirable values as evidenced by their discussion and actions.

As in case of other objectives we come closer to achieving our goals if they conceived as behaviors. For example, in connection with a study of environmental pollution: As a result of participating in activities planned to help produce responsible intelligent citizens children will be able to: observe an environment and describe its conditions, identify some of the most pressing problems, plan specific courses of to improve environmental situations, demonstrate by specific behaviors the ability assume leadership and responsibility in helping bring about changes for the better in the immediate environment, and originate and pursue experiences and expel that provide data about unsolved environmental problems.

Perhaps we have written too emphatically and too much about objectives. But they are important, for they guide our science teaching in every detail. We shall continue to refer to them and try to make them even more concrete throughout this text. Every day we teach, we should challenge the things we do with children by ourselves: What behaviors do we expect on the part of children? If the answer is questionable, then let us try hard to find a better way of teaching. If the answer is satisfactory, let us strive to increase the effectiveness of what we are already doing. Let us attempt to be more specific in our expectations and pattern our evaluations of these expectations. Above all, let us keep in mind that science deserves to be included in the elementary curriculum only to the extent that it contributes to the goals of the total program.

What we have said about keeping in mind the goals of learning in science are equally true for the teaching of every other subject in the elementary school. We point this out to emphasize our contention that good science teaching is very similar to good teaching in other subjects. Great strides could be made in our educational program if we applied the following criterion to the curriculum: Does the study of this problem, the use of this activity, this plan of work actually contribute to the attainment of our overall goals? If problems, activities, and plans that did not meet this standard were discarded and replaced our school program would be immeasurably revitalized.

It's what happens in the classroom that counts.

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