# Science for All Children

## A Guide to Improving Elementary Science Education in Your School District

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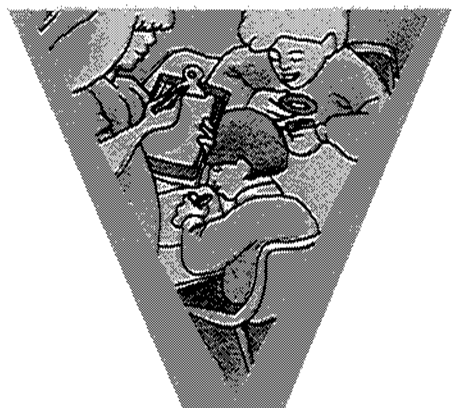


8

# Assessment Strategies for Inquiry-Centered Science

*Assessing science through paper-and-pencil tests is akin to assessing a basketball player's skills by giving a written test. We may find out what someone knows about basketball, but we won't know how well that person plays the game.*

— **George Hein and Sabra Price,**
***Active Assessments for Active Science*, 1994**

Principals and science coordinators often hear teachers lament that traditional assessments simply don't work in inquiry-centered classrooms. "Paper-and-pencil tests only give information on part of what we teach," they say. "We need something else to use to give us a better picture of what our students know and are able to do."

Traditional tests—usually multiple-choice, short-answer tests given at the end of a unit of study—cannot assess all the richness of learning that takes place in the inquiry-centered science classroom. A multiple-choice test cannot effectively evaluate whether students have learned how to design an experiment, make accurate observations and measurements, analyze data, and reach reasonable conclusions. Multiple-choice tests are also not very effective in assessing student understanding of concepts such as buoyancy or the role bees play in the life cycle of plants. Measuring students' grasp of these skills and concepts requires alternative forms of assessment.

This chapter outlines several ways to structure assessment activities that can effectively determine each student's progress toward the attainment of science inquiry skills and concepts. To illustrate each form of assessment, we have included examples from three curriculum programs—Full Option Science System (FOSS), Insights, and Science and Technology for Children (STC). Throughout the chapter, we will concentrate on how the teacher can assess student learning on a daily basis.

The chapter also describes strategies that can be used to assess the science program as a whole. We present guidelines school districts can use to determine how the implementation of the science program is proceeding.

## Assessing Student Learning

Just as it is challenging to institute inquiry-based instruction in the classroom, so is it difficult to incorporate new assessment strategies into classroom evaluation. For this reason, it is reassuring to know that teachers need not create new assessment strategies on their own. Many of the national curriculum programs include such strategies in their teacher's guides. These suggestions provide a good starting point.

Most teachers find it helpful to begin to use the new assessment strategies slowly and carefully. It is neither necessary nor advisable to eliminate traditional testing. In fact, one of the guiding principles behind assessment is that the more diverse the strategies used, the more the teacher can learn about each student. Over time, each teacher will discover ways to balance traditional tests and alternative assessments to obtain a complete picture of how well students are progressing.

Although the focus in this section is on assessment in the classroom, it is important to recognize that assessment is a contro-

*During an informal assessment for a module on ecosystems, a teacher talks with fifth-grade students about their observations.*

versial issue in science education. Within the classroom, using a range of assessment tools provides information on both student learning and future teaching strategies. Within a school district, however, standardized tests are often used as a means of making schools accountable for student learning.

Our focus here is on helping teachers develop more effective strategies for assessing student learning in their classrooms. The following assessment strategies have been used effectively in many inquiry-centered science classrooms throughout the country. Many of them have been incorporated into national science curriculum programs.

### Matched Pre- and Post-Module Assessments

Pre- and post-module assessments serve two important functions. The first is to track how much students have learned during the unit. For example, the teacher could ask a question or assign an investigation at the beginning of each module to find out how much students know about the subject. At the end of the module, students could answer the same question or perform the same investigation, enabling the teacher to observe how their understanding of a subject has grown.

Such assessments can take many forms. For example, many modules in the STC elementary science curriculum begin with a brainstorming session during which children are asked what they know about a subject and what they would like to learn about it. At the end of the module, they are asked the same questions again, giving the teacher an opportunity to assess how much students have learned over the course of the unit.

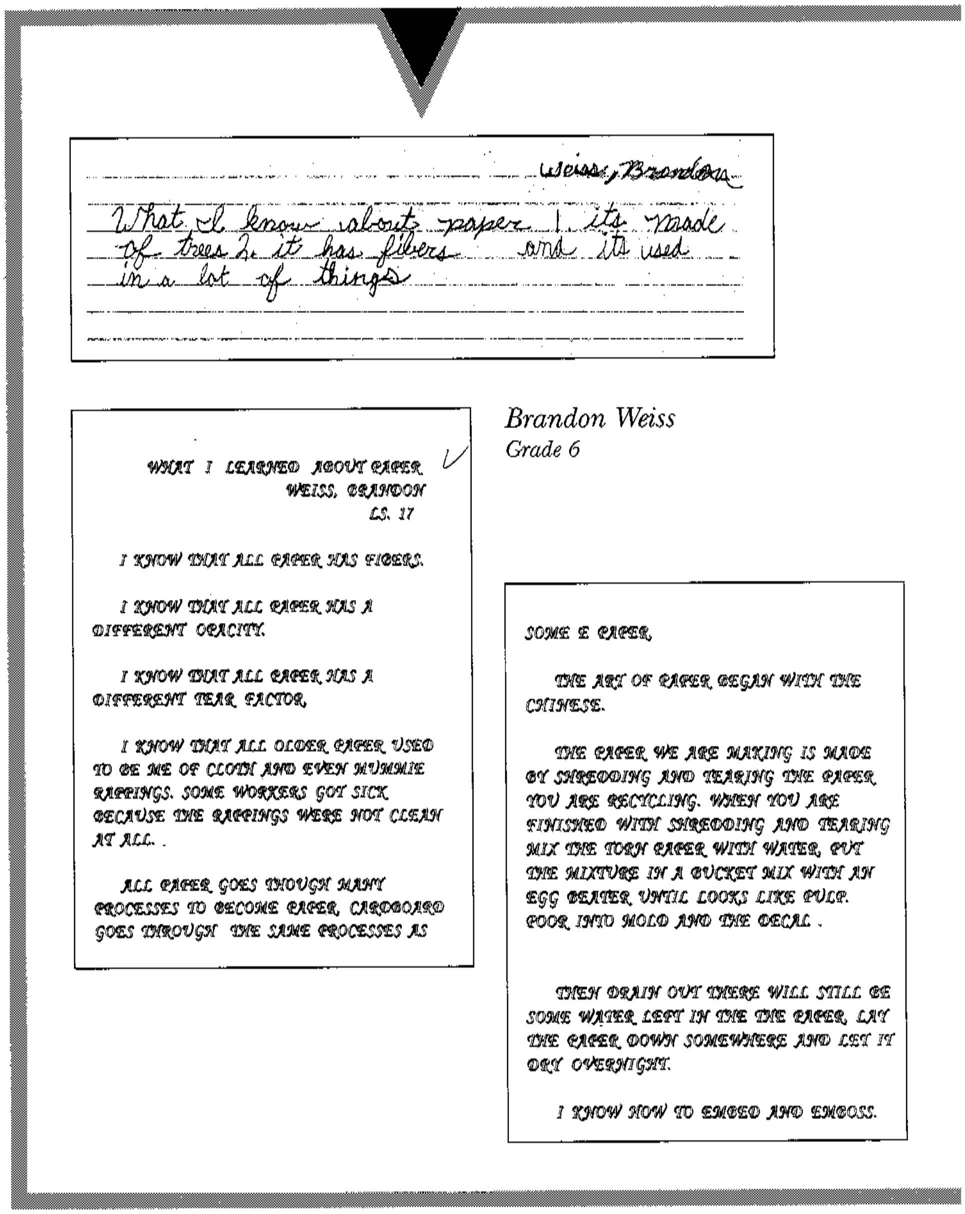
A pre-module assessment can also give the teacher information on what questions students are interested in pursuing. As the class progresses through the unit, the teacher can refer to the pre-module assessment to further refine teaching strategies. The post-module data can then be used as a way for the teacher to measure the success of his or her teaching strategies.

Other examples of pre- and post-module assessments include having students write about a subject, draw a picture, or perform a simple experiment. These devices give teachers important "before-and-after" information. Figure 8-1 shows examples of pre- and post-module assessments.

The Insights elementary science program has a more formal pre-module assessment. Each module in this program begins with an introductory questionnaire that is linked to the goals of that module. The questionnaire may include content-related questions as well as questions designed to assess students' problem-solving abilities. At the end of the module, students complete the questionnaire again; the two versions of the questionnaire provide teachers with a written record of students' progress. Younger students complete the questionnaire through interviews. Figure 8-2 shows part of an introductory questionnaire from the Insights *Reading the Environment* module.

### *Embedded Assessments*

These assessments are woven, or embedded, into the instructional sequence in the module. They may be part of the activities that naturally occur in a lesson or a logical extension of the lesson's



Weiss, Brandon

What I know about paper 1. its made of trees 2. it has fibers and its used in a lot of things

WHAT I LEARNED ABOUT PAPER
WEISS, BRANDON
LS. 17

I KNOW THAT ALL PAPER HAS FIBERS.

I KNOW THAT ALL PAPER HAS A DIFFERENT OPACITY.

I KNOW THAT ALL PAPER HAS A DIFFERENT TEAR FACTOR,

I KNOW THAT ALL OLDER PAPER USED TO BE ME OF CLOTH AND EVEN MUMMIE RAPPINGS. SOME WORKERS GOT SICK BECAUSE THE RAPPINGS WERE NOT CLEAN AT ALL. .

ALL PAPER GOES THOUGH MANY PROCESSES TO BECOME PAPER, CARDBOARD GOES THROUGH THE SAME PROCESSES AS

SOME E PAPER,

THE ART OF PAPER BEGAN WITH THE CHINESE.

THE PAPER WE ARE MAKING IS MADE BY SHREDDING AND TEARING THE PAPER YOU ARE RECYCLING. WHEN YOU ARE FINISHED WITH SHREDDING AND TEARING MIX THE TORN PAPER WITH WATER, PUT THE MIXTURE IN A BUCKET MIX WITH AN EGG BEATER UNTIL LOOKS LIKE PULP. POOR INTO MOLD AND THE DECAL .

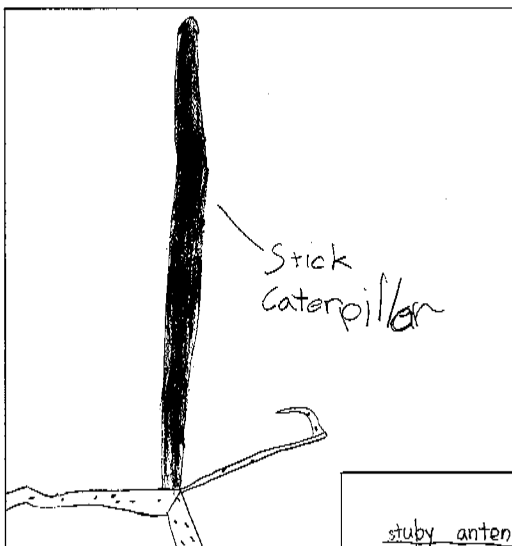
THEN DRAIN OUT THERE WILL STILL BE SOME WATER LEFT IN THE THE PAPER, LAY THE PAPER DOWN SOMEWHERE AND LET IT DRY OVERNIGHT.

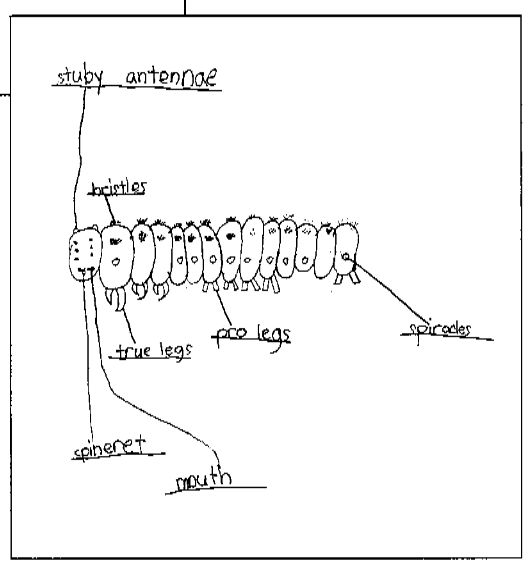
I KNOW HOW TO EMBED AND EMBOSS.

*Brandon Weiss*
*Grade 6*

*Figure 8-1. Pre- and post-module writing samples and drawings from the sixth-grade module* The Technology of Paper *(STC) and the second-grade module* The Life Cycle of Butterflies *(STC)*

*Luke Bostian*
*Grade 2*



*Introductory Questionnaire*

Name ______________________________ Date ______________

**_Reading the Environment_**
**Introductory Questionnaire**

DIRECTIONS TO STUDENTS

Answer each question below as completely as possible in the space provided. Use the back of the paper or an extra sheet if you need more space. In some of the questions, there are words in italics. If you think you know the meaning of the word (even if you are not sure), try to answer the question. If you do not know the meaning of the word at all, and cannot even guess, write: "I do not know this word." If there are any other words (not in italics) whose meaning you do not know, ask your teacher to explain them.

1. Think of something in your neighborhood that is not living and that has changed in the past couple of years. In the space below, name it and describe as completely as you can what it was like in the past, before it changed.

*Reading the Environment* *EDC © 1991*

*Figure 8-2. Introductory questionnaire from the fourth-grade module* Reading the Environment *(Insights)*

2. What evidence do you see that tells you the thing you named in question 1 has changed?

Describe below what this thing is like now. State exactly what the change is that you have noticed. For example: "There was a change in the street. It has cracks in it. The evidence I see is a crack and the street around it is breaking into small pieces. I think it is being worn down."

3. What do you think caused the change(s) you noted in question 2?

4. Give an example of a *fossil* and describe what it looks like.

central activity. Embedded assessments are based on the assumption that assessment and learning are two sides of the same coin. In fact, many educators assert that from the students' vantage point, there should be a seamless flow between instruction and assessment.[1] The biggest difference between an embedded assessment and other learning activities is that the assessment is designed to enable the teacher to obtain and record information about student learning.

The following are examples of embedded assessments:

- After studying STC's *Electric Circuits* module for fourth-graders, students are asked to wire a cardboard house. The activity enables the teacher to assess whether students can apply what they have learned about circuits to a "real-life" situation.
- Throughout the FOSS *Paper* module (a kindergarten unit), students are invited to engage in discussions that reveal their understanding of key concepts.
- At the end of STC's fifth-grade *Food Chemistry* module, students use tests they learned about in the unit to determine which nutrients are in a marshmallow.

**Prediction Activities**

A prediction is different from a guess because it is based on previous experience and knowledge of a subject. By asking students to make predictions at appropriate times, teachers can assess the science concepts their students have mastered and how well they can apply that knowledge to a new situation. For example, during a module on buoyancy (STC's *Floating and Sinking*), students may be given an assortment of objects and asked to predict which ones will float and which will sink. If students consider both weight and volume in making their predictions, the teacher will know that students have gained some understanding of the concept. If they guess randomly, they are telling the teacher that they have a limited understanding of the concept. In either case, the teacher has gained valuable information.

### *Final Assessments*

These assessments are used at the end of a science unit or module. Although many final assessments include paper-and-pencil tests, they can take many other forms. Examples of final assessments are described below.

**Hands-on Assessments.** This type of assessment provides an opportunity for teachers to observe how well students can perform an experiment similar to one they worked on during the module. Hands-on assessments allow teachers to see how students approach a problem, gather data, record results, and draw conclusions from their findings. For example, after experimenting with water in the FOSS *Water* module, students are given a new problem that must be solved through experimentation. The Insights module *Reading the Environment* has a hands-on assessment in which students are asked to design an experiment that will help them decide what kind of stone to use for building in a city where acid rain is a problem.

Another way to organize hands-on assessments is for the teacher to set up stations throughout the room that offer a series of tasks for children to complete. For example, after finishing a module on chemical tests, students may be asked to perform a filtration task at one table, a mixing task at another, and data analysis at a third table. By observing how the students go about the tasks, reviewing the kinds of records they make, and checking their results, the teacher will gain information about what the students have learned. This work can be done individually or in cooperative groups.

**Paper-and-Pencil Tests.** These are questions included at the end of the unit. The FOSS curriculum divides paper-and-pencil assessments into two categories: pictorial assessments and reflective questions assessments. FOSS pictorial assessments evaluate how well students can think through problems that require both knowledge and the application of ideas to a new situation. For example, pictorial assessments from the *Water* module include figuring out why a plastic bottle of water left in the car trunk overnight cracked when the temperature dropped and why water that spilled on the sidewalk seemed to disappear.

Reflective assessments evaluate how well students can express themselves in writing, as indicated by the way students respond to problem-solving questions.

In the STC module *Measuring Time,* students are asked to graph hypothetical data, analyze data from a graph, and discuss in detail reasons for the moon's phases. Activities such as these encourage students to go beyond simply recalling isolated pieces of information and to think critically in applying knowledge to new situations.

**Science Notebooks.** Students can be asked to prepare individual science notebooks that include all the observations and records generated during the module. The notebooks may include stories and poems (see Figure 8-3), record sheets, charts, tables, and graphs. Drawings also reveal what students have learned (see Figure 8-4). The teacher should assess the level of detail, use of labels, and quality of explanations accompanying the drawings.

Science notebooks are useful for both teachers and students. Notebooks are a powerful assessment tool for teachers and an effective way for students to keep a record of what they have done in the module.

A portfolio is a selected group of student work. Students themselves can select pieces that they feel represent significant learning. Usually, the teacher and students work together to develop selection criteria, which may include materials that were the hardest to do or projects that provoked the most learning. Through this process, students have an opportunity to reflect on what they've learned.

### *Informal Assessments*

Many teachers also find it helpful to conduct informal assessments of students' progress. These involve reviewing written materials, observing students at work, and simply walking around the room and listening to students' conversations. By asking the right questions, teachers can uncover students' reasoning and the steps they used to solve problems. The questions that students ask can also be a source of information about their understanding. In addition, individual and group presentations can give teachers insights into students' interpretation of what they have learned. Finally, questions posed by students following presentations can provide opportunities to gather important information.

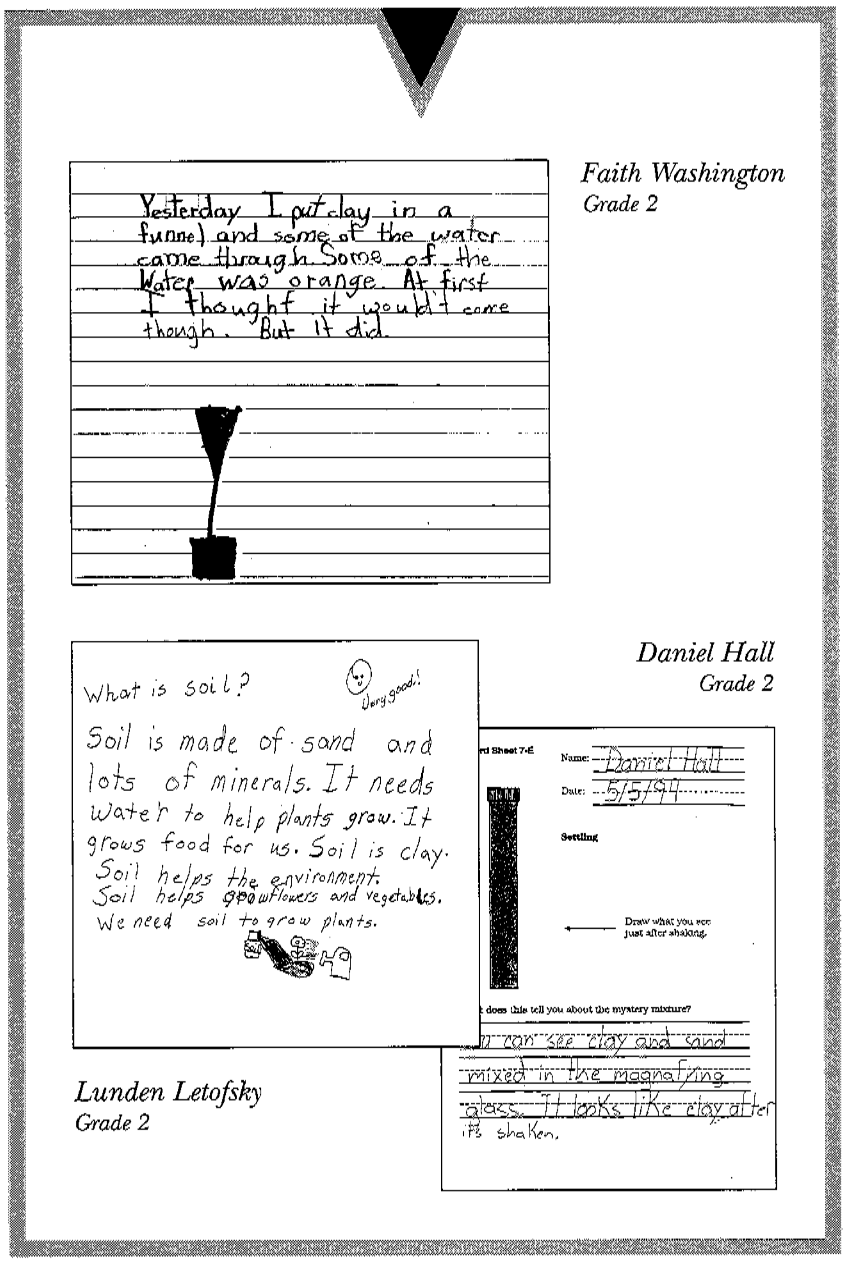
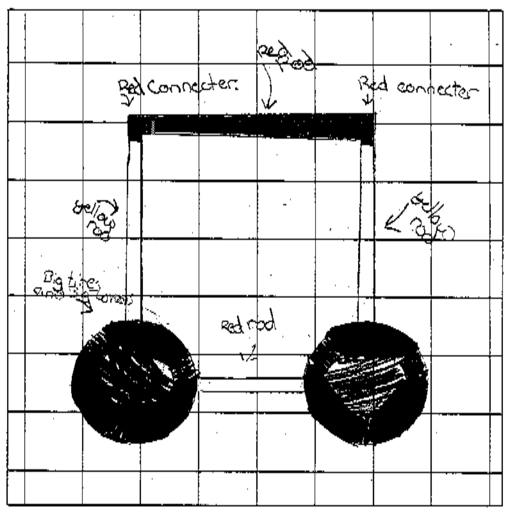



*Figure 8-3. Writing samples from the second-grade module* Soils *(STC)*




*Shaughn Bischoff*
*Alex Jaeger*
*Jenny Minnard*
*Margaret Pace*
*Emilee Schultz*
*Julie Wilke*
*Grade 4*

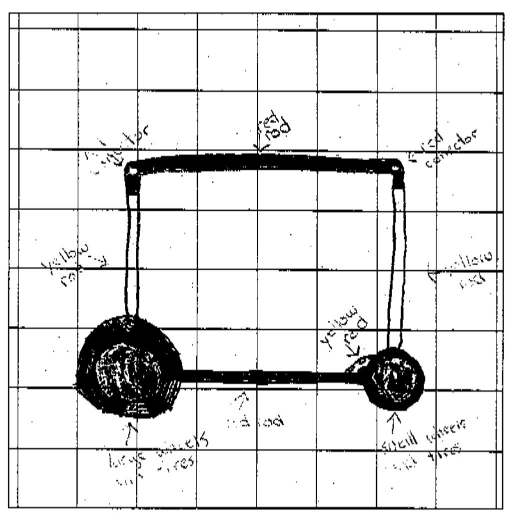


*Figure 8-4. Student drawings from the fourth-grade module* Motion and Design *(STC)*

### *Documentation and Record Keeping*

One of the hardest parts of incorporating alternative assessments into the inquiry-centered science program is developing an accurate record-keeping system. Many teacher's guides include record-keeping charts that help teachers focus on the goals of each assessment instrument.

For example, the STC program includes an observation sheet that teachers may photocopy and use in evaluating each student. The sheet highlights each module's key concepts and skills. For one module, *Balancing and Weighing*, concepts listed include the relationship between the amount of weight and its position on the balance beam, what is meant by the term "weighing," and the relationship between weight and volume. Skills listed include performing simple experiments with a balance beam, using an equal-arm balance, and applying strategies for comparing and weighing to solve problems. Alongside each of these concepts and skills is a space for the teacher to write observations. Figure 8-5 is a sample recording chart from the STC program. The chief advantages of this chart are that it provides a structure for teachers to use as they experiment with new assessment strategies and it can be adapted to suit the needs and record-keeping styles of different teachers.

The FOSS program includes a student worksheet with each of its assessments. To help teachers interpret the results on these sheets, the teacher's guide includes a chart that identifies the purpose of each question. For example, teachers are told that the purpose of the question about the cracked water bottle is to give students an opportunity to explain what happens when water freezes. The purpose of the question about the water that disappeared is to determine whether the students can explain how water evaporates. Figure 8-6 shows a sample observation chart from FOSS's *Water* module.

The Insights program has four parts to its assessment framework: the introductory questionnaire (pre-assessment), the embedded assessment, the post-module assessment, and ongoing assessments throughout the module. The teacher uses student profile charts to record the ongoing assessments and an evaluation rubric to inform the analysis of the formal pieces. The rubric ranges from "0" (no answer or "I don't know") to "5" (a complete and correct response). Figure 8-7 shows the complete Insights rubric.

Blackline Master

***Balancing and Weighing:* Observations of Student Performance**

| Concepts | Observations |
|---|---|
| • Balance is affected by the amount of weight, the position of weight, and the position of the fulcrum. | |
| • Weighing is the process of balancing an object against a certain number of standard units. | |
| • The weight of an object is not determined by its size. | |
| • Equal volumes of different foods will not all have equal weights; equal weights of different foods will not all have equal volumes. | |
| **Skills** | |
| • Performing simple experiments with balance. | |
| • Applying previous experiences with balancing to build mobiles. | |
| • Using an equal-arm balance to compare and weigh. | |
| • Predicting the serial order for the weights of objects and foods. | |
| • Applying strategies for comparing and weighing to solve problems. | |
| • Recording results on record sheets, bar graphs, line plots, data tables, and Venn diagrams. | |
| • Communicating ideas, observations, and experiences through writing, drawing, and discussion. | |
| • Reading to learn more about balancing and weighing. | |

STC / *Balancing and Weighing*

*Figure 8-5. Teacher's observation chart from the second-grade module* Balancing and Weighing *(STC)*

## Water Assessment

### The Reflective Questions Assessment

The **Reflective Questions Assessment** is made up of written questions that ask students to describe and explain events. It takes students about 20 minutes to complete all the questions.

#### Getting Ready for the Reflective Questions Assessment

Make copies of the two student sheets for this assessment. The entire set of questions can be given at one sitting. The tasks can be easily completed by students at their own desks. No equipment is needed.

#### Doing the Reflective Questions Assessment

Instruct students to read each task carefully, then do what the directions say. In most cases they will be asked to explain events.

#### Recording the Results of the Reflective Questions Assessment

The answer sheet gives answers or reasonable responses to the tasks. Feel free to adjust the ranges for acceptable answers based on the capabilities of your students.

On the *Water Module Reflective Questions Assessment Teacher's Chart*, each task in the assessment is clearly delineated along the top margin. This sheet provides a convenient visual summary of individual students' and the class's understanding of water properties and interactions.

The simplest way to use the teacher's chart is to place a check beside each student's name under the appropriate task. A blank indicates that the student did not complete the task satisfactorily.

The Water Module REFLECTIVE QUESTIONS ASSESSMENT Teacher's Chart

| Student name | Change of State | | Hardness | Water Use and Water Quality | | | |
|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2 | 3a | 3b | 3c | 4 |
| | explains effect of freezing water | explains how water evaporates | describes how flowing water dissolves materials | lists five uses of water in the home | circles which household use requires quality water | explains why | describes two tests for detecting dissolved materials |
| 1 | | | | | | | |
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| 24 | | | | | | | |

*Figure 8-6. Teacher's assessment chart from the third/fourth-grade module* Water *(FOSS)*

# Introductory Questionnaire

**Materials**

*For each student:*

- Introductory Questionnaire
- extra paper if desired

**NOTE**

With the exception of words identified in italics, this is an assessment of understanding and experience, not an assessment of technical vocabulary. Note which students are having trouble with the language of the questionnaire. They may need extra help throughout the module.

## Advance Preparation

- Make copies of the Introductory Questionnaire for each student.
- The questionnaire is intended as a written assessment; however, if you have students with special needs or limited English facility, you are encouraged to translate, paraphrase, or replace it with an interview .
- Familiarize yourself with the questions so as to be able to elaborate on them if students have trouble with particular words.

## Evaluating the Introductory Questionnaire

Guidelines to code the level or depth of knowledge the student has about a concept or skill.

5 – a complete and correct response.

4 – an essentially correct response but one that omits some detail(s), or underlying explanations, or contains a slight inaccuracy.

3 – a response that is wrong or skimpy simply because the student does not know the concept or information.

2 – a naive conception: a response that is logical and coherent, and explains the data from the student's point of view, but happens to be scientifically wrong. There are many examples in history, such as the flat-earth theory. Note that this is different from an error that is made through mere lack of information.

1 – a naive, childish answer, or one that repeats the question.

0 – no answer, or "I don't know."



*Figure 8-7. Rubric for evaluating the introductory questionnaire in an Insights module*

## Assessing the Science Program

In addition to assessing individual student progress with the new curriculum, school districts need two different kinds of information to assess the overall success of the science program. The first, and by far the most challenging to acquire, is information about whether the science program is resulting in significant changes in teaching and in student learning. The National Science Education Standards address this issue and acknowledge the difficulty in gathering this information, which needs to include the assessment of student knowledge and skills over time as well as changes in students' attitudes toward science. The second kind of information that school districts need is a measure of how they are progressing in their efforts to address each of the five elements of science education reform: curriculum, professional development, materials support, assessment, and administrative and community support.

George Hein, director of the Program Evaluation and Research Group at Lesley College in Cambridge, Massachusetts, and evaluator of the National Science Resources Center's (NSRC) Elementary Science Leadership Institute program, developed five rubrics that districts can use to assess the progress of their science programs (Figure 8-8). Each rubric corresponds to one of the elements of an effective elementary science program. The rubrics begin at level 0 (no action has been taken) and end at level 5 (complete implementation). Levels 2 through 4 describe the sequence typically followed in establishing a science program: developing a plan, initiating a small-scale reform effort, and expanding this effort each year.

Hein, Carol Baldassari, and Laura Hudson used the rubrics to determine the progress that school district teams that have attended the NSRC Leadership Institutes have made and to find out the paths they followed during their reform efforts. By interviewing each team and applying the rubrics to the responses, Hein and his colleagues determined that assessment has been the most difficult element to implement. Curriculum development and professional development have been easier to incorporate and have usually been done first. Establishing a materials support system has been accomplished as funding and administrative support have permitted.

## Five Rubrics Used to Assess the Progress of Science Programs

### Levels of Curriculum Reform

*Level* 0 Totally textbook-dominated program, no materials.

*Level* 1 Some (any) inquiry-centered science curriculum units based on individual school (or teacher) decision.

*Level* 2 District piloting inquiry-centered science curriculum units in part of system, with textbooks still dominant.

*Level* 3 Districtwide plan exists to introduce inquiry-centered science curriculum into entire system and/or early stage of implementation.

*Level* 4 Considerable progress in implementing inquiry-centered science curriculum units in entire system and/or evidence that texts are no longer used or are used primarily as supplements.

*Level* 5 Systemwide implementation of inquiry-centered elementary science program.

### Levels of Professional Development Activities

*Level* 0 No teacher professional development program.

*Level* 1 Professional development program limited to introduction of hands-on science curriculum units to some teachers.

*Level* 2 A plan for professional development for all teachers and/or beginning of development of teacher leaders exists. Evidence of other activities (workshops, museum, college connections).

*Level* 3 Implementation of first-level workshops for most or all teachers in the district. A plan for advanced professional development activities for teacher leaders exists. Ongoing classroom support for up to one-half of teachers in district.

*Level* 4 Implementation of first-level activities for all teachers and provision for advanced professional development for all teachers. Evidence of systematic connection between district activities and opportunities at other institutions (museums, colleges, etc.). Ongoing classroom support for most teachers.

*Level* 5 Funded, coherent, continuous system for staff development articulated with developmental needs of all teachers, curriculum implementation, assessment, and other professional development activities.

*Figure 8-8*

### Levels of Development of Centralized Materials Support Systems

*Level* 0 No plans for a materials support system.

*Level* 1 Recognized need for a materials support system for science, chose school-based or individual teacher responsibility, or began planning for center, but plans aborted.

*Level* 2 Temporary system that includes ordering and refurbishing materials and supplies for pilot classrooms or schools, or in the planning stage for districtwide system.

*Level* 3 Beginning to implement systemwide materials support system, but current system only partial: insufficient staffing, funding, etc.

*Level* 4 Established districtwide materials support system.

*Level* 5 Integrated districtwide math/science materials and professional development center; a functioning "teacher center."

### Levels of Student Assessment

*Level* 0 No change, no plan for change.

*Level* 1 Studying the issue, planning, changes driven by outside forces (new state mandates).

*Level* 2 Some use of alternative assessment strategies in individual schools or by teachers using inquiry-centered curriculum materials. Policy of acquiring curriculum materials that incorporate active assessment strategies.

*Level* 3 Systematic professional development on assessment and/or teachers developing active assessments.

*Level* 4 Initiating systemwide implementation of active assessment tied to grading practices and substituting for traditional, test-based grades.

*Level* 5 Complete implementation of districtwide active science assessment, and/or new science assessment is part of large districtwide assessment plan.

*continued on next page*

## Five Rubrics Used to Assess the Progress of Science Programs *continued*

### Levels of Partnership Activities

*Level* 0 No stakeholders from the community, including scientists or engineers, are working with the district for the sole purpose of supporting its science program.

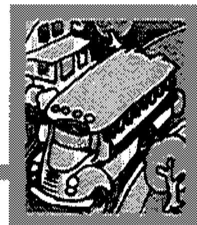
*Level* 1 Some stakeholders (scientists, engineers, parents, etc.) have been identified, and relationships between them and teachers or principals in some schools have been initiated. Their purposes may vary, or their involvement may be short-term or event-specific.

*Level* 2 Through a formal structure, district seeks to coordinate existing disparate efforts or to involve new institutions as partners to support the inquiry-centered science program.

*Level* 3 Partial plan for district, corporate, and/or university partnerships has been created and first steps have been initiated.

*Level* 4 District develops comprehensive plan with partners to secure community support and financial assistance for systemic reform.

*Level* 5 Plan is implemented and maintained.




- New assessment strategies are needed for inquiry-centered science, because traditional tests cannot assess the wide range of learning that takes place.
- Key strategies include pre- and post-module assessments, embedded assessments, prediction activities, and final assessments.
- If teachers are clear about the objective of an assessment, they will understand why a particular type of assessment is being used. For example, if a teacher wants to know whether students have learned how to design an experiment, an appropriate assessment would be to ask them to solve a problem through experimentation.
- Five rubrics—one for each element of the science program—can help school districts assess the progress they are making in improving their elementary science programs.

## For Further Reading

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