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Discussed are generalizations, criteria, and techniques for student and teacher evaluation in elementary school science. Part 1 relates examples of evaluative activities in first, fifth, and sixth grade classes and briefly discusses them relative to two important evaluative questions. These are--(1) Are the evaluative activities related to the objectives of the science lessons? (2) What is the purpose of the evaluation? Part 2 emphasizes that the purposes for science teaching must be clear and discusses three objectives commonly accepted for elementary science programs. These are (1) to help children acquire knowledge about the universe, (2) to help children develop the attitudes and values that are compatible with science, and (3) to help children learn the methods of discovery, the skills of inquiry, the procedures of scientists, the ways of finding out about the natural world, and the ways of solving problems. Part 3 discusses the use of behavioral objectives as an avenue for evaluating the objectives discussed in Part 2. Various examples of instruments for evaluating student growth are included. Ateacher self-evaluation checklist is also provided. (DS)

NATIONAL SCIENCE TEACHERS ASSOCIATION

how to . . .

EVALUATE SCIENCE LEARNING

in the elementary school

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The world—the universe—and all that's in it are a child's oyster! Something to be examined, to be turned over and looked at, to be probed, questioned, taken apart, put together, explored. The universe yields its secrets to inquiring children as well as to scientists and other curious persons. But it yields them sparingly. Science teaching in the elementary school helps children engage in the exploration more efficiently and effectively than would their own random, individual activity.

We know enough about learning to say with confidence that children engaged in formal or informal, systematic or unsystematic, planned or unplanned approaches to a study of the world around them will learn something. Each child will learn to a degree related to his involvement in the process and his capacity at any time. The challenge of science teaching in school is to assist children in every way possible to learn more of what is interesting, and hopefully significant, in science.

Is science being taught in your school? If the answer is YES, then it is fair to move to the next question: How well are the children doing? A premise that cannot be avoided and one that teachers must hold ever present is that *children tend to learn those things they have an opportunity to learn* and *they do not learn those things they have no opportunity to learn.*

If teachers accept this premise wholeheartedly and believe that their school has an excellent program in science, they should have some way to evaluate their teaching of science.

To give the reader an idea of how he might evaluate his teaching, let's visit three hypothetical classrooms where evaluation activities are underway.

First Grade

While the children with the help of a teacher aide work at miscellaneous individual tasks, the teacher talks with selected children one at a time about some objects of assorted sizes, shapes, and colors on the table. The teacher asks each child to do two things: (1) "Here are six wooden rods of different lengths. Please put the three longest rods in this box and the three shortest ones in that box. Can you do that?" and (2) "Here is a rock and here is a golf ball. Can you find out and tell me which is heavier? Here we have a spring balance."

After each child had responded to each question as best he could, the teacher records the observation or conclusion about each child's performance in a chart like this:

	SORTING RODS		WEIGHING OBJECTS	
NAME	Answer	Remarks	Answer	Remarks
John	Ok		Ok	without scales
Jane	Ok		Ok guessed	didn't use scales
June		mixed short and long	incorrect	didn't use scales
Jack	Ok		Ok	used scales
Jim		only played with sticks		played with objects on scales, no answer

Fifth Grade

Each child is given a sheet of paper with the following information on it.

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Plant Growth

The chart below records the growth of three bean seedlings. Study the facts recorded on the chart. There are six statements below the chart. In the space before each statement write True, False, or Uncertain. (Uncertain means that you can't tell from the facts given in the table.)

Date	Height in Inches		
	Bean Seedling #1	Bean Seedling #2	Bean Seedling #3
Oct. 3	3	3	3
Oct. 6	3½	4	5
Oct. 9	4	5½	7
Oct. 12	4½	7	9

_______ Each bean plant was 3 inches tall at the beginning of the experiment.

_______ Bean seedling Number 1 grew 1½ inches in nine days.

_______ Bean Number 2 grew more than any of the others in the nine days.

_______ Bean Number 3 was planted in the richest soil.

_______ Bean Number 1 was in a cool place.

_______ Bean Number 3 would be 11 inches tall on October 15.

Sixth Grade

Each pupil is given the following "test": *Plan an investigation to check this statement (hypothesis): Water evaporates more quickly in warm air than in cool air.*

What is your plan? What materials will you use?

What observations will you make?

How do you intend to record your observations?

Three different types of evaluation activities have been described. Are these samples of evaluation "good"? The question is significant, but as readers we are in no position to make any judgment in the matter. Before we can make judgments we need answers to two questions.

First, are the evaluative activities related to the objectives of the science lessons? If the objective in the first grade was to help children learn to differentiate lengths or to classify objects by length, then the evaluation item was at least relevant to that objective. Or, if the purpose was to learn to use a spring balance to weigh objects, the activity seems relevant.

If a purpose in the fifth grade was to learn to interpret data in charts, this item is relevant. The sixth grade evaluation was relevant if the pupils were expected to learn to plan investigations (experiments) involving simple controlled conditions or variables. The activities described above do not seem to be aimed at evaluating the recall of specific facts of science.

Second, what is the purpose of the evaluation? If you knew that the first-grade children as a group had had no experience with a spring balance nor with the concept of weight or weighing and that the results were to be used in grading the children, you might say the evaluation activity was poor indeed. But when you are told that this was a pretest to be used by the teacher in planning subsequent experiences for the children (particularly for those children who do not know how to "weigh" objects) then you might agree that the evaluation procedure was good. Continuing evaluation is necessary if the teacher is to change teaching practices and procedures in order to improve the learning situation. The teacher's record of each child's response will be useful in determining the child's progress when "weighing objects" is a part of the formal instruction as well as when planning such an activity.

Thus, we see that the three examples are "good" ways of evaluating science teaching only in those classes where they fit the objectives or are employed for a purpose clearly understood by the teacher.

Evaluation of science teaching can proceed intelligently when a school and the teachers have accepted objectives for teaching. Victor's point made in relation to the many elementary science curriculum projects is relevant here.[1] He points out that provisions must be made for adequate evaluations. Too much emphasis is given to teacher testimonials and pupil enthusiasm and too little to develop other evaluative means. The number of objectives in science teaching need not be great, but they should be clearly specified. Teaching to achieve a *few* important objectives seems eminently better than to identify and then neglect or forget about *many* objectives.

The Purposes for Teaching Science Must be Clear

Elementary teachers should not have to evolve the statements of purposes for teaching science. But someone must do it, and teachers may help. A school or school system surely has the responsibility for formulating the objectives. Whatever their source, every teacher must understand the objectives and adapt them to the particular group of children with whom he works. The success of science teaching should be evaluated in terms of the growth of each pupil toward maturity or competence with respect to all of the objectives.

Three categories of objectives commonly accepted in science programs for children are suggested.

To help children acquire knowledge about the universe. This means learning more and more about *what is, what happens, how events happen, what interactions occur* between objects and energies in the universe. The activity of scientists leads them to be able to give better or more accurate descriptions of the kinds of matter and energy and their interactions. These descriptions may take the form of facts, principles, laws, theories, or concepts. Scientific knowledge may also be in the form of workable and increasingly accurate explanations of events. Some persons interpret this cluster of objectives as the *information base* with which children interpret and understand the natural world.

Evaluating children's growth in relation to this objective is accomplished through observing them recall information; use information to solve problems; make valid explanations, interpretations, applications, predictions, and the like.

This cluster of objectives has been referred to by Bloom as being in the cognitive domain.[2] Anderson summarizes the meaning of various levels within this domain in an exceedingly useful way for teachers of elementary science:[3]

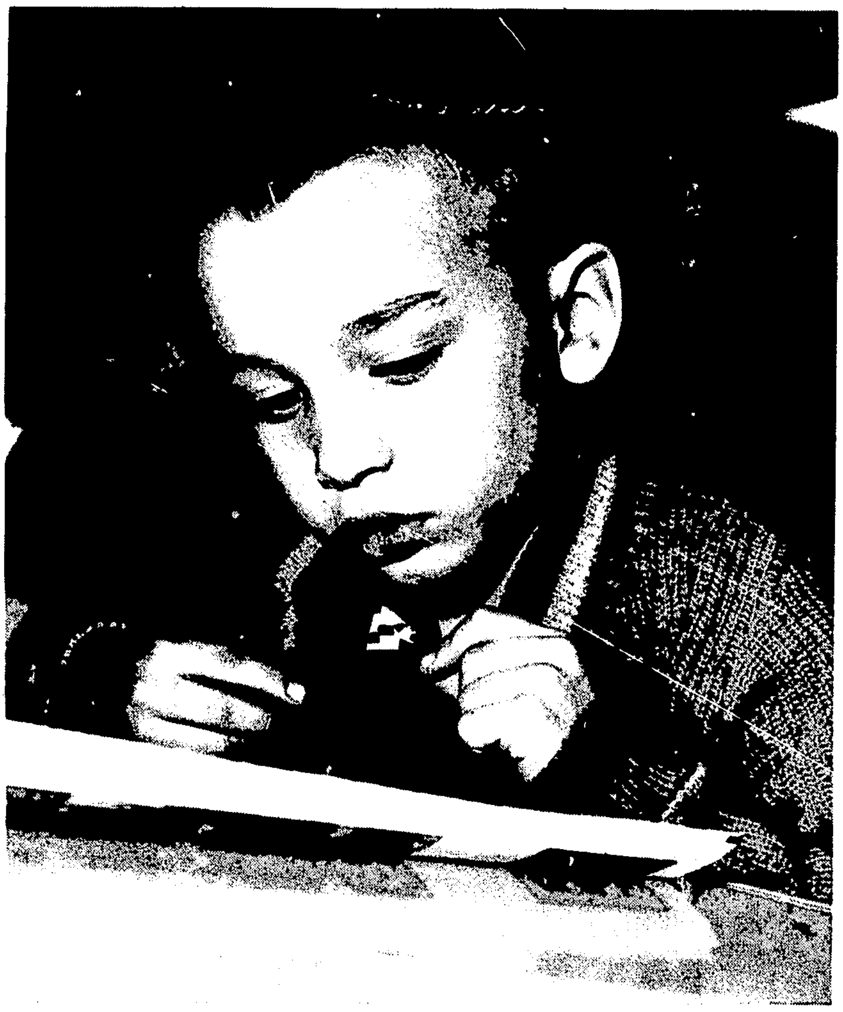
The first and lowest level in the cognitive domain is the *knowledge* level. It includes the recall of specifics (e.g., ice is a form of water), structures (e.g., the skeletal structure of vertebrates), or scientific processes (e.g., a control is an important part of an experiment). The knowledge level emphasizes that which would be described as remembering.

The second level is *comprehension* which includes translation from one form to another. Examples would be drawing a graph of daily temperature changes from a list of temperatures recorded over a period of days or weeks, or explaining verbally what is meant by a statement which is expressed in mathematical symbols.

Application, which is the third level, requires the ability to apply abstract ideas in a concrete situation. Examples would be the ability to use a knowledge of the relationship between heat and the expansion and contraction of liquids to explain how a thermometer works, use a knowledge of classification to classify a group of seashells according to size, shape, or color, or use a knowledge of electric circuits to cause a light bulb to light using a cell, bulb, and pieces of wire.

Analysis, the fourth level, involves breaking down an idea into its various parts and determining the relationship between the parts. Determining which statements about an experiment are facts and which are hypotheses, or determining which factors led to an unexpected conclusion of any experiment would be examples.

Synthesis, the fifth level, includes taking parts and putting them together to form a whole such as skill in expressing verbally or in writing the results of an experiment using an appropriate organization of ideas. Other examples



When a child participates as an investigator or discoverer, he feels important.

[1] Victor, Edward. "Controversial Aspects of the Elementary Science Curriculum Projects." *Science and Children*, Volume 5, No. 2. October 1967. pp. 27-31.

[2] Bloom, Benjamin S., Editor. *Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I:* "Cognitive Domain." David McKay Co., Inc., New York. 1956.

[3] Anderson, Ronald. "Evaluation in Elementary School Science (Part I)." *Science and Children*, Volume 5, No. 1. September 1967. pp. 20-23.

would be formulating an hypothesis to explain why some animals are less active in the daytime than at night or why water poured on a fire will often put out the fire.

Evaluation, the highest of the six levels in the cognitive domain, includes making judgments. An example is the ability to state the fallacies in an analysis of an experiment. Another example is the ability to evaluate popular beliefs about health.

Within Anderson's summary are many excellent clues for evaluating children's growth in relation to using science information.

To help children learn the methods of discovery, the skills of inquiry, the procedures of scientists, the ways of finding out about the natural world, the ways of solving problems. This cluster of objectives includes such behaviors as

questioning	explaining	classifying
observing	speculating	generalizing
hypothesizing	inferring	analyzing
predicting	estimating	
describing	measuring	

These behaviors are often referred to as the processes of science.

To help children develop the attitudes and values that are compatible with science. Among these are a respect for the results of honest investigation, a healthy skepticism of generalizations not based on observations, and little faith in conclusions based on incomplete or inaccurate data. Though there are significant areas of life in our culture where values are derived neither scientifically nor from science, still there are areas where human values are both molded by and help mold science. It is a human value, for example, to accept the results of scientists when there is assurance that certain well-described procedures have been involved in discovering new knowledge or in testing certain hypotheses. Man values this kind of knowledge and attitude in science as he does in other areas, but science should not be thought of as having the solution for all problems.

It is important in the scientific world to report scientific knowledge to qualified peers so it may be checked or challenged. Likewise, children should learn to accept the value of sharing what they learn in science classes with others so it may be evaluated. How are they to share it?

Examples of specific behaviors of children related to scientific attitudes are these:

1. Shows willingness to have his ideas questioned
2. Modifies his views in the face of new evidence
3. Shows a disposition not to jump to conclusions
4. Looks upon guesses and hypotheses as ideas to be tested
5. Shows respect for ideas of others
6. Seeks data and information to validate observations or explanations
7. Exhibits a healthy skepticism for generalizations not based on verifiable (repeatable) observations
8. Questions conclusions based on incomplete data

Behavioral Objectives in Science

What behaviors of children indicate that they are achieving or maturing in relation to the stated objectives? How can a teacher tell whether a child is developing a "scientific attitude"? Stating the objectives in "behavioral terms" will set the stage for more direct identification of evidence that a child has attained a degree of maturity with respect to an objective. But what is a *behavioral objective?* Simply stated, as Anderson points out, a *behavioral objective* is a statement of *what children should be able to do* as a result of successful teaching and learning.[4] A distinction might be made between two kinds of behavioral objectives: (1) those "performances" which are conscious and deliberate and the other (2) involuntary or subconscious behaviors or responses to the noncontrived situations.

Mager has written that the statement of objectives in terms of "to write, to recite, to identify, to differentiate, to solve, to construct, to list, to compare, to contrast," enables a teacher at once to know what to look for as evidence of success.[5] These are particularly appropriate to the processes of science.

Demonstrating certain skills is a goal of science learning.

It is more difficult to state behavioral objectives that relate to scientific attitudes. But a few well-stated objectives in this category are probably sufficient on the assumption that a teaching environment conducive to learning them will perforce yield good results in other, perhaps minor objectives related to attitudes and appreciation. Neither a science teacher nor his pupils can hope to achieve all things, and careful attention to a

[4] Anderson. *op. cit.* p. 22.

[5] Mager, Robert F. *Preparing Instructional Objectives.* Fearon Publishers, Palo Alto, California. 1962. p. 11.

few objectives may be more important and rewarding than superficial attention to many.

Evaluating growth in using the methods of scientists. There is no substitute for a carefully structured conversation with each child to get an idea of his understandings in science. A record of periodic observations on each child is useful in judging growth or change over a period of time.

Have the children learned the *ways* to get valid descriptions and explanations about materials and events in the natural world? That is, are they able to observe better, experiment, read, and collect and interpret facts—skills which scientists employ? These also represent intellectual skills which are used by everyone in ordinary, daily activities.

Listening to children's answers gives a teacher some idea of their understanding.

As implied by the checklists which follow, an evaluation by a direct approach in which children are asked to do something is best. The teacher must present situations requiring children to demonstrate their skill in those behaviors which are among the goals of instruction. By this behavior a child will reveal his accomplishments!

Can he make a graph?	Can he use a microscope?
Can he read a thermometer?	Can he classify objects?
Can he organize facts?	Can he isolate pertinent from irrelevant data?
Can he plan an experiment?	

These behaviors can be added to appropriate checklists if they are appropriate to the particular portion of the science program being evaluated.

The checklists that follow provide the teacher and children with convenient ways to record observations or judgments for evaluating different aspects of the science program. It is suggested that any or all of these be used if the teacher finds them helpful in evaluating the learning of his students.

TEACHER EVALUATION [a]

To check for growth in process of inquiry

Grade:

Teacher:

Year:

	Names of Children					
Suggested a prediction						
Offered ways of testing prediction						
Changed opinion for better idea						
Selected materials with purpose						
Used "I think," "I don't know"						
Criticized his own work						
Observed carefully						
Stated relationships while observing						
Repeated work and/or changed for better procedures						
Used data to draw inferences						

[a] **Science in Florida Elementary Schools.** State Department of Education, Tallahassee, Florida. Bulletin 73. 1967. pp. 218-223. (This and the following three checklists adapted with permission.)

TEACHER AND CHILDREN EVALUATE AN INVESTIGATION (GROUP)

Problem:

1. What did we do that helped you most to find an answer to our question?	
2. What could we have done better?	
3. What new ideas did we discover?	
4. What new words did we learn from this study?	
5. If you tried the experiments at home, were the results the same as in school?	
6. What predictions were we able to test with the materials we had?	
7. What different ways could we have used to keep records of our observations?	
8. What materials and equipment helped us most?	
9. What equipment did we have to construct?	
10. How did we use numbers and measurement to help find answers?	

These questions will need to be revised, some omitted, others added to be appropriate for different age groups and for the particular investigation to be evaluated with children.

TEACHER EVALUATION

Evaluating performance with manipulative materials

Grade:

Teacher:

Year:

	Names of Children					
Manipulates materials with ease						
Observes closely while working						
Reveals stick-to-itiveness						
Suggests new uses of materials						
Finds relationships						
Avoids hasty inferences						
Describes discoveries clearly						
Asks new questions						
Independent in clean up						
Uses safety precautions						

Evaluating growth in understanding and applying scientific knowledge. The facts, principles, generalizations, and concepts of science are of value primarily as they help children understand, interpret, and explain phenomena. Children's progress in science can in part be determined by the degree to which they draw on more precise or more complex groupings of facts or principles or more involved interrelationships of knowledge in explaining events or describing phenomena. As children study science they should be able to move from relatively simple, imprecise explanations to more elaborate and precise explanations.

There is no more direct way of assessing children's understanding of natural phenomena than to get their verbal or written explanations to questions or of observed phenomena. For example:

1. The shadow of the stick got longer as the sun moved each hour between noon and sunset. How can you explain this?
2. The candle burned two minutes in a large jar but only 20 seconds in a small one. How do you explain the difference?
3. Bean seeds grew into bean seedlings and pea seeds grew into pea seedlings. Does that surprise you? Why or why not?
4. A boy attached a string to a horseshoe magnet and let the magnet down through cracks in a board walk to pick up a penny he saw there. Do you think he succeeded? Explain.

Listening to children's answers or reading answers to the above kinds of questions gives a teacher a good idea of their understanding. By studying their replies, the teacher can detect where children lack information, where they are using misinformation, or where they are applying certain principles in the wrong context.

Another type of evaluation instrument to assess children's knowledge requires them to select from given statements of principles, concepts, or bodies of fact those that most appropriately explain a given situation. If the children cannot read the items, someone may read to them.

TEACHER'S RECORD

SKILLS OF INQUIRY

Names of Children	Is curious Asks questions on variety of topics	Predicts Hypothesizes Speculates	Plans investigations Observes closely Keeps records	Repeats experiments Gathers information from different sources	Bases answers on evidence or on reliable data

Situation: During the afternoon a small glass jar had some twigs in it. On one of the twigs was a dark brown object shaped like a very large peanut. The next morning the peanut-like object was broken and on the twig was a beautiful butterfly. Which one of the statements below best explains what probably happened?

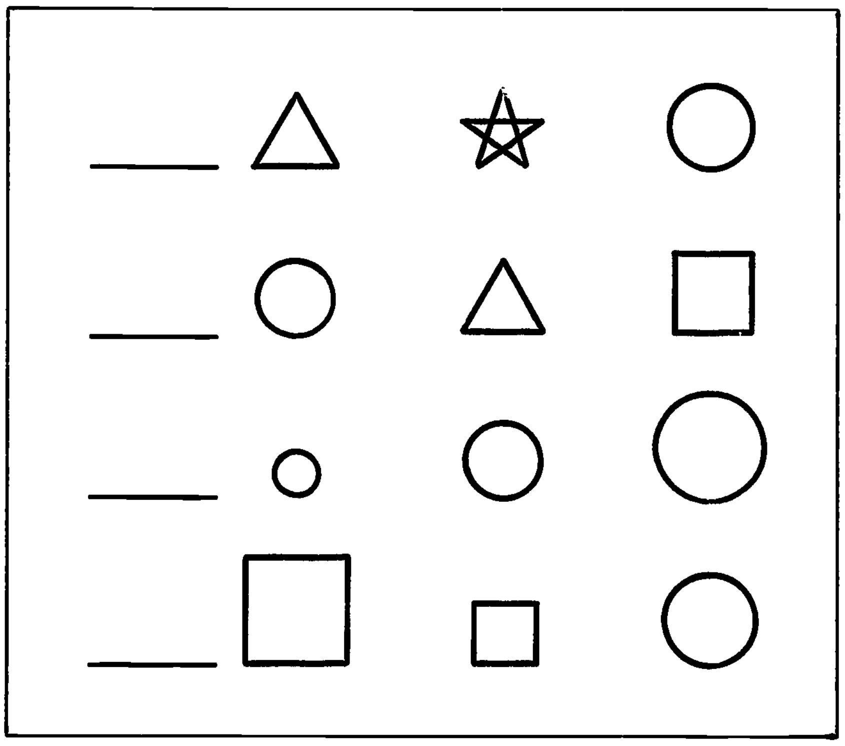
_____ 1. Someone opened the jar and put a butterfly in.

_____ 2. The butterfly came out of the peanut-shaped object.

_____ 3. The butterfly hatched overnight from an egg on a twig.

Why do you select the answer you do?

Situation: Here are drawings of several objects. Put 1 check (✓) by the group that is most alike **by shape** of the objects in it. Put 2 checks (✓✓) by the group that is most alike **by the size** of the objects in it.



Situation: Several children were playing outdoors on a cold winter day. Some of them wore glasses. When they went inside the warm school building their glasses "fogged" over. Which statements below help explain why the glasses fogged over?

_____ Cool air cannot hold as much water vapor as warm air can.

_____ Warm air cannot hold as much water vapor as cool air can.

_____ Cold objects tend to cool the air around them.

_____ Most air around us has moisture in it.

_____ Glass always condenses moisture in the air.

Evaluating development of scientific attitudes. The evaluation of attitudes can best be made by observing children directly as they work and play with other children, not only during the time science is being studied but at other times as well. As suggested earlier, defining attitudes as behavioral objectives is not easy. Attitudes generally predispose children to behave in certain ways. These ways can be observed in the children's conversations, their approach to the solution of problems, how they react to opinions of others. The items on this check list (built from the behaviors mentioned on page 4) provide a beginning for evaluating each child in selected behaviors related to scientific attitudes.

	Names of Children					
A child						
Shows willingness to have his ideas questioned						
Modifies his views in the face of new evidence						
Shows a disposition not to jump to conclusions						
Looks upon guesses and hypotheses as ideas to be tested						
Shows respect for ideas of others						
Seeks data and information to validate observations or explanations						
Exhibits a healthy skepticism for generalizations not based on verifiable (repeatable) observations						
Questions conclusions based on incomplete data						

Specific words are hardly ever explanations of phenomena. In evaluating children's knowledge of science, it is rarely good practice to ask the children to supply a word as an explanation. For example, the word *gravity* is not an explanation of falling bodies. It is simply a word we associate with the phenomenon of earth's pull on objects. *Evaporation* is the word we use to identify or refer to liquids disappearing from an open container, but the word is not the explanation of the phenomenon. So, in evaluating children's knowledge of concepts, we must seek more than a single word.

Learning to classify objects is one of the goals of the science program.

Children's self-concepts are important. The study of science in the elementary school should not be a threat to the self-concept or feeling of worth of children. When their self-concept or self-image is threatened, there are several possible consequences, none of which is emotionally or intellectually constructive. So it is a challenge to involve children in the study of science in ways to help them develop a sense of self-worth. When a child is participating as a full-fledged investigator or discoverer or observer, *he feels important because he is important*. He is being a scientist.

But the self-concept is sometimes shattered and the joy of learning dispelled by evaluation which reflects, in one quick stroke, that we expect children to perform (or recall) in ways not consistent with science. Testing children in "subject matter" can produce anxiety in them.

In general the child should understand how the results of evaluation are to be used. If he does not know, then he may develop a kind of anxiety or fear not only of "tests" and other forms of evaluation but the process of science itself.

For example, if the goal is to build interest in the physical environment, but the testing attempts to measure academic achievement, there is certain to be a disjunction which traps the child. He can reject the evaluation since what he is expected to *know* or *do* seems not to be related to what he thought he was learning.

A strong case may be made that evaluation of science teaching in the elementary school should be used almost exclusively as a way of diagnosing learning, or planning teaching procedures and counseling with pupils—not as a means of "testing" for grading purposes.

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Evaluation Checklist

No doubt there is an optimum combination of teaching procedures, use of resource materials, involvement of children, and other factors, which yields the greatest growth toward the objectives for each child. A search for this optimum combination must be a continuing search for every science teacher. And the search must continue along with the evaluation of children's learning in science.

Toward that end a checklist is suggested here for teachers to use in appraising the kind of teaching-learning environment they provide. It includes techniques and resources useful in science teaching and it may be checked to reflect techniques and resources already being used by the teacher.

TEACHER'S SELF-EVALUATION CHECKLIST

In my classroom there is an opportunity or provision for pupils to:	Often	Sometimes	Rarely or Never
1. Recognize and raise problems which are of interest and importance	____	____	____
2. Acquire skill in limiting and defining problems	____	____	____
3. Develop an understanding of the basic concepts involved in the problem defined	____	____	____
4. Evaluate and challenge sources of information	____	____	____
5. Distinguish between fact and fancy	____	____	____
6. Propose hypotheses	____	____	____
7. Develop experiments to test hypotheses	____	____	____
8. Use some of the common scientific instruments	____	____	____
9. Observe accurately	____	____	____
10. Report and record data	____	____	____
11. Explain natural phenomena as they relate to the problem	____	____	____
12. Withhold judgment until evidence from all available sources is collected	____	____	____
13. Apply concepts developed to other problems	____	____	____
14. Apply learned concepts to daily life	____	____	____
15. Engage in individual science interests and projects	____	____	____
16. Increase proficiency in basic skills (arithmetic, writing, reading) through science activity	____	____	____