Workshop I | Workshop II | Workshop III | Workshop IV | Workshop V

Assessing for Learning Facilitator's Guide

WORKSHOP IV: ASSESSING SCIENCE IDEAS

A Professional Development Curriculum from the Institute for Inquiry®

The fourth in a set of five workshops for teacher professional development

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You can download your own copy of this guide at www.exploratorium.edu/ifi/assessing. A wealth of background material, for this and the other guides in the series, can be found at www.exploratorium.edu/ifi/library.

In order to access these materials, you will need Macromedia Flash Player 5 or higher and Adobe Acrobat Reader 4 or higher, available for free downloading at www.exploratorium.edu/ifi/help. These plug-ins may require additional memory.

You can download any of the ASSESSING FOR LEARNING workshop guides at www.exploratorium.edu/ifi/workshops.

Assessing Science Ideas

Welcome

Welcome to *Assessing Science Ideas*, the fourth workshop in the ASSESSING FOR LEARNING series. The five workshops in this series introduce formative assessment and offer ways for teachers to begin applying elements of formative assessment in their own classrooms.

This five-part curriculum is designed to be presented in sequence and in its entirety. To help facilitators review key concepts that pertain to the entire curriculum, each workshop guide contains a section on the basics of formative assessment.

Created by British educator and author Wynne Harlen in collaboration with the staff of the Exploratorium Institute for Inquiry in San Francisco, this curriculum has been offered to science educators and professional developers since 1996.

In 2000, the National Science Foundation asked that the Institute for Inquiry make these workshops available to even more educators. The result is a series of guides that provide step-by-step instructions and access to support materials online so that professional developers and teacher educators can present these workshops on their own.

LYNN RANKIN
Director
Institute for Inquiry

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Acknowledgments

ASSESSING FOR LEARNING is based on original work by British educator and author Wynne Harlen in collaboration with the Exploratorium's Institute for Inquiry in San Francisco. Formerly Director of the Scottish Research Council, Dr. Harlen has spent the last thirty years involved in research on assessment and student learning in primary science education. Her books, including *The Teaching of Science in Primary Schools; Primary Science: Taking the Plunge;* and *Teaching, Learning, and Assessing Science 5–12,* are used by educators throughout the world. Since 1996 she has been the primary presenter of a five-day series of workshops on formative assessment at the Institute for Inquiry. The core ideas and activities from those workshops, as well as Dr. Harlen's original drafts of this document, form the basis for these guides.

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ABOUT THIS WORKSHOP

- **The Workshop in Context**
- **Workshop Overview**

The Workshop in Context

Assessing for Learning

Assessing Science Ideas is the fourth of five workshops in the Assessing for Learning curriculum. The workshops in this curriculum are designed to be used sequentially so that participants work step-by-step toward a full understanding of formative assessment. All five workshops take as their starting point the Formative Assessment Basics, introduced on page 10 of this guide and available in each of the five facilitator guides in this series.

The Assessing for Learning curriculum consists of the following workshops:

Workshop I: Introduction to Formative Assessment

Participants discover the purpose of formative assessment and find out how it differs from summative assessment (about 2 hours).

Workshop II: Assessing Process Skills

Participants learn how to observe and interpret students' use of the process skills of science (about 3 hours).

Workshop III: Effective Questioning

Participants identify questions that are useful for eliciting students' ideas and for encouraging the use of science process skills (about 2 hours).

Workshop IV: Assessing Science Ideas

Participants create indicators of development for specific scientific ideas and consider the nature of feedback that helps student learning (about 2 hours).

Workshop V: Student Self-Assessment

Participants investigate the value of students assessing their own and their peers' work and explore ways to communicate goals and criteria to students (about 2 hours).

How to Use the Curriculum

This curriculum is designed to be presented in sequence and in its entirety. If you decide to present less than the full curriculum, it's important to communicate this to participants, so they aren't left with the impression that they have been introduced to all the main ideas related to formative assessment. For example:

- Doing only Workshop I would be a good introduction to formative assessment, but would not offer teachers any practical strategies to implement in the classroom.
- Doing Workshops II, III, IV, or V alone would offer classroom strategies, but without the overview of formative assessment to put those strategies in context.
- Doing Workshop I following by one of the other workshops would provide an overview of formative assessment and a single strategy to implement it, but would give an incomplete picture of formative assessment practice.

Workshop Overview

A Quick Summary

Assessing Science Ideas is the fourth in a set of five guides in the ASSESSING FOR LEARNING curriculum. The guides are designed to help facilitators plan and present professional development workshops for educators interested in developing an understanding of formative assessment and how to begin to apply it in their classroom.

The first workshop in this series introduced the Formative Assessment Cycle, which provides the conceptual foundation for the curriculum.

This workshop takes participants through the parts of the Formative Assessment Cycle that relate to interpreting and using information about student ideas. As they write and draw in response to teacher assignments, students provide important clues about the developmental level of their ideas on particular topics. By carefully interpreting the clues contained in student work, teachers can better understand student thinking, and use this information to help students learn more.

In order to do this, a teacher has to know what to look for in relation to the goal of a student's work. To help teachers focus on relevant features to determine the level of understanding a student has reached, and to help teachers decide what students' next steps might be, we introduce a set of generic developmental indicators of ideas. Like the developmental indicators of science process skills introduced in Workshop II, *Assessing Process Skills*, these indicators show increasing levels of sophistication in how students think about scientific ideas. They show, for instance, that students' ideas typically develop:

- from a level where they can only describe rather than explain a phenomenon
- to a level where they can explain a phenomenon using relevant ideas
- to a level where they can apply ideas encountered in one setting to another.

This general framework can be applied to any topic by considering the relevant ideas.

Having decided on next steps for learning, participants then consider how to communicate those goals to students, and examine ways to help students take those steps. In the classroom, giving effective feedback is crucial, whether written (marking) or oral (conferencing). There are simple guidelines teachers can follow to help ensure that the feedback they give students will assist them in taking the necessary next steps in learning. But giving feedback can be time consuming, so participants also explore ways to make it manageable in practice.

Goals

- **To give teachers experience in interpreting evidence of the development of ideas from students' writings and drawings.**
- **To equip teachers with the means for designing next steps for students to take in further developing their ideas.**

The Goals of the Workshop

One of the overall aims of the ASSESSING FOR LEARNING curriculum is to help teachers understand formative assessment as a recurring cycle of events. Information about the Formative Assessment Cycle is provided in

the Formative Assessment Basics section of this guide, which begins on page 10.

The Formative Assessment Cycle, presented in detail in Workshop I of this series (*Introduction to Formative Assessment*), begins with the collection of evidence relating to the science goals of student work. By interpreting that evidence, a teacher can determine students' current levels of understanding or abilities relating to science goals, decide what next developmental steps to take to achieve those goals, and finally, determine how to help students take those next steps.

This workshop—*Assessing Science Ideas*—focuses on ways teachers can identify a student's level of development in understanding science ideas, and offers strategies for helping students further their development of science ideas.

How the Workshop Works

This workshop takes about two and a half hours and is designed to be led by one facilitator, although you may prefer to have two facilitators working together. Typically, planning takes about four hours, not including the time necessary to prepare materials. In this guide, we list materials for 36 participants. For fewer participants, quantities of materials and other workshop logistics can be adjusted as needed.

We recommend 12 to 36 participants for our workshops. Having fewer than 12 does not allow for the lively group interaction that is such an important component of the workshop. Having more than 36 makes whole-group discussions unwieldy and can necessitate an additional facilitator.

At the beginning of this workshop, the facilitator introduces the workshop, shows a sample of student work, and models how a teacher can use generic indicators of the development of student ideas as the basis for creating specific indicators that relate to the topic being studied. The facilitator also offers examples of actions a teacher can take to help students take next steps in learning. Participants then work in pairs interpreting other examples of student work.

Take-Home Messages

- It's important to be able to identify evidence of understanding in students' work before making interpretations.
- Behavioral indicators of development for specific ideas can be identified from generic indicators and used to identify next steps in learning.
- Effective feedback to students should be nonjudgmental and indicate the next steps students should take to improve their learning.

Next, participants work in groups of three to compose written feedback on the student work they examined. Then, together, the whole group considers the distinction between, and efficacy of, "judgmental" versus "nonjudgmental" feedback. Participants consider and add to a list of the "do's and don'ts" of effective feedback.

In the last part of the workshop, participants share ideas about how to put what they have learned into practice in the classroom. The workshop concludes with a summary of the main pedagogical ideas introduced, as expressed by the take-home messages.

About the Take-Home Messages

The take-home messages are brief statements that convey the central pedagogical ideas encountered during the workshop. By introducing the messages early on, facilitators set the context for what is to follow, and inform participants of the purpose and content of the

workshop. This transparency of purpose is an important initial step in establishing an atmosphere of trust between facilitators and learners. Such trust is critical in creating a climate in which learners feel comfortable expressing opinions and considering new ideas.

Understanding of the messages deepens as the workshop progresses, and as participants become intellectually engaged in building new ideas based on their firsthand experiences and their conversations with each other. The take-home messages are revisited at the end of the workshop as a way to summarize and reinforce the understandings participants have constructed.

FORMATIVE ASSESSMENT BASICS

- **The Inquiry Connection**
- **The Formative Assessment Cycle**
- **Additional Resources**

The Inquiry Connection

Formative Assessment and Learning Science through Inquiry

From their earliest years, children develop ideas about the world that make sense to them, but don't necessarily correspond to the scientific view. How do we help children develop their ideas into more scientific ones?

Experience and research show that merely teaching "correct" scientific ideas does not necessarily change students' understanding. Change is more likely to happen when students test their scientific ideas for themselves. Teaching through inquiry helps students test their existing ideas about scientific phenomena, consider alternative ideas, and gradually develop an understanding that is more consistent with evidence and with the scientific view of how things work. But students often need help with this process. Formative assessment gives teachers the means to help students express their ideas and rigorously test them.

In general, when students engage in science inquiry, they go through the following phases:

• They begin by observing and exploring materials, and they raise questions about their observations.

• They choose a question to investigate, and then plan and do an investigation to try to answer their question.

• During the course of the investigation, they come up with ideas to explain what they're seeing, and find ways to test those ideas.

• Finally, they interpret the results of their investigations and communicate those results to others.

In order to help students have productive inquiry experiences in which they express and test ideas that can lead to new scientific understanding, teachers need to check in and offer guidance in every phase of the process. To do their investigations, students must be able to ask questions that can be investigated. And in order for students to draw conclusions based on evidence, they need to be able to plan systematic investigations to gather that evidence. The teacher's role in this process is to find out how the student is doing in each phase, and help them make progress.

To know how students are doing, teachers need a way to "get into students' heads" and understand how they're thinking. Each of the above phases of inquiry is an entry point for the teacher to carry out assessment that will provide information on how students understand science concepts, and on how effectively they are using the process skills of science (such as observing, questioning, planning, interpreting and communicating). The teacher can then use this information to determine what next steps students need to take in order to increase their understanding of science concepts and improve their ability to use the process skills of science. The teacher can then guide students in ways that will help them take next steps in learning.

Ideas about Formative Assessment

"Ideas about assessments have undergone important changes in recent years. In the new view, assessment and learning are two sides of the same coin. . . . When students engage in assessments, they should learn from those assessments."

National Research Council, *National Science Education Standards.* (Washington, DC: National Academy Press, 1996), pp. 5–6.

But of course it is the students who do the learning—and the more they are aware of the learning goals of their activities, the more they are able to recognize for themselves how to make progress. Part of the teacher's role, then, is to share goals with students, provide them with skills and opportunities for assessing their own progress, and help in deciding their next steps. All these aspects of teaching—gathering information about students' learning, interpreting it in terms of their progress, using it to decide next steps, feeding back to students how to move forward, and helping students understand the goals of their work and assess their own progress—are encompassed in the concept of formative assessment, and form the basis for the ASSESSING FOR LEARNING curriculum.

While formative assessment is essential when teaching science through inquiry, this powerful teaching strategy can also be applied effectively to all science teaching approaches (as well as any other curricular topic). Because formative assessment involves periodically checking students' current understanding during—rather than after—instruction, it provides useful information which allows teachers to tailor their teaching to a single student's, or a whole class's, specific needs. Using assessment to inform teaching is important in any instructional approach. However, it is critical to inquiry, in which students are raising questions and designing investigations to test their own ideas. Teachers must assess progress at every step of the investigation in order to ensure that their investigations are sound enough for students to draw useful conclusions that help them more fully develop their scientific ideas.

Assessment and Inquiry

"Assessments have become more sophisticated and varied as they have focused on higher-order skills. Rather than simply checking whether students have memorized certain items of information, new assessments probe for students' understanding, reasoning, and use of that knowledge—the skills that are developed through inquiry."

National Research Council, *National Science Education Standards.* (Washington, DC: National Academy Press, 1996, p. 6.

The Formative Assessment Cycle

Overview

Assessment is part of every teacher's job. The type of assessment teachers are most familiar with—in which they examine students' work in order to determine grades, write evaluations, compare levels of achievement, and make decisions about promotion—is called *summative assessment.*

In doing *formative assessment*, teachers also examine and evaluate students' thinking—but in this case, they do so in order to make pedagogical decisions for the purpose of helping students get closer to learning goals. Teachers use the information they gather about student work to determine what students need to do next that will help them progress toward the goals of the lesson.

The value of this kind of assessment is attested to not only by individual teachers who have used it effectively in their classrooms, but also by a significant body of research, as the sidebar at right, "Research on Formative Assessment," indicates.

Research on Formative Assessment

"In a review of research on assessment and classroom learning, Black and Wiliam [Black, P. J., and D. Wiliam. 1998. 'Assessment and Classroom Learning.' *Assessment in Education.* 5 (1) 7–74, 1998.] identified and analyzed 250 studies comparing classrooms where formative assessment was and was not practiced. This revealed striking evidence that, on almost every kind of academic measure, students whose teachers systematically applied formative assessment techniques outperformed similar students who did not receive such treatment. These differences were significant, both statistically and educationally.

"There was also evidence that the gain was greatest for lower-achieving students. This exhaustive study leaves the reader convinced that the improvement of formative assessment practices in United States classrooms might be the closest thing to the elusive 'magic bullet' that education reformers might find."

Wynne Harlen. *Enhancing Inquiry through Formative Assessment.* (San Francisco: Exploratorium, 2003) pp. 7–8.

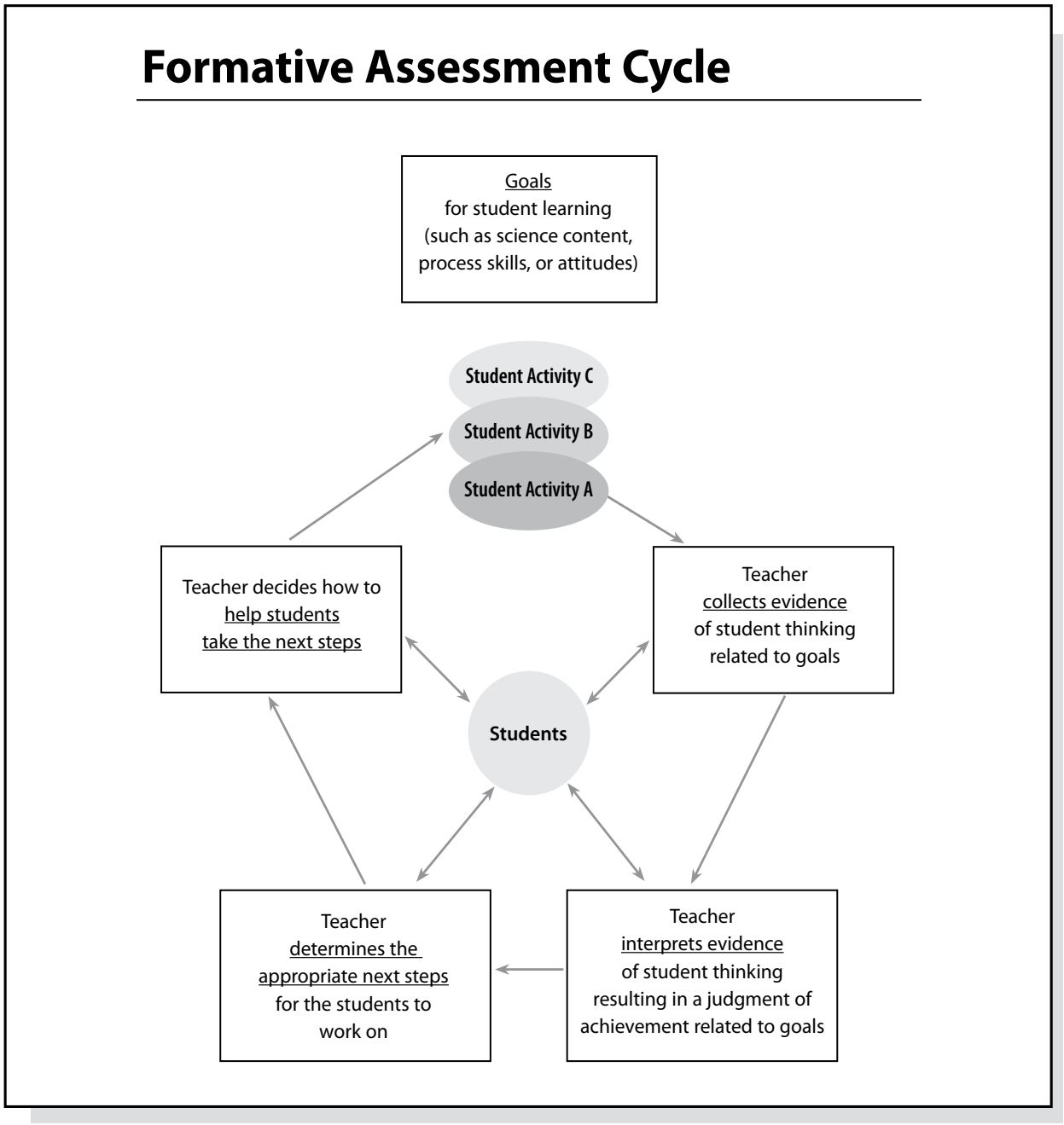
The Formative Assessment Cycle

It's useful to think of what teachers (and students) do in formative assessment as a cycle of events, as shown in the diagram on the next page and on M1. If you follow the diagram clockwise, you'll be able to see how the process can bring students ever closer to the learning goals.

Before instruction begins, the teacher decides what the learning goals will be. These goals, shown at the top of the diagram, can be scientific attitudes, conceptual ideas about science content, or science process skills, since all are important in science instruction.

The teacher also chooses an initial learning activity (represented in the diagram as Activity A) meant to begin the process of helping students achieve the learning goals. Although the teacher can have plans for subsequent activities students might do to reach these goals, it's important to remain flexible. Information gathered and interpreted in the course of formative assessment may suggest ways of modifying plans so they more effectively address goals.

Teacher Collects Evidence Relating to Goals. During the initial activity (Activity A), the teacher collects evidence of students' thinking in relation to the goals. The teacher can gather evidence in many ways, such as by watching students as they work,



questioning them, or by asking them to communicate their understanding through writing or drawing.

Gathering evidence should be an integral part of any lesson. Lessons may already include opportunities to elicit the use of certain process skills or the application of specific scientific ideas, or the teacher may need to plan something especially for this purpose. Planning may involve deciding, for instance, what questions to ask in order to encourage the kinds of thinking and learning intended in a particular activity.

Lesson preparation that includes plans for eliciting student thinking in relation to the learning goals has a double benefit. First, it ensures that students use and develop process skills and scientific ideas; and

"One teacher, in planning a lesson on simple circuits, decided to have the students draw on the whiteboard all the circuits they tried to construct, both those that did and those that didn't work. This form of communication gave her an immediate picture of the way the students' ideas were developing and enabled her to work with those who were unsure and needed help understanding what is essential in a complete circuit."

Wynne Harlen. *Enhancing Inquiry through Formative Assessment.* (San Francisco: Exploratorium, 2003) p. 22.

second, it gives teachers opportunities to assess the development of those skills and ideas. In this way, teaching and assessment are closely intertwined.

Teacher Interprets Evidence. Once evidence of student work has been gathered, the teacher needs to interpret that evidence to find out how students are progressing toward their learning goals. In order to do this, the teacher considers more than just the extent to which the student has reached the learning goal, but also the student's experience, past achievements, recent progress, and the effort the student has made. The teacher's interpretation is then student-referenced, allowing the teacher to match next steps with the needs of the individual student.

A classroom teacher asked her students to draw a picture of a crayfish, label the parts, and describe the function of each. She wanted to see how her students used their process skills of close observation, and to elicit their understanding of structure and function. One student's drawing labeled only the legs, but distinguished between those used for movement and those used for feeding. Despite the fact that the student's work was incomplete, the teacher saw it as an indication that he had observed very closely and understood issues of structure and function. For the teacher, this was a sign of improvement, since the student had not been able to focus well in previous observations.

—Institute for Inquiry

Teacher Determines Appropriate Next Steps. The process of interpreting evidence leads the teacher to arrive at a judgment about where students are in relation to the learning goals. In the diagram, the phrase "judgment of achievement" in the lower right-hand box refers to what the teacher thinks a student knows in relation to goals, and not how well the student is doing.

Once this judgment has been made, the teacher determines the developmental steps students need to take next in order to increase their understanding of scientific ideas, improve their science process skills, or enhance their scientific attitudes.

In a third-grade classroom, students were investigating the effects of water on plant growth: they had given different amounts of water to similar plants in various places around the room. The teacher decided that the next step was to have her students think about how to choose which condition to keep the same (such as the location of the plants) in order to make their experiment a "fair test."

—Institute for Inquiry

Teachers are accustomed to drawing on their experience to decide what would help students who show varying degrees of mastery. But there are also a number of sources that can help teachers consider the developmental progression of certain scientific ideas and process skills. For more information, see the Additional Resources on page 17.

It is this iterative process that distinguishes formative assessment from other kinds of assessment. Here, information about student achievement is gathered and interpreted and used to help make the next instructional decision.

In order to help her students plan for a "fair test," a third-grade teacher asked her students how they could tell if differences in plant growth were due to differences in the amount of water each plant received, or to where the plant was located. The students responded by deciding that it would be important to keep all the plants in the same place. That way, they reasoned, they could test for the effect of watering without being confused by the effects of light or heat from different locations.

—Institute for Inquiry

For instance, if a teacher is trying to help further develop students' conceptual ideas, useful strategies include helping students test their existing scientific ideas, providing access to more scientific ideas than they currently have, and enhancing communication and reflection. Teachers can help students design experiments and investigations to test their ideas. They can give students reference materials, or introduce them to alternative, more scientific ideas and support them in thinking about those ideas. And they can set up situations in which students work together to create explanations of scientific phenomena they encounter in experiments and investigations.

About the Student's Role in the Formative Assessment Cycle

Students are at the center of the Formative Assessment Cycle because they play a central role in formative assessment. Every action a teacher takes during the cycle involves interactions with students.

In addition to teachers evaluating and supporting student progress toward learning goals, students can also take action on their own behalf. When students know about the goals of instruction, they can give the teacher evidence about their own understanding in relation to those goals. The more students can take on the role of self-assessment, the more they can move toward being able to decide their own next steps.

Student Self-Assessment

"Student participation is a key component of successful assessment strategies at every step. If students are to participate effectively in the process, they need to be clear about the target and the criteria for good work, to assess their own efforts in light of the criteria, and to share responsibility in taking action in light of the feedback."

National Research Council. *Classroom Assessment and the National Science Education Standards*. (Washington, DC.: National Academy Press, 2000) p. 1.

Additional Resources

These resources can provide valuable information about formative assessment to facilitators and participants alike.

- ❑ Black, Paul, and Dylan Wiliam. "Inside the Black Box: Raising Standards through Classroom Assessment." Online article available at www.pdkintl.org/kappan/kbla9810.htm.
- ❑ Black, Paul, Christine Harrison, Clare Lee, Bethan Marshal, and Dylan Wiliam. *Working Inside the Black Box: Assessment for Learning in the Classroom.* London: King's College Department of Education & Professional Studies, 2002. Particularly useful for Workshops III, IV, and V.
- ❑ Harlen, Wynne. "Encouraging and Handling Children's Questions." Chapter 13 in *The Teaching of Science in Primary Schools.* London: David Fulton Ltd., 2000. Particularly useful for Workshop III.
- ❑ Harlen, Wynne. *Enhancing Inquiry through Formative Assessment.* San Francisco: Exploratorium, 2003. This monograph sets out research evidence and theoretical points to make the case for using formative assessment in inquiry science teaching. Available online at www.exploratorium.edu/ifi/resources/harlen_monograph.pdf.
- ❑ Harlen, Wynne. *Teaching, Learning & Assessing Science 5–12.* London: Sage Publications, 2006. This book presents a theoretical rationale for why science should be taught in constructivist ways. Chapters 7–12 offer an explanation of the role formative assessment plays in that type of teaching.

In addition to the resources above, the publications listed below can offer support for teachers interested in further information on science education standards and the developmental progression of science ideas and process skills at different grade levels.

- American Association for the Advancement of Science. *Atlas of Scientific Literacy.* Washington, DC: American Association for the Advancement of Science and the National Science Teachers Association, 2001.
- American Association for the Advancement of Science. *Benchmarks for Science Literacy.* New York: Oxford University Press, 1993.
- National Assessment of Educational Progress (NAEP). "The NAEP Science Achievement Levels." National Center for Education Statistics (NCES), 2002. http://nces.ed.gov/nationsreportcard/science/achieveall.asp.
- National Research Council. *National Science Education Standards.* Washington, DC: National Academy Press, 1996.

PLANNING AND PREPARATION

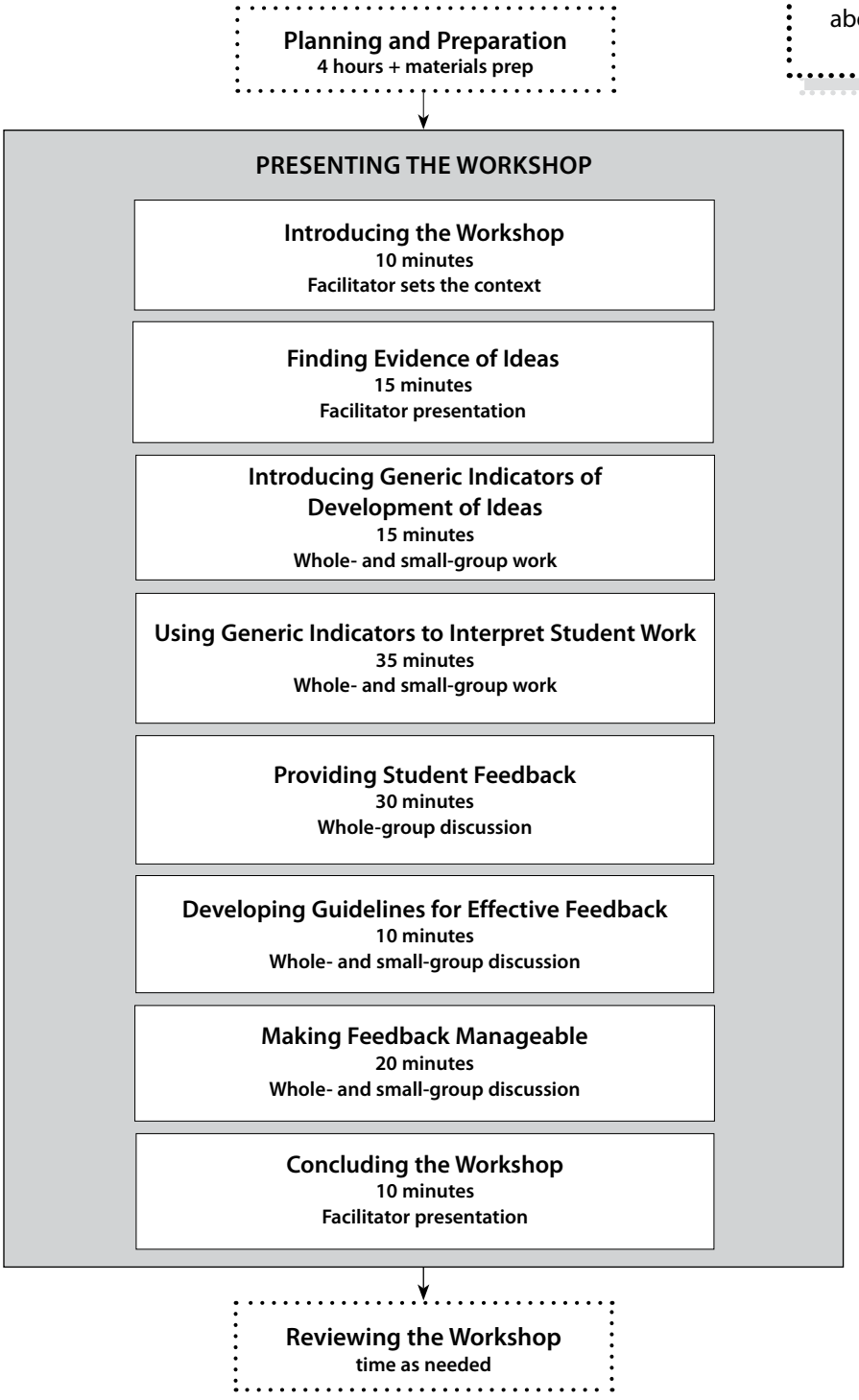
- **Workshop at a Glance**
- **Essential Planning Steps**
- **Charts, Overheads, and Handouts**
- **Materials and Equipment**

Workshop at a Glance

Facilitators needed: 1–2

Participants accommodated: 30–36

Time to present the session: about 2.5 hours



Essential Planning Steps

Planning Time Needed

Typically, planning takes about 4 hours, not including time to gather and prepare materials and equipment.

Overview

The *Assessing Science Ideas* workshop requires a good deal of planning and preparation. Below you'll find step-by-step instructions, divided into three categories: Before the Workshop, On the Day of the Workshop, and After the Workshop.

The workshop requires one facilitator, although you might choose to have two and divide up the steps. If two facilitators will be presenting the workshop, it's important to go over these steps together, arriving at a shared understanding of workshop goals. There's a lot to do, including reading through this entire guide, preparing to lead discussions, trying the workshop yourselves as if you were participants, arranging for an appropriate space, and preparing charts and handouts.

You'll also want to set aside time after the workshop to talk with your co-facilitator about what went well and what could be improved for subsequent workshops.

Before the Workshop

1. Read this guide all the way through. It is essential for you to read through this guide before doing any of the other planning steps. You may want to flag sections that don't make immediate sense to you, coming back to them as the goals of the workshop become clearer.

2. Become familiar with the formative assessment basics. Review the Formative Assessment Basics section (page 10). This is the foundation of the entire curriculum.

3. Prepare materials. Gather and organize all materials (see the complete list on pages 23–24).

• Prepare the handouts, charts, and overheads, and organize them in the order in which you will use them during the workshop. Masters start on page 46. They are identified with the letter *M* and numbered in order of use.

• Study the list of Additional Resources on page 17, deciding what you might want to copy for distribution at the end of the workshop.

An Important Note from the Institute for Inquiry

This workshop is the result of many years of development with educators across the country. While its format may seem adaptable, using it in ways other than those described here will not only change the participants' experience, but the outcome as well. We recommend becoming familiar with the planning and presentation of the workshop and experiencing its intended results before considering any adaptation.

4. Do the workshop as learners. Meet with your co-facilitator, if there is one, and go through the workshop as if you were participants.

Do all the same tasks workshop participants will be asked to do. This will help you better understand the kinds of responses they will give, the kinds of problems that could come up, and the kinds of questions people may ask.

5. Go over the workshop as facilitators. Go through the workshop again, this time as facilitators. If there

will be more than one facilitator, decide which sections and tasks each facilitator will be responsible for.

A Note About Scripts

Many of the steps in this guide contain scripted information, set in italic type and marked with gray arrows. The scripts are intended to illustrate one way of presenting information and instructions to workshop participants. While the content of the scripts is crucial, the exact wording is not. After thoroughly familiarizing yourself with the scripts and noting the important points, you may decide to convey the information in your own words rather than reading the scripts to participants word for word.

6. Familiarize yourself with each step. Be sure you understand the purpose of each section and each discussion. Keep the take-home messages (M2) in mind as your overall guide. These messages express the pedagogical ideas participants should take away from the workshop.

Note that four workshop sections— Finding Evidence of Ideas (page 28), Introducing Generic Indicators of Development of Ideas (page 30), Using Generic Indicators to Interpret Student Work (page 32), and Providing Student Feedback (page 34)—are particularly demanding and require careful preparation.

- Finding Evidence of Ideas (page 28) asks a facilitator to model the process of examining a sample of student work, creating indicators of development for the ideas in the work, using them to interpret the work, and suggesting possible actions the teacher could take to help students take next steps in learning. This presentation will be most effective if the facilitator knows the material thoroughly and has rehearsed to make the presentation as succinct as possible.

- In Using Generic Indicators to Interpret Student Work (page 32), participants try out the process that has just been modeled. Again, you'll need to know the work thoroughly and practice interpreting it as the participants would to anticipate possible responses.

- Providing Student Feedback (page 34) asks the facilitator to distinguish judgmental from nonjudgmental teacher comments. Read this section carefully so you'll feel confident that you can recognize each kind of comment.

7. Be prepared to set the context. Setting the context for the workshop is crucial. The facilitator who introduces the workshop should study the script in Steps 1 and 2 of Introducing the Workshop (page 26), and practice presenting this information.

- The facilitator should also be prepared to relate this workshop to district goals, standards, and other professional development activities.

8. Plan time and space carefully. You'll need a space large enough for 30–36 participants to work together comfortably. You'll also need a place to post charts so all can see, and/or a blank wall for projecting overheads.

- Create a detailed schedule for facilitators to refer to during the workshop. Note the beginning and ending times for each step (e.g., Set context & distribute handouts, 9:00–9:05; Explain how workshop relates to goals and standards, 9:05–9:10).

- Prepare a simplified version of the schedule for participants, which you can post at the beginning of the workshop. A sample schedule is shown on the following page.

Sample Schedule for Participants

9:00–9:10	Introducing the Workshop
9:10–9:25	Finding Evidence of Ideas
9:25–9:40	Introducing Generic Indicators of Development of Ideas
9:40–10:15	Using Generic Indicators to Interpret Student Work
10:15–10:45	Providing Student Feedback
10:45–10:55	Developing Guidelines for Effective Feedback
10:55–11:15	Making Feedback Manageable
11:15–11:25	Concluding the Workshop

On the Day of the Workshop

1. Prepare the room. Set up your equipment and put handouts, charts, and overheads where you'll have access to them when you need them.

2. Watch your schedule. Refer to the schedule you created (see Step 8, above) to keep the workshop on track.

After the Workshop

You and you co-facilitator (if there is one) should take some time to reflect on your experiences. Issues of logistics, communication, outcomes, and expectations can be addressed at this point. The Facilitation Review (page 42) will allow you to assess the results of your work and identify successes and challenges that can help guide subsequent workshops.

Charts, Overheads, and Handouts

Masters begin on page 46. They are identified by the letter *M* (for Master) and are numbered in order of use. Note that some masters will be used as both handouts and charts or overheads.

Charts or Overheads You can prepare these as either large charts or overheads. If you have access to a copy machine that can enlarge to poster size, enlarge these masters 400% to create charts that are 34" x 44". Otherwise, hand-copy the masters onto chart paper or poster paper approximately the same size. If you prefer to use an overhead projector, masters can be copied onto transparencies.	**Master Available on Page**
❑ The Formative Assessment Cycle (for Introducing the Workshop)	M1
❑ Take-Home Messages (for Introducing the Workshop and Concluding the Workshop)	M2
❑ Student Work Samples: Sound (for Finding Evidence of Ideas)	M3
❑ Comparing Generic and Specific Indicators of Ideas (for Introducing Generic Indicators of Development of Ideas)	M4
❑ Student Work Sample: Solar House with Newspaper (for Providing Student Feedback)	M8
❑ Student Work Sample: Solar House with Tin Foil (for Providing Student Feedback)	M9

Handouts Photocopy one handout for each participant.	**Master Available on Page**
❑ The Formative Assessment Cycle (for Introducing the Workshop)	M1
❑ Take-Home Messages (for Introducing the Workshop and Concluding the Workshop)	M2
❑ "Student Work Samples: Sound" (for Finding Evidence of Ideas and Introducing Generic Indicators of the Development of Ideas)	M3
❑ Comparing Generic and Specific Indicators of Ideas (for Introducing Generic Indicators of the Development of Ideas)	M4
❑ Student Work Sample: Crayfish (for Using Generic Indicators to Interpret Student Work)	M5
❑ Assessing Ideas Activity Sheet (for Using Generic Indicators to Interpret Student Work)	M6
❑ Effective Feedback Activity Sheet (for Providing Student Feedback)	M7
❑ Some Do's and Don'ts for Evaluating Student Work (for Developing Guidelines for Effective Feedback)	M10
❑ Developmental Indicators for Assessing Process Skills, Attitudes, and Concepts (for Concluding the Workshop)	M11a–c

Materials and Equipment

- ❑ Overhead projector and marking pens (optional)
- ❑ Flip chart
- ❑ Marker for recording on the flip chart
- ❑ Writing paper and pens/pencils for each participant

PRESENTING THE WORKSHOP

- **Introducing the Workshop**
- **Finding Evidence of Ideas**
- **Introducing Generic Indicators of Development of Ideas**
- **Using Generic Indicators to Interpret Student Work**
- **Providing Student Feedback**
- **Developing Guidelines for Effective Feedback**
- **Making Feedback Manageable**
- **Concluding the Workshop**

Introducing the Workshop

Overview

In this opening section, facilitators talk about the workshop's purpose, touch on how the Formative Assessment Cycle can serve as a framework for putting formative assessment into practice, and introduce the take-home messages, the central pedagogical ideas of the workshop.

This is also a time to explain how participants will be working together. Letting everyone know what they will be doing is an important step in building trust and demonstrating respect for the participants as learners. A respectful atmosphere is essential to fostering a free and open exchange of ideas.

Note that this part of the workshop refers back to the Formative Assessment Cycle introduced in the first workshop, *Introduction to Formative Assessment*. For more information on this cycle, which forms the foundation for this series, see the Formative Assessment Basics section in this guide, which begins on page 10.

5 Steps • 10 Minutes

1. Set the context by describing the workshop. Introduce yourselves and welcome participants. Then, in your own words, relate the following information:

▶ *This is the fourth of five workshops in the* ASSESSING FOR LEARNING *series. It's designed to further your understanding of formative assessment by interpreting and using evidence about students' scientific ideas.*

2. Post chart M1: "Formative Assessment Cycle" and distribute the corresponding handout. Say:

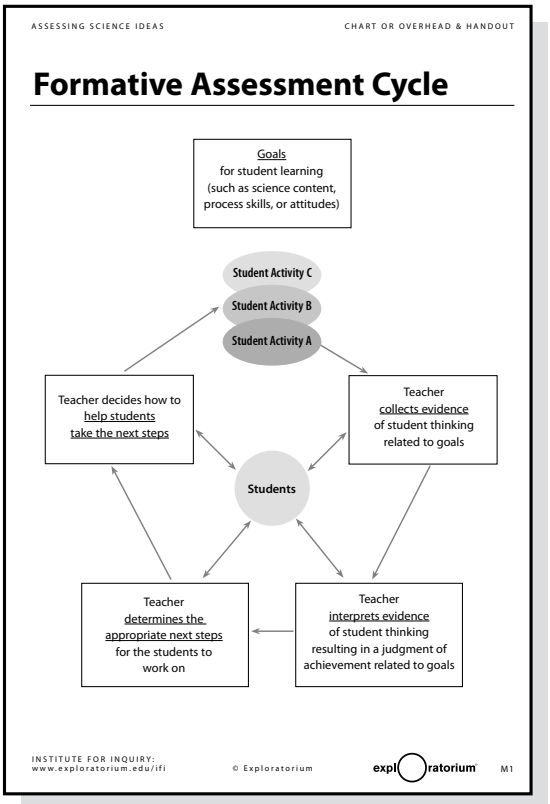
▶ *The first workshop in this series introduced the Formative Assessment Cycle. In the second workshop, we considered how observation could help teachers collect evidence of student's use of process skills.*

Call attention to the "collects evidence" part of the cycle. Then continue:

▶ *The third workshop focused on collecting evidence of student ideas by asking questions.*

Call attention to the "determines the appropriate next steps" part of the cycle. Then continue:

▶ *This workshop builds on the last, showing you how to help students develop*



M1

Materials Reminder

During this part of the workshop, facilitators will need to:

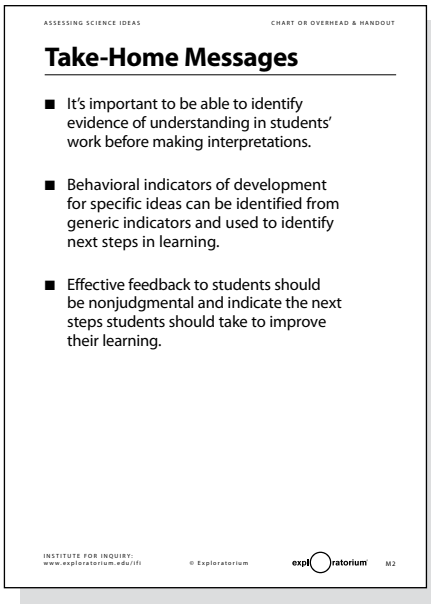
- **Post chart M1: "Formative Assessment Cycle" and distribute corresponding handout**
- **Post chart M2: "Take-Home Messages" and distribute corresponding handout**

their scientific ideas by helping them know how to take next steps. Once you find out what ideas students have, one of the most effective ways of helping students develop their ideas is by giving them feedback. Often, this is done by writing responses on their work.

In this workshop, we'll consider several pieces of student work, talking about how to analyze that work and respond to it in ways that most effectively advance student learning. Because analyzing and thoughtfully responding to student work is time consuming, we'll also discuss practical strategies for making this manageable.

3. Post chart M2: "Take-Home Messages" and distribute the corresponding handout. Tell participants:

► *Throughout the workshop, you'll be working to develop your own understanding of the pedagogical ideas these messages express.*


ASSESSING SCIENCE IDEAS CHART OR OVERHEAD & HANDOUT

Take-Home Messages

- It's important to be able to identify evidence of understanding in students' work before making interpretations.
- Behavioral indicators of development for specific ideas can be identified from generic indicators and used to identify next steps in learning.
- Effective feedback to students should be nonjudgmental and indicate the next steps students should take to improve their learning.

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M2

4. Explain how the workshop relates to your district's goals, standards, and other professional development activities for science education.

5. Tell participants that the workshop will take about two and a half hours. Also let them know if there will be a break.

Finding Evidence of Ideas

Overview

The first step in interpreting the development of students' ideas is to look carefully at their work.

Often, close reading of student work can yield evidence that is easily overlooked at a single reading. While it's not practical for teachers to carefully scrutinize every piece of work students create, this exercise shows how much evidence a teacher may find in student work. This evidence can then be used to interpret what students are thinking.

4 Steps ◆ 15 Minutes

1. Explain the process the group will be using for gathering evidence (5 minutes). Tell participants:

► *The first step in applying formative assessment to understanding student ideas is being able to identify the clues you can find in their work.*

Teachers have a great deal of written and drawn student work to look through. If they try giving attention to all of it, some pieces will inevitably be reviewed more quickly than others. As a result, it's easy to miss valuable information—especially when teachers look at many similar pieces. So it's useful, as a professional development activity, to practice ways of carefully scrutinizing student work before making judgments of it.

When examining student work closely, it's important to keep two things in mind:

• *the goals of the activity, and*

• *specific indicators that can provide clues to student development.*

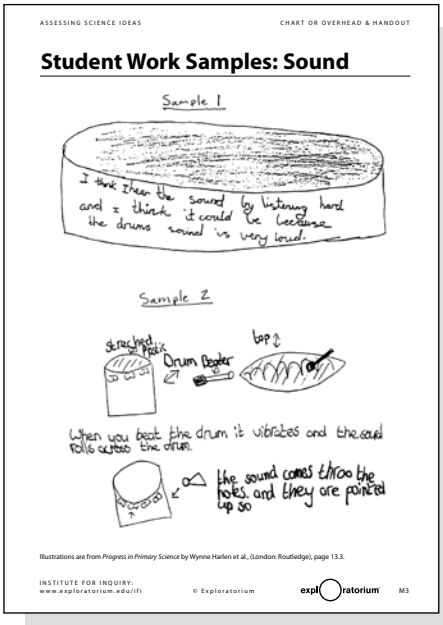
That's what we're going to do now. We'll look closely at several examples of student work and interpret them using a list of developmental indicators. Then we'll use those indicators to help decide what a student's next step in learning should be. Finally, we'll consider ways to help students take those next steps.

2. Post chart M3: "Student Work Samples: Sound" and distribute the corresponding handout (5 minutes). Tell participants:

► *Let's begin by looking together at some student work.*

These samples came from students in a mixed-age class (seven to nine years), who were being introduced to the topic of sound. The teacher provided some simple instruments and objects to use for making sound, and the students explored them over the course of a week before the formal activities began.

Because the teacher wanted to find out about the ideas her students already had about sound, she asked them to consider the sound made by a drum. Then she had them use drawings and writing to answer these two questions:


ASSESSING SCIENCE IDEAS CHART OR OVERHEAD & HANDOUT

Student Work Samples: Sound

Sample 1

I think I hear the sound by listening hard and I think it could be because the drums sound is very loud.

Sample 2

stretched plastic Drum Beater bop

When you beat the drum it vibrates and the sound rolls across the drum.

the sound comes throo the holes and they are pointed up so

Illustrations are from *Progress in Primary Science* by Wynne Harlen et al., (London: Routledge), page 13.3.

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M3

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Post chart M3: "Student Work Samples: Sound" and distribute corresponding handout**

1. How did their drums make sound?

2. How did they hear the sound?

The teacher wanted her students to understand that the sound came from vibrations, and that they heard the sound when the vibrations reached their ears.

3. Model a way to identify the evidence of ideas found in students' work (4 minutes). Tell participants:

► *In the first piece, by a younger student, there's a drawing of a drum.*

In this piece, there's a reasonable attempt to show that the drum is cylindrical. But notice that none of the parts are labeled, and the answers to the teacher's questions are expressed in terms of what "I think." The explanation of hearing is stated in terms of what the child does, not of what the sound does. It's almost as if she has to actively listen to make herself hear. Similarly, she explains the loudness of the sound as a property of the drum rather than as the result of anything being done to the drum.

The second sample has three drawings and more writing. In this piece, the student has labeled the parts of the drum. A second drawing showing just the top of the drum has wavy lines across it and shows the "beater." The words indicate that he thinks that "when you beat the drum it vibrates," so there is a connection between the beating and the vibration. There is a statement that "the sound rolls across the drum," but it's not clear what this means. The third drawing shows some decorative holes around the side of the drum. These are carefully drawn as if the shape is significant ("they are pointed up"), and the statement indicates that it's through the holes that the sound comes out of the drum.

4. Emphasize the need to closely analyze the work (1 minute). Explain to participants:

► *In this example, we've looked closely at two students' work, highlighting elements that were written or drawn by them. When we start looking at additional samples, the first step is to be aware of the significant elements contained in the student's work, to observe before interpreting, so an interpretation can be based on as complete a picture as possible.*

Introducing Generic Indicators of Development of Ideas

Overview

In this part of the workshop, participants examine the development of student ideas using a list of generic developmental indicators. They then learn how to use those generic indicators to create ones that are specific to the conceptual content of a particular activity.

Like the indicators used in Workshop II, which identified levels of student's abilities to use process skills, this workshop gives teachers a way to look at developmental levels in evaluating student ideas. These indicators help teachers in two ways:

• They help teachers focus on what to look for as evidence of where students are developmentally, and

• They show what the next level of learning looks like, so teachers can guide students in taking next steps.

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Post chart M4: "Comparing Generic and Specific Indicators of Ideas" and distribute corresponding handout**
- **Make sure participants still have handout M3: "Student Work Samples: Sound"**

5 Steps • 15 Minutes

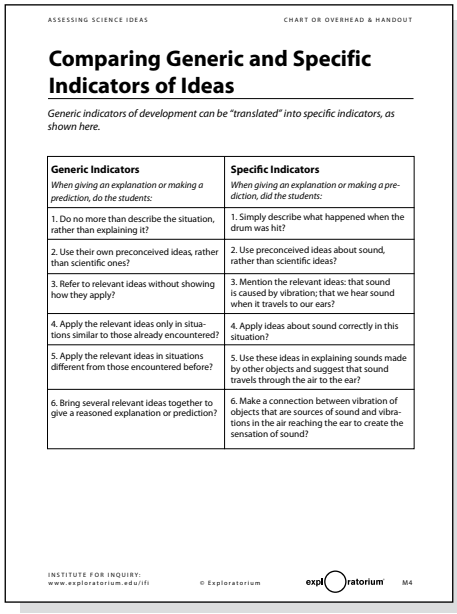
1. Post chart M4: "Comparing Generic and Specific Indicators of Ideas" and distribute the corresponding handout.

2. Introduce the idea of generic developmental indicators, and model how to apply them to specific activities (15 minutes). Explain:

► *Students show their ideas whenever they give an explanation or make a prediction. Because there is a general pattern in the way these ideas are expressed, we can use this pattern as indicative of developmental stages that can be broadly applied.*

These are generic indicators of development of scientific ideas. They are similar to the indicators of development of science process skills from Workshop II.

Like those, these indicators increase in sophistication from one to six and can be used both to help focus on what to look for and to help decide appropriate next instructional steps. They differ from the indicators of development of skills because these are generic. This is useful because it would be overwhelming to try to develop indicators for every topic individually; instead, this general framework can be applied to any topic.



ASSESSING SCIENCE IDEAS CHART OR OVERHEAD & HANDOUT

Comparing Generic and Specific Indicators of Ideas

Generic indicators of development can be "translated" into specific indicators, as shown here.

Generic Indicators *When giving an explanation or making a prediction, do the students:*	Specific Indicators *When giving an explanation or making a prediction, did the students:*
1. Do no more than describe the situation, rather than explaining it?	1. Simply describe what happened when the drum was hit?
2. Use their own preconceived ideas, rather than scientific ones?	2. Use preconceived ideas about sound, rather than scientific ideas?
3. Refer to relevant ideas without showing how they apply?	3. Mention the relevant ideas: that sound is caused by vibration; that we hear sound when it travels to our ears?
4. Apply the relevant ideas only in situations similar to those already encountered?	4. Apply ideas about sound correctly in this situation?
5. Apply the relevant ideas in situations different from those encountered before?	5. Use these ideas in explaining sounds made by other objects and suggest that sound travels through the air to the ear?
6. Bring several relevant ideas together to give a reasoned explanation or prediction?	6. Make a connection between vibration of objects that are sources of sound and vibrations in the air reaching the ear to create the sensation of sound?

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M4

Briefly, this framework shows that students' ideas develop from a level where they can:

• only describe rather than explain a phenomenon

• to a level where they can explain a phenomenon using relevant ideas

• to a level where they can apply ideas encountered in one setting to another.

Let's keep working with the student samples on sound we just looked at. But this time, let's see

how we can apply generic indicators to that specific activity. Then, we'll try using the generic indicators with another piece of student work.

3. Ask participants to refer to handout M4. Then explain:

▶ *On one side of this handout is a list of six generic criteria that indicate the development of student ideas. On the other are the same indicators "translated" into more specific criteria for the sound examples we just looked at.*

Let's read through the handout, linking the specific indicators to the generic indicators.

4. Read handout M4 aloud, comparing the specific indicators to the generic indicators. As you read through the generic list, link each one to the corresponding indicator on the specific list. Point out how the specific indicators can be "translated" from the generic indicators.

5. When you've gone through the whole list, relate the statements to the samples distributed earlier (handout M3: "Student Work Samples: Sound"). Ask participants to look at Sample 1 (the drawing with the words inside the drum) and explain:

▶ *Now let's see how these statements relate to the students' work, and what they can tell us about the next steps these students might take in advancing their learning.*

Let's look first at the top drawing, which was done by the younger student. Notice that this student has done more than just describe what happens; there is also an attempt to explain it. Maybe the statement "I think I hear the sound by listening hard" is some indication that the ears are involved. But there's no indication that the drum vibrates.

This shows that the student is at the level described in Indicator 2 on the list. This is already enough to suggest "next steps" for this student—to work on the idea that sound is caused by vibration, detailed in Indicator 3. This is what is important about formative assessment: it allows you to identify and suggest next steps, rather than simply "labeling" the student.

There are many options for helping a student see that vibration is involved when a drum makes a sound. The teacher could ask the student to "feel" the drumhead when it is hit, for example, or to explore what happens to the sound if the drumhead is prevented from vibrating when hit.

Ask participants to refer to Sample 2 on handout M3 (the drawings with the beater) and say:

▶ *Now let's see what Sample 2 tells us about this student's level of understanding, and the appropriate next steps in learning.*

Notice that this student does mention vibration, but does not specifically connect it with sound. That may be the next step for this student—to consolidate his understanding of how vibration is involved (Indicator 3), before moving on to correctly apply his idea of vibration to this specific situation (Indicator 4). To address this, the teacher might ask the student if he thinks there's a relationship between the sound and the vibration.

Note that the students who created these samples were not asked to apply their ideas to other situations, so only statements 1 through 4 are relevant.

Using Generic Indicators to Interpret Student Work

Overview

Once they've have seen the process modeled, this section of the workshop gives participants the opportunity to practice using the generic indicators of ideas to identify and assess the ideas found in student work, and to determine possible next steps for learning.

4 Steps ◆ 35 Minutes

1. Distribute writing materials to each participant and introduce the activity (10 minutes). Tell people that now they'll have the opportunity to try for themselves the process that was just modeled. Say:

▶ *Now that we've seen how specific indicators of development can be created from generic ones, let's try interpreting another example of student work.*

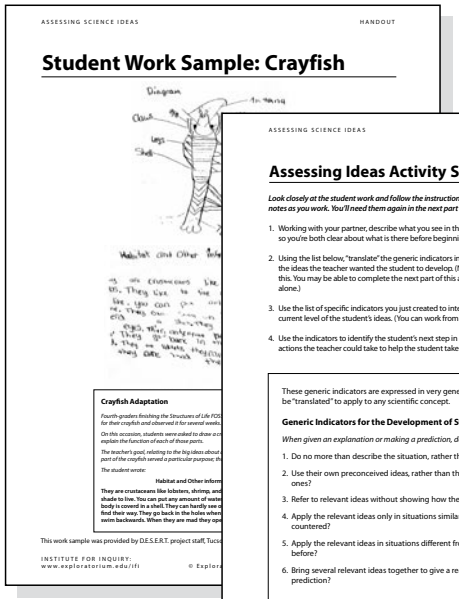
2. Distribute handout M5: "Student Work Sample: Crayfish" and M6: "Assessing Ideas Activity Sheet." Tell people:

▶ *Before we begin, let's quickly go over the four-step process we took, which is detailed on your Activity Sheet.*

- *First, we looked closely at the student work to see what ideas were present.*
- *Second, we "translated" the generic indicators into specific ones about sound.*
- *Third, we interpreted the work to decide what level the student was on, and what the next step would be for them, and*
- *Fourth, we identified some specific actions the teacher could try to help the student take the next step in learning.*

3. Ask participants to find a partner and begin working (15 minutes). Tell people they will be working in pairs, using handout M6: "Assessing Ideas Activity Sheet" to analyze the crayfish scenario on handout M5. Explain that they'll have 15 minutes to work on this sample. Say:

▶ *First, let's look at the Crayfish work sample using the "Assessing Ideas Activity Sheet." Working in pairs, spend the first 5 minutes describing to each other what you see in the work. That's item 1 on the activity sheet. Then take 10 minutes to complete Items 2 through 4 on the activity sheet.*


ASSESSING SCIENCE IDEAS HANDOUT

Student Work Sample: Crayfish

Crayfish Adaptation

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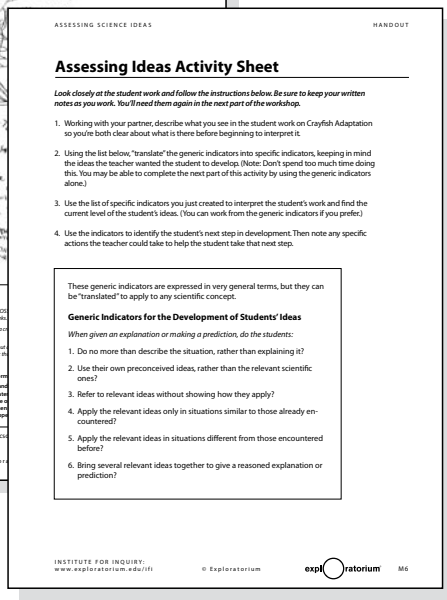
M5


ASSESSING SCIENCE IDEAS HANDOUT

Assessing Ideas Activity Sheet

Look closely at the student work and follow the instructions below. Be sure to keep your written notes as you work. You'll need them again in the next part of the workshop.

1. Working with your partner, describe what you see in the student work on Crayfish Adaptation so you're both clear about what is there before beginning to interpret it.
2. Using the list below, "translate" the generic indicators into specific indicators, keeping in mind the ideas the teacher wanted the student to develop. (Note: Don't spend too much time doing this. You may be able to complete the next part of this activity by using the generic indicators alone.)
3. Use the list of specific indicators you just created to interpret the student's work and find the current level of the student's ideas. (You can work from the generic indicators if you prefer.)
4. Use the indicators to identify the student's next step in development. Then note any specific actions the teacher could take to help the student take that next step.

These generic indicators are expressed in very general terms, but they can be "translated" to apply to any scientific concept.

Generic Indicators for the Development of Students' Ideas

When given an explanation or making a prediction, do the students:

1. Do no more than describe the situation, rather than explaining it?
2. Use their own preconceived ideas, rather than the relevant scientific ones?
3. Refer to relevant ideas without showing how they apply?
4. Apply the relevant ideas only in situations similar to those already encountered?
5. Apply the relevant ideas in situations different from those encountered before?
6. Bring several relevant ideas together to give a reasoned explanation or prediction?

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M6

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Distribute handout M5: "Student Work Sample: Crayfish"**
- **Distribute writing paper and pens or pencils**
- **Distribute handout M6: "Assessing Ideas Activity Sheet"**

As you work, take into account the teacher's goal for his students, which is stated on the work sample. Note that you may be able to skip to Step 2 and use the generic indicators directly.

4. Have participants share their responses (10 minutes). After 15 minutes, collect feedback on the activity and ask people to share their responses.

As participants respond, listen to whether they found evidence to identify the level of students' current work; what next steps they suggest for the students; and what specific action(s) the teacher might take to help those next steps. If participants don't phrase their responses in this way, you can help rephrase for them. For example, you might say:

► *It sounds as if you're saying that this student doesn't always apply the relevant ideas because he lists all the crayfish parts but only describes the function of some of them. So the next step would be to work on understanding the functions of the rest of the parts. To help him do this, the teacher might suggest listing the parts with the function next to each.*

After you have rephrased a response, check to be sure participants are in agreement with your phrasing and ask if another group has something to add.

Take one or two more responses and do the same thing. Then tell participants to hang on to their notes from number 4 on the activity sheet, which will be useful for the next part of the workshop. If participants have not all had an opportunity to finish their work, reassure them that there will be more time to consider specific actions in the next section of the workshop.

Facilitation Hint:
Help Participants Pace Themselves

As participants work, circulate and help them pace themselves.

- For the first 5 minutes, they should be looking at the work to find evidence of student ideas (number 1).
- For the second 5 minutes, they should be working on numbers 2 and 3. If they begin falling behind, remind them that doing number 3 on the activity sheet will help clarify number 2.
- For the last 5 minutes, encourage people to try to get to number 4 before time is up. If they begin to fall behind, reassure them that there will be more time to consider specific actions later in the workshop.

Providing Student Feedback

Overview

In the classroom, teachers regularly communicate their judgments to students in the form of feedback on assigned work. As part of the everyday interaction between student and teacher, some of that feedback is spoken. But a large part is written—in particular, when teachers mark papers. In either case, guidelines for giving effective feedback are the same.

In this part of the workshop, participants give feedback on samples of student work. This exercise serves as a basis for the next section of the workshop, which considers general guidelines for giving effective feedback.

Materials Reminder

During this part of the workshop, facilitators will need to:

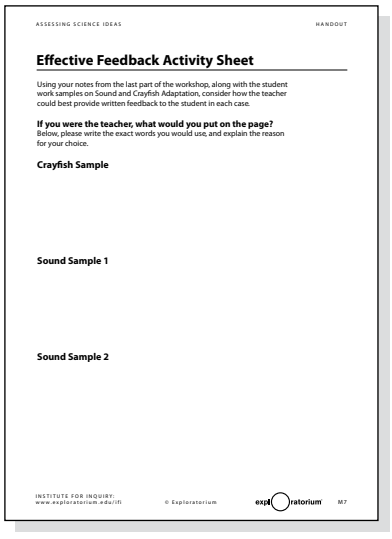
- **Have the flip chart and marker ready to use**
- **Distribute handout M7: "Effective Feedback Activity Sheet"**
- **Post chart M8: "Student Work Sample: Solar House with Newspaper"**
- **Post chart M9: "Student Work Sample: Solar House with Tin Foil"**

5 Steps • 30 Minutes

1. Introduce the activity. For this activity, have people work in groups of three. Then distribute handout M7: "Effective Feedback Activity Sheet" and ask participants to get out the student samples they've been working with (Sound and Crayfish).

2. Using the Activity Sheet, ask participants to give written feedback on the student work (15 minutes). Ask people to refer to handout M7 and say:

▶ *For the next 15 minutes, I'd like you each to decide what you would write on the student work samples you've seen in order to provide feedback to these students. Start with the crayfish sample, and work on the others if there's time. Write the exact words you would use—don't just give a general indication of what you would say. The reason for this is to get a feel for how specific words can affect the messages you give students. Write your comments on the handout, and then we'll share our findings.*



ASSESSING SCIENCE IDEAS HANDOUT

Effective Feedback Activity Sheet

Using your notes from the last part of the workshop, along with the student work samples on Sound and Crayfish Adaptation, consider how the teacher could best provide written feedback to the student in each case.

If you were the teacher, what would you put on the page?
Below, please write the exact words you would use, and explain the reason for your choice.

Crayfish Sample

Sound Sample 1

Sound Sample 2

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M7

3. Introduce the difference between judgmental and nonjudgmental comments (10 minutes). After 15 minutes is up, tell the groups to stop working and get ready to share their findings. Write suggestions from about five groups on the flip chart, without making comments. When you've finished, tell participants:

▶ *I want to stop here for a moment so we can look more closely at different kinds of comments teachers often give students. There is a distinction, in particular, between comments that are judgmental and those that aren't.*

• ***Nonjudgmental comments*** *focus on the task and offer comments on what to do next, encouraging students to think about their work instead of their feelings.*

• ***Judgmental comments*** *relate*

to the student or the quality of the work in an overall way that does not indicate why it is, or is not, "good" They often encourage students to label themselves or compare themselves with others.

If participants have written helpful, nonjudgmental comments, point out some examples. Then, identify any judgmental comments or parts of comments (i.e. "Good work," "You tried hard") by underlining them. Tell people:

► *I've underlined some examples of judgmental comments. Research has shown that these are the most frequent types of comments teachers make. Some of these comments may seem to be supportive or encouraging, such as "Well done," "Much improved," or "You can do better."*

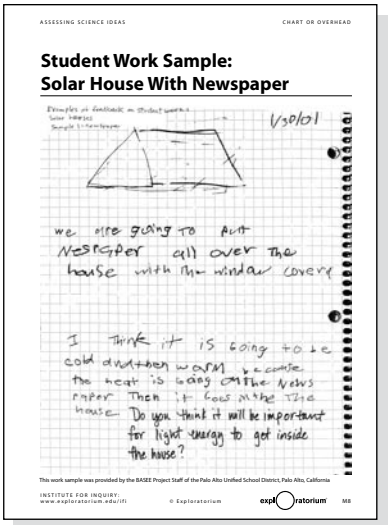
Teachers often insist they need to give praise in order to encourage students and make them feel good. This is fine, as long as they do it for this purpose and don't expect it to have a formative effect on learning.

It may seem that having both kinds of comments—one for encouragement and one for guidance—would be the most effective combination. But how helpful are such comments to students' learning? In fact, research has shown that students look for praise, and when they find it, look no further in the comments. So anything written after a "Well done!" type of comment will not be noticed.

Let's take a look, now, at some examples of nonjudgmental feedback, which leads students to improve their work or think further about it.

4. Show examples of nonjudgmental feedback (5 minutes). Post chart M8: "Student Work Sample: Solar House with Newspaper," and tell people:

► *Here's another sample of student work. In this case, the class was asked to make a prediction about what would happen to the temperature inside a solar house if they were to put some sort of material over the house. This group says, "We are going to put newspaper all over the house with the windows covered." Then their prediction is, "I think it is going to be cold and then warm because the heat is going on the newspaper. Then it goes in the house."*


ASSESSING SCIENCE IDEAS CHART OR OVERHEAD

Student Work Sample: Solar House With Newspaper

1/30/01

we are going to put Newspaper all over the house with the window covers

I think it is going to be cold and then warm because the heat is going on the news paper. Then it goes in the house. Do you think it will be important for light energy to get inside the house?

This work sample was provided by the BASEE Project Staff of the Palo Alto Unified School District, Palo Alto, California

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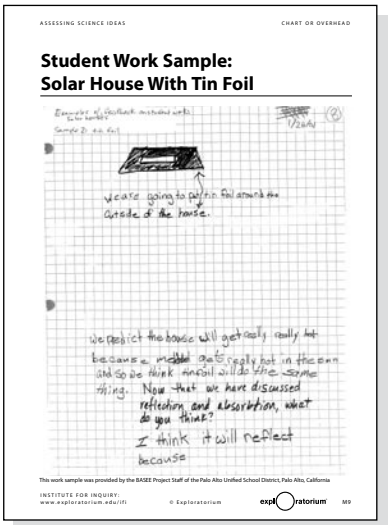
M8

The teacher then makes this nonjudgmental response: "Do you think it will be important for light energy to get inside the house?"

Now post chart M9: "Student Work Sample: Solar House with Tin Foil" and say:

► *In this sample, the students say, "We are going to put tin foil around the house," and their prediction is, "We predict the house will get really, really hot because metal gets really hot in the sun, and so we think tin foil will do the same thing."*


ASSESSING SCIENCE IDEAS CHART OR OVERHEAD

Student Work Sample: Solar House With Tin Foil

1/24/01

we are going to put tin foil around the outside of the house.

We predict the house will get really really hot because metal gets really hot in the sun and so we think tin foil will do the same thing. Now that we have discussed reflection and absorption, what do you think?

I think it will reflect because

This work sample was provided by the BASEE Project Staff of the Palo Alto Unified School District, Palo Alto, California

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M9

The teacher then responds with the nonjudgmental

comment, "Now that we have discussed absorption and reflection, what do you think?"

5. **Conclude this part of the workshop.** Tell participants:

- *Using a nonjudgmental comment is one way to give students effective feedback. In the next part of the workshop, we'll look at some other ways to do this.*

Facilitation Hint:
Watch for Useful Opportunities

While groups are writing their responses to the student work, circulate and see if you can find examples of judgmental and nonjudgmental comments. This way, when you take comments, you can ask particular groups to share while being sure to get at least one example of each.

Developing Guidelines for Effective Feedback

Overview

Providing students with effective feedback can help them take the next steps in learning. It's useful for teachers to keep guidelines in mind as they talk with students and mark their papers. In this section, we consider some "do's and don'ts" in providing consistent and effective feedback.

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Have a flip chart and marker ready**
- **Distribute handout M10: "Some Do's and Don'ts of Evaluating Student Work"**

3 Steps • 10 Minutes

1. Describe this part of the workshop (5 minutes). Explain:

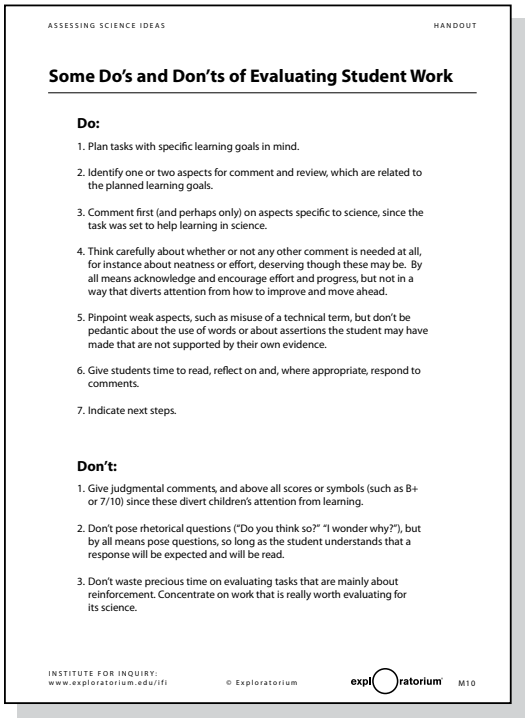
► *In order to be consistent in providing students with feedback that will help them take the next steps in learning, it's useful to develop some guidelines to keep in mind as you talk with students and mark their papers.*

In this part of the workshop, we'll consider a list of guidelines for providing such feedback, and you'll be able to add your own suggestions and comments to this list.

2. Distribute handout M10: "Some Do's and Don'ts of Evaluating Student Work." Read the handout aloud and then ask participants to add suggestions or comments. Say:

► *Let's take a few minutes to discuss this list. Consider,*

- *First, your own experiences receiving feedback*
- *Second, the research findings on judgmental comments we talked about earlier*
- *Third, your own practice giving feedback to students*
- *And fourth, your own responses to the list: Do you agree or disagree with any or all of them? Why?*



ASSESSING SCIENCE IDEAS HANDOUT

Some Do's and Don'ts of Evaluating Student Work

Do:

1. Plan tasks with specific learning goals in mind.
2. Identify one or two aspects for comment and review, which are related to the planned learning goals.
3. Comment first (and perhaps only) on aspects specific to science, since the task was set to help learning in science.
4. Think carefully about whether or not any other comment is needed at all, for instance about neatness or effort, deserving though these may be. By all means acknowledge and encourage effort and progress, but not in a way that diverts attention from how to improve and move ahead.
5. Pinpoint weak aspects, such as misuse of a technical term, but don't be pedantic about the use of words or about assertions the student may have made that are not supported by their own evidence.
6. Give students time to read, reflect on and, where appropriate, respond to comments.
7. Indicate next steps.

Don't:

1. Give judgmental comments, and above all scores or symbols (such as B+ or 7/10) since these divert children's attention from learning.
2. Don't pose rhetorical questions ("Do you think so?" "I wonder why?"), but by all means pose questions, so long as the student understands that a response will be expected and will be read.
3. Don't waste precious time on evaluating tasks that are mainly about reinforcement. Concentrate on work that is really worth evaluating for its science.

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M10

3. Have participants share their responses (5 minutes). Record them on the flip chart, accepting all suggestions. If people bring up any disagreements with items on the list, be sure to ask for their reasons.

Making Feedback Manageable

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Have a flip chart and a marker ready**

Overview

For teachers, giving the kind of feedback addressed here can be very time consuming. It's important to consider how to keep it from becoming overwhelming. In this part of the workshop, participants share ideas about how to make feedback manageable.

3 Steps • 20 Minutes

1. Introduce the next part of the workshop. Explain:

► *Giving the kind of feedback we've been talking about can be very time consuming, so it's important to consider how to keep it from becoming overwhelming. In this part of the workshop, we'll discuss ideas about how to make feedback manageable.*

We can start by considering a few suggestions. For instance:

- *Being selective—that is, thoroughly marking the most important work for assessing students' progress and initialing other work to indicate that you've noted it's been done*
- *Developing a school policy on selective marking and sharing it with parents*
- *Involving students in self-assessment.*

2. Have participants form discussion groups of 4–6 at their tables. Be sure participants have writing materials available. Then ask them to discuss different ways to make feedback manageable. Tell people:

► *Working with your group, take 10 minutes to discuss additional strategies for giving feedback on student work that is practical and manageable. Please choose one person to be the recorder for your group. We'll share responses in ten minutes.*

While participants are working, a facilitator should label a fresh page of the flip chart "Guidelines for Making Feedback Manageable."

3. Have participants share their responses (5 minutes). After 10 minutes, have people finish up, and then ask the recorder for each group to share its responses. Record them on the flip chart, accepting all suggestions. Suggest to participants that they may want to write down for future reference the suggestions that seem useful to them.

Concluding the Workshop

Overview

Bring the workshop to a close by summarizing what participants did, and the concepts they considered, in terms of the central pedagogical ideas expressed in the take-home messages.

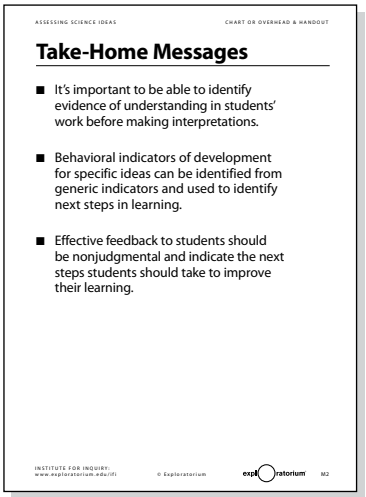
4 Steps • 10 Minutes

1. Summarize the main features of the workshop.
Tell people:

▶ *In this workshop, we found evidence of students' ideas by looking closely at their work, used generic indicators to help interpret the work, and decided how a teacher might help students take next steps in learning.*

We also looked at different ways to comment on student work, shared strategies for helping students take next steps in learning, and discussed some guidelines for making feedback effective and manageable.

2. Post chart M2: "Take-Home Messages" and ask participants to look again at the "Take-Home Messages" handout they received at the beginning of the workshop.
Tell people:


ASSESSING SCIENCE IDEAS CHART OR OVERHEAD & HANDOUT

Take-Home Messages

- It's important to be able to identify evidence of understanding in students' work before making interpretations.
- Behavioral indicators of development for specific ideas can be identified from generic indicators and used to identify next steps in learning.
- Effective feedback to students should be nonjudgmental and indicate the next steps students should take to improve their learning.

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M2

▶ *Let's take a minute to go over the take-home messages once again. As we noted at the beginning of the workshop, the main pedagogical ideas that emerged from the work done here today are expressed in the take-home messages.*

Materials Reminder

During this part of the workshop, facilitators will need to:

- **Post chart M2: "Take-Home Messages"**
- **Distribute handout M11a–c: "Developmental Indicators for Assessing Student Learning"**
- **Distribute any additional resources you've prepared.**

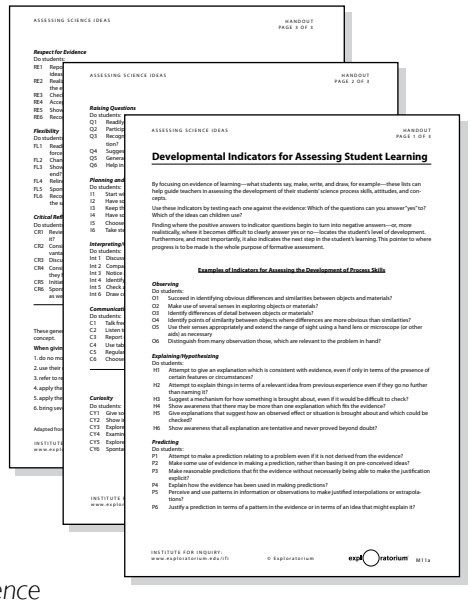
Read the take-home messages aloud and relate them to the main ideas that came up in the workshop.

3. Before participants leave, distribute the three-page handout M11: "Developmental Indicators for Assessing Student Learning." As you distribute the handout, tell people:

▶ *The next workshop in this series deals with how teachers can help students do self-assessments as they work towards learning goals.*

This workshop, though, like the previous two, focused on ways teachers can identify developmental levels of students' learning in relation to various kinds of learning goals.

The three-page handout I'm distributing now is a compilation of the indicators of development we've seen for science


ASSESSING SCIENCE IDEAS HANDOUT PAGE 1 OF 3

Developmental Indicators for Assessing Student Learning

By focusing on evidence of learning—what students say, make, write, and draw, for example—these lists can help guide teachers in assessing the development of their students' science process skills, attitudes, and concepts.

Use these indicators by testing each one against the evidence: Which of the questions can you answer "yes" to? Which of the ideas can children use?

Finding where the positive answers to indicator questions begin to turn into negative answers—or, more realistically, where it becomes difficult to clearly answer yes or no—locates the student's level of development. Furthermore, and most importantly, it also indicates the next step in the student's learning. This pointer to where progress is to be made is the whole purpose of formative assessment.

Examples of Indicators for Assessing the Development of Process Skills

Observing
Do students:
O1 Succeed in identifying obvious differences and similarities between objects and materials?
O2 Make use of several senses in exploring objects or materials?
O3 Identify differences of detail between objects or materials?
O4 Identify points of similarity between objects where differences are more obvious than similarities?
O5 Use their senses appropriately and extend the range of sight using a hand lens or microscope (or other aids) as necessary
O6 Distinguish from many observation those, which are relevant to the problem in hand?

Explaining/Hypothesizing
Do students:
H1 Attempt to give an explanation which is consistent with evidence, even if only in terms of the presence of certain features or circumstances?
H2 Attempt to explain things in terms of a relevant idea from previous experience even if they go no further than naming it?
H3 Suggest a mechanism for how something is brought about, even if it would be difficult to check?
H4 Show awareness that there may be more than one explanation which fits the evidence?
H5 Give explanations that suggest how an observed effect or situation is brought about and which could be checked?
H6 Show awareness that all explanation are tentative and never proved beyond doubt?

Predicting
Do students:
P1 Attempt to make a prediction relating to a problem even if it is not derived from the evidence?
P2 Make some use of evidence in making a prediction, rather than basing it on pre-conceived ideas?
P3 Make reasonable predictions that fit the evidence without necessarily being able to make the justification explicit?
P4 Explain how the evidence has been used in making predictions?
P5 Perceive and use patterns in information or observations to make justified interpolations or extrapolations?
P6 Justify a prediction in terms of a pattern in the evidence or in terms of an idea that might explain it?

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M11a–c

process skills—from Workshop II—and science ideas—from this workshop. In addition, it includes a list of developmental indicators for science attitudes. Together, these three pieces constitute a complete range of criteria for student assessment. All three are important goals in science instruction.

Pass out any additional resources you've prepared.

4. Thank participants and bring the workshop to a close. As appropriate, let people know about upcoming workshops, and when and where they will take place.

REVIEWING THE WORKSHOP

- **Facilitation Review**

Facilitation Review

Overview

It's a good idea to set aside some time after the workshop to get together with your co-facilitator (if you had one) and reflect on what worked and what didn't work. You can think and talk about your own facilitation and the workshop design, and consider what adjustments you can make for subsequent workshops. You'll also want to consider how the group's understanding of formative assessment developed during the workshop.

If you were the sole facilitator, take some time to consider the questions below and jot down notes for use when you present the workshop again.

4 Steps ◆ Time as needed

1. Acknowledge what you did well, and reflect on the goals. Start by taking a few minutes to talk about what went well during the workshop. Share any insights you gained about good facilitation strategies. Identify some things you did that helped groups get over difficult spots. Also, ask yourselves what you might do differently next time to improve the workshop.

2. Go through the workshop from beginning to end. Discuss not only how you facilitated different parts of the workshop, but also what participants did, and what they learned in each part of the workshop:

- Were all participants fully engaged in all parts of the workshop? Were there some steps that seemed particularly difficult for any of them? What could you do to encourage more active participation or help participants through difficult spots?
- Did participants develop their own understanding of the take-home messages? If so, how did they demonstrate their understanding? If not, what could you do differently to help them arrive at an understanding?
- Were participants inspired to consider applying some of their new ideas in their own classrooms?

3. Review the logistics of the workshop.

- Did you remain on schedule?
- Did you ever feel rushed to complete a step or did you finish early?
- What adjustments could you make that would be helpful?
- How did the distribution and cleanup of materials go?
- Is there anything you could do next time to make the workshop run more smoothly?

4. Consider how you worked together with your co-facilitator.

- Were you able to transition smoothly from one part of the workshop to the next?
- Were you able to transition smoothly between the roles of primary and secondary facilitator?
- Did you communicate effectively with each other during the workshop?
- What could you do to improve transitions and communication?

MORE FROM THE INSTITUTE FOR INQUIRY

- **About the Exploratorium Institute for Inquiry**
- **More Workshops on the Web**

About the Exploratorium Institute for Inquiry

The Exploratorium is San Francisco's innovative museum of science, art, and human perception. Here, hundreds of interactive exhibits engage visitors in seeking answers to the questions that emerge as they play and experiment with all kinds of intriguing phenomena.

The process of discovery and exploration is at the foundation of the Exploratorium Institute for Inquiry (IFI), a group of scientists and educators dedicated to developing and promoting inquiry-based science learning.

For more than thirty years, we have been educating teachers, administrators, and professional developers about the theory and practice of inquiry-based learning. Our workshops emphasize both the importance of engaging learners in firsthand experience with materials and phenomena, and the necessity for learners to play an active role in building new knowledge. Our work is shaped and refined by our own knowledge and experience, and by the invaluable input of teachers and professional developers working in the field.

For more information contact

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Since 1969, the Exploratorium has been bringing hands-on learning to visitors from around the world. Filled with hundreds of interactive exhibits, the museum offers programs for the public as well as for science and education professionals.

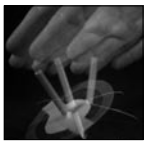
More Workshops on the Web

In addition to the ASSESSING FOR LEARNING curriculum, the Exploratorium also offers a series of five FUNDAMENTALS OF INQUIRY workshops. You can find more information at www.exploratorium.edu/ifi.

The FUNDAMENTALS OF INQUIRY curriculum is organized into three areas:

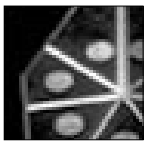
Elements of Inquiry

Three workshops that serve as building blocks for an immersion into inquiry by focusing on various hands-on approaches and process skills related to inquiry learning.



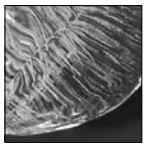
Workshop I: Comparing Approaches to Hands-On Science

Participants discover that different approaches to hands-on teaching support different goals for learning (about 3.5 hours).
Preview the workshop at www.exploratorium.edu/ifi/comparing



Workshop II: Process Skills

Participants identify the tools needed to carry out inquiry—the process skills—and examine the role of these skills in learning (about 3.5 hours).
Preview the workshop at www.exploratorium.edu/ifi/skills



Workshop III: Raising Questions

Participants examine the kinds of questions learners ask about phenomena and find out how to turn "noninvestigable" questions into "investigable" ones (about 3.5 hours).
Preview the workshop at www.exploratorium.edu/ifi/questions

Immersion in Inquiry

In this workshop, participants plan and conduct an investigation that illustrates how deep conceptual content—in this case, about stream flow and erosion—can be learned through a carefully orchestrated science inquiry process. At the same time, the activity illuminates the process of inquiry itself.

Workshop IV: Stream Table Inquiry

Participants experience inquiry firsthand, learning scientific process and content through an extended investigation (about 6 hours).
Preview the workshop at www.exploratorium.edu/ifi/streamtable

Connections to the Classroom

This last workshop focuses on helping participants make connections between what they have experienced in the previous workshops and what they can do in their classrooms to incorporate more science inquiry.

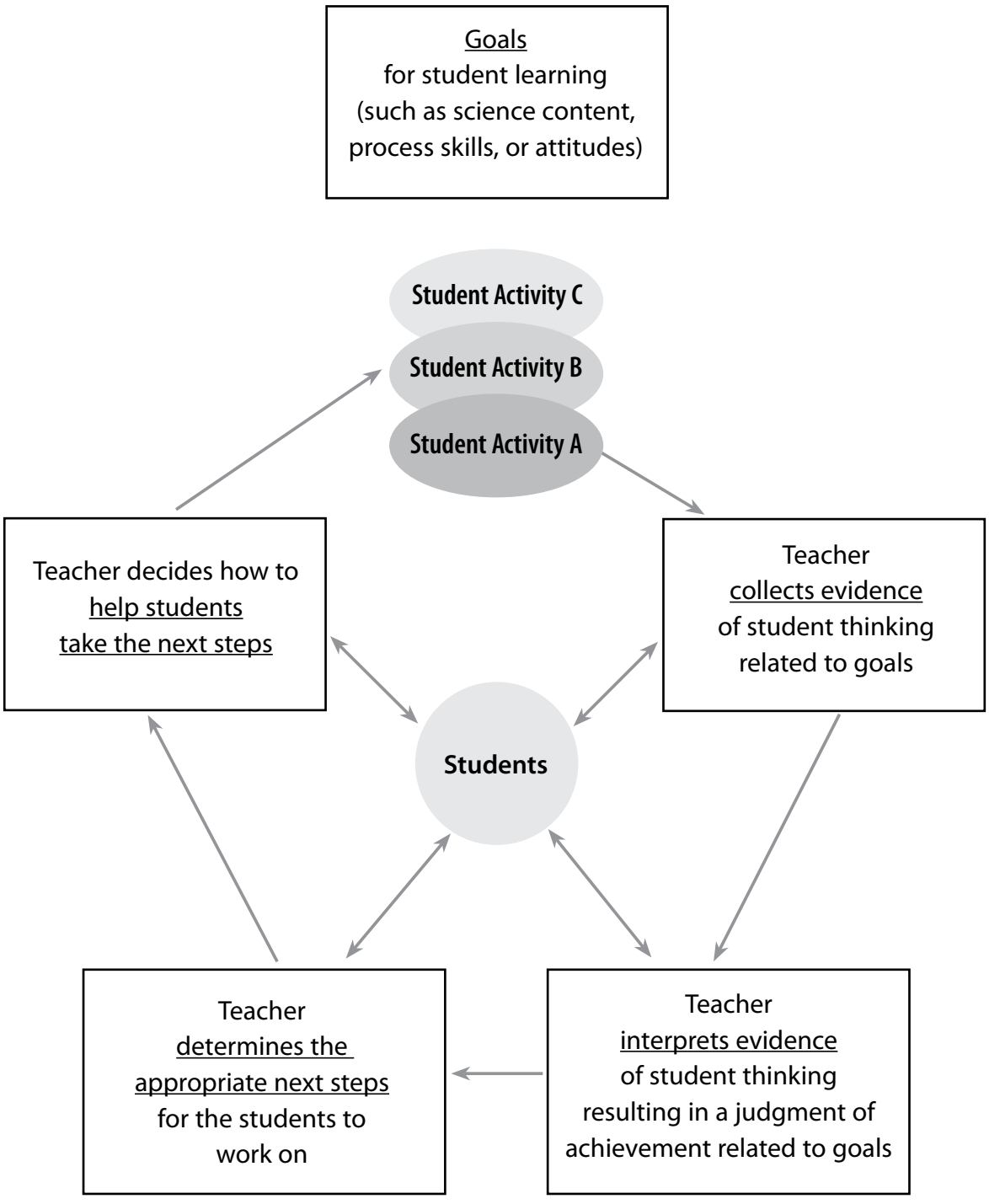
Workshop V: Subtle Shifts: Adapting Activities for Inquiry

Participants examine how current classroom activities can be modified to incorporate elements of inquiry (about 3 hours).
Preview the workshop at www.exploratorium.edu/ifi/subtleshifts

REPRODUCIBLE MASTERS

		Page
• **Formative Assessment Cycle**	chart or overhead & handout	M1
• **Take-Home Messages**	chart or overhead & handout	M2
• **Student Work Samples: Sound**	chart or overhead & handout	M3
• **Comparing Generic and Specific Indicators of Ideas**	chart or overhead & handout	M4
• **Student Work Sample: Crayfish**	handout	M5
• **Assessing Ideas Activity Sheet**	handout	M6
• **Effective Feedback Activity Sheet**	handout	M7
• **Student Work Sample: Solar House with Newspaper**	chart or overhead	M8
• **Student Work Sample: Solar House with Tin Foil**	chart or overhead	M9
• **Some Do's and Don'ts for Evaluating Student Work**	handout	M10
• **Developmental Indicators for Assessing Student Learning**	handout	M11a–c

Formative Assessment Cycle



Take-Home Messages

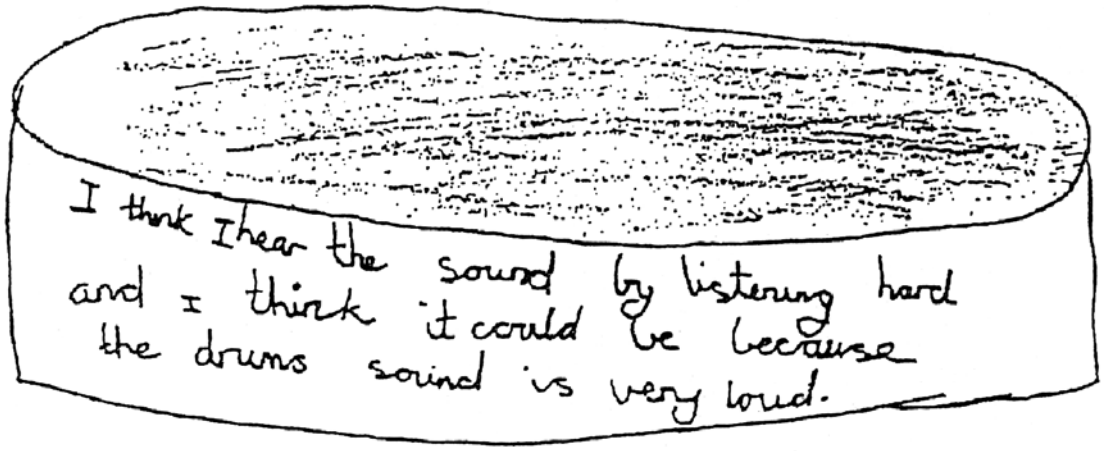
- It's important to be able to identify evidence of understanding in students' work before making interpretations.

- Behavioral indicators of development for specific ideas can be identified from generic indicators and used to identify next steps in learning.

- Effective feedback to students should be nonjudgmental and indicate the next steps students should take to improve their learning.

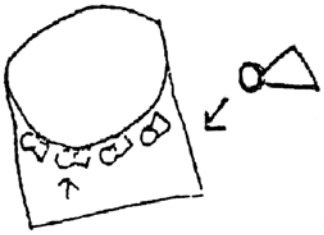
Student Work Samples: Sound

Sample 1



Sample 2

When you beat the drum it vibrates and the sound rolls across the drum.



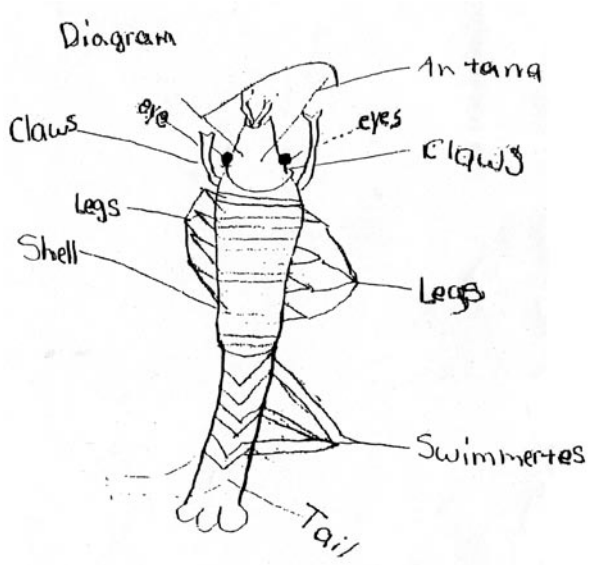
the sound comes throo the holes. and they are pointed up so

Comparing Generic and Specific Indicators of Ideas

Generic indicators of development can be "translated" into specific indicators, as shown here.

Generic Indicators *When giving an explanation or making a prediction, do the students:*	**Specific Indicators** *When giving an explanation or making a prediction, did the students:*
1. Do no more than describe the situation, rather than explaining it?	1. Simply describe what happened when the drum was hit?
2. Use their own preconceived ideas, rather than scientific ones?	2. Use preconceived ideas about sound, rather than scientific ideas?
3. Refer to relevant ideas without showing how they apply?	3. Mention the relevant ideas: that sound is caused by vibration; that we hear sound when it travels to our ears?
4. Apply the relevant ideas only in situations similar to those already encountered?	4. Apply ideas about sound correctly in this situation?
5. Apply the relevant ideas in situations different from those encountered before?	5. Use these ideas in explaining sounds made by other objects and suggest that sound travels through the air to the ear?
6. Bring several relevant ideas together to give a reasoned explanation or prediction?	6. Make a connection between vibration of objects that are sources of sound and vibrations in the air reaching the ear to create the sensation of sound?

Student Work Sample: Crayfish



Habitat and Other information about the Craw Dad

y are crustaceans like lobsters, Shrimp, and
bs. They like to live on rocks. They need Shade
live. you can put any amount of water in the
ne. They can swim on its side. It's body is
erd a shell. They can hardly See out
eyes. Thier antennae helps them find their
. They go back in the holes when they
. They eat pelttets. they can swim backwards.
they are mad they open they claws.

Crayfish Adaptation

Fourth-graders finishing the Structures of Life FOSS Kit set up a habitat for a crayfish. They cared for their crayfish and observed it for several weeks.

On this occasion, students were asked to draw a crayfish, correctly label all its body parts, and explain the function of each of those parts.

The teacher's goal, relating to the big ideas about adaptation, focused on understanding that each part of the crayfish served a particular purpose; that each structure had a particular function.

The student wrote:

Habitat and Other information about the Craw Dad

They are crustaceans like lobsters, shrimp, and crabs. They like to live on rocks. They need shade to live. You can put any amount of water in the home. They can swim on it's side. It's body is coverd in a shell. They can hardly see out of their eyes. Thier antennae helps them find their way. They go back in the holes when they are scard. They eat pelttets. They can swim backwards. When they are mad they open they claws.

This work sample was provided by D.E.S.E.R.T. project staff, Tucson Unified School District, Tucson, Arizona.

Assessing Ideas Activity Sheet

Look closely at the student work and follow the instructions below. Be sure to keep your written notes as you work. You'll need them again in the next part of the workshop.

1. Working with your partner, describe what you see in the student work on Crayfish Adaptation so you're both clear about what is there before beginning to interpret it.

2. Using the list below, "translate" the generic indicators into specific indicators, keeping in mind the ideas the teacher wanted the student to develop. (Note: Don't spend too much time doing this. You may be able to complete the next part of this activity by using the generic indicators alone.)

3. Use the list of specific indicators you just created to interpret the student's work and find the current level of the student's ideas. (You can work from the generic indicators if you prefer.)

4. Use the indicators to identify the student's next step in development. Then note any specific actions the teacher could take to help the student take that next step.

These generic indicators are expressed in very general terms, but they can be "translated" to apply to any scientific concept.

Generic Indicators for the Development of Students' Ideas

When given an explanation or making a prediction, do the students:

1. Do no more than describe the situation, rather than explaining it?
2. Use their own preconceived ideas, rather than the relevant scientific ones?
3. Refer to relevant ideas without showing how they apply?
4. Apply the relevant ideas only in situations similar to those already encountered?
5. Apply the relevant ideas in situations different from those encountered before?
6. Bring several relevant ideas together to give a reasoned explanation or prediction?

Effective Feedback Activity Sheet

Using your notes from the last part of the workshop, along with the student work samples on Sound and Crayfish Adaptation, consider how the teacher could best provide written feedback to the student in each case.

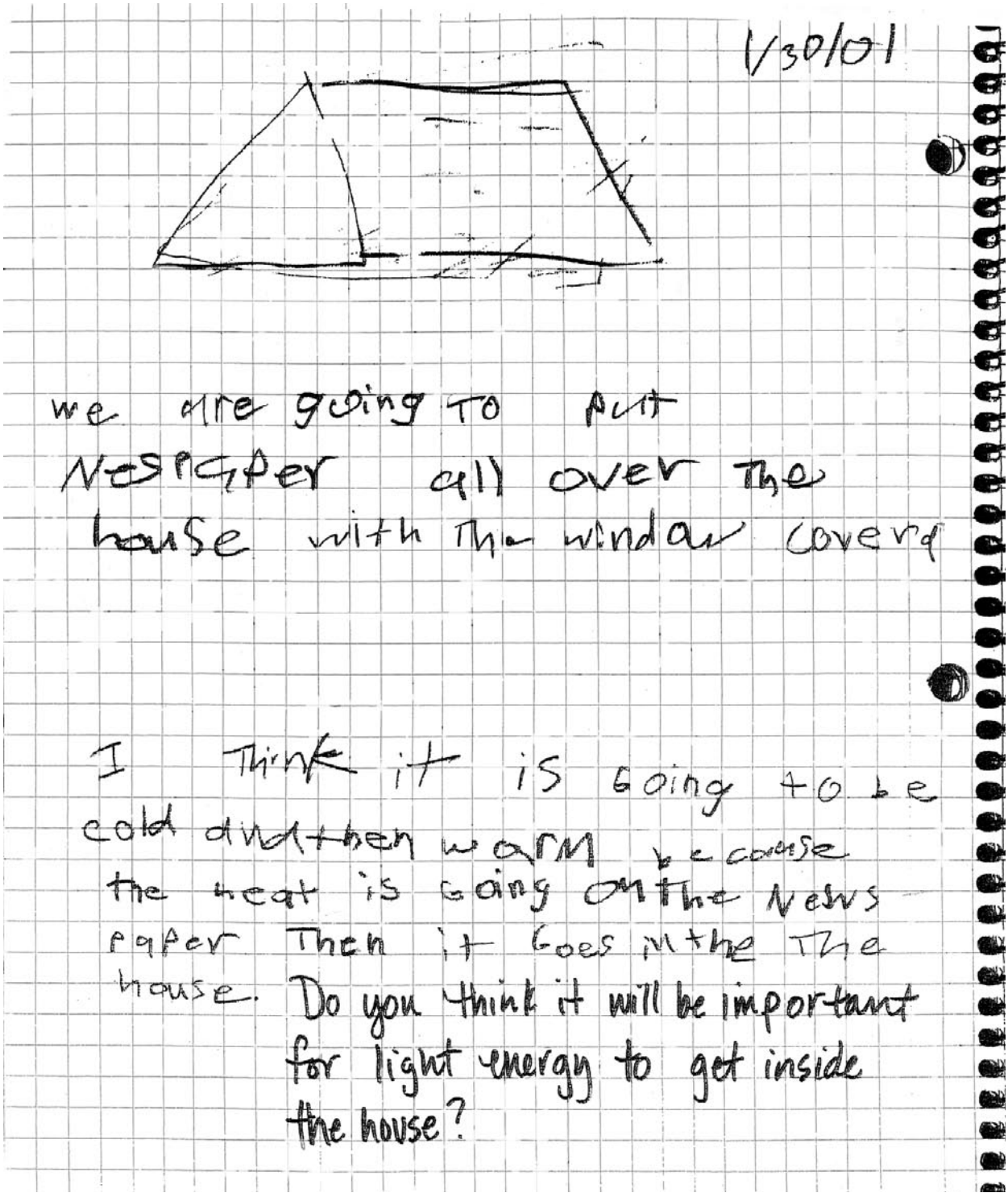
If you were the teacher, what would you put on the page?
Below, please write the exact words you would use, and explain the reason for your choice.

Crayfish Sample

Sound Sample 1

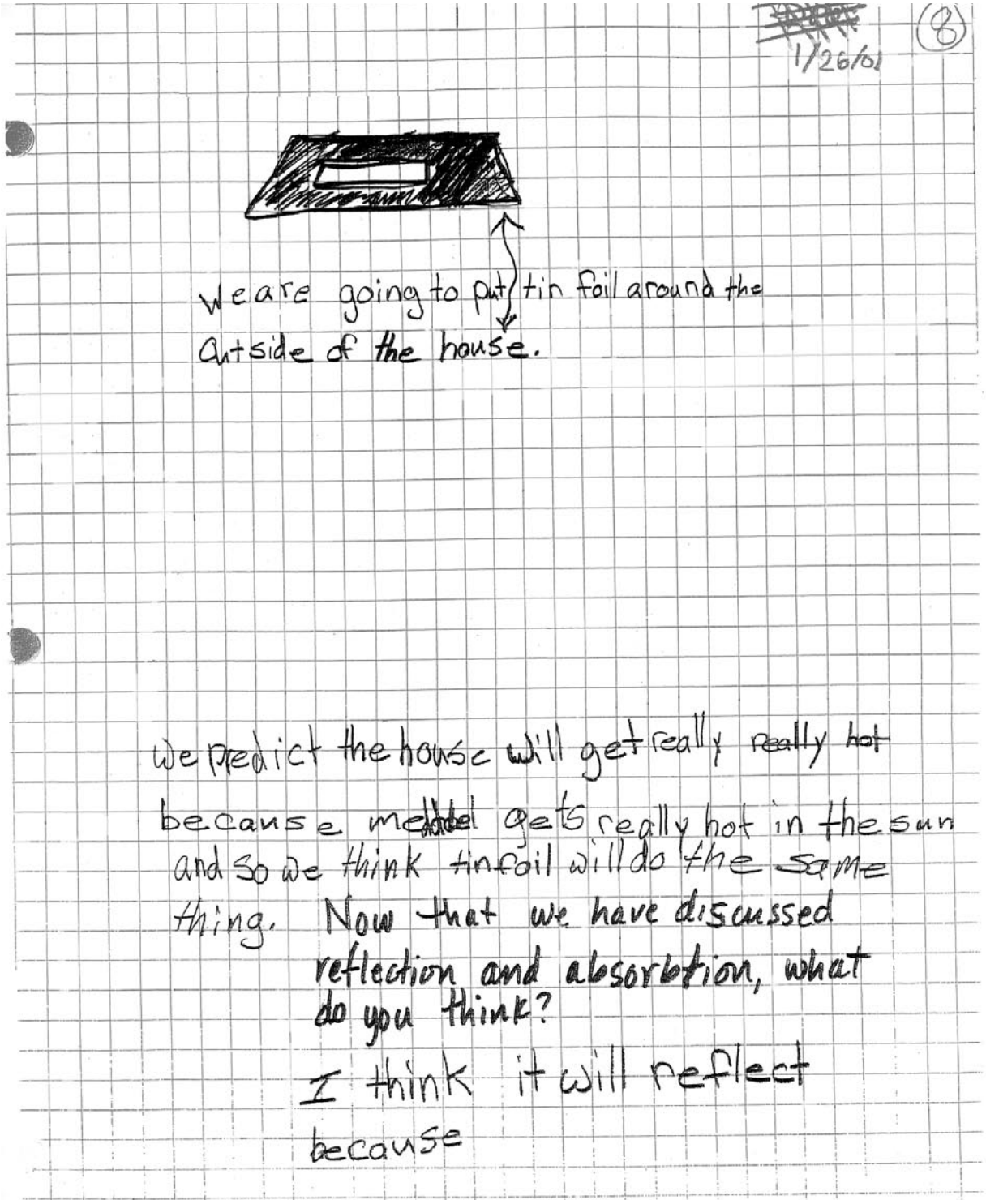
Sound Sample 2

Student Work Sample: Solar House With Newspaper



This work sample was provided by the BASEE Project Staff of the Palo Alto Unified School District, Palo Alto, California

Student Work Sample: Solar House With Tin Foil



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Some Do's and Don'ts of Evaluating Student Work

Do:

1. Plan tasks with specific learning goals in mind.

2. Identify one or two aspects for comment and review, which are related to the planned learning goals.

3. Comment first (and perhaps only) on aspects specific to science, since the task was set to help learning in science.

4. Think carefully about whether or not any other comment is needed at all, for instance about neatness or effort, deserving though these may be. By all means acknowledge and encourage effort and progress, but not in a way that diverts attention from how to improve and move ahead.

5. Pinpoint weak aspects, such as misuse of a technical term, but don't be pedantic about the use of words or about assertions the student may have made that are not supported by their own evidence.

6. Give students time to read, reflect on and, where appropriate, respond to comments.

7. Indicate next steps.

Don't:

1. Give judgmental comments, and above all scores or symbols (such as B+ or 7/10) since these divert children's attention from learning.

2. Don't pose rhetorical questions ("Do you think so?" "I wonder why?"), but by all means pose questions, so long as the student understands that a response will be expected and will be read.

3. Don't waste precious time on evaluating tasks that are mainly about reinforcement. Concentrate on work that is really worth evaluating for its science.

Developmental Indicators for Assessing Student Learning

By focusing on evidence of learning—what students say, make, write, and draw, for example—these lists can help guide teachers in assessing the development of their students' science process skills, attitudes, and concepts.

Use these indicators by testing each one against the evidence: Which of the questions can you answer "yes" to? Which of the ideas can children use?

Finding where the positive answers to indicator questions begin to turn into negative answers—or, more realistically, where it becomes difficult to clearly answer yes or no—locates the student's level of development. Furthermore, and most importantly, it also indicates the next step in the student's learning. This pointer to where progress is to be made is the whole purpose of formative assessment.

Examples of Indicators for Assessing the Development of Process Skills

Observing

Do students:

O1 Succeed in identifying obvious differences and similarities between objects and materials?
O2 Make use of several senses in exploring objects or materials?
O3 Identify differences of detail between objects or materials?
O4 Identify points of similarity between objects where differences are more obvious than similarities?
O5 Use their senses appropriately and extend the range of sight using a hand lens or microscope (or other aids) as necessary
O6 Distinguish from many observation those which are relevant to the problem in hand?

Explaining/Hypothesizing

Do students:

H1 Attempt to give an explanation that is consistent with evidence, even if only in terms of the presence of certain features or circumstances?
H2 Attempt to explain things in terms of a relevant idea from previous experience even if they go no further than naming it?
H3 Suggest a mechanism for how something is brought about, even if it would be difficult to check?
H4 Show awareness that there may be more than one explanation that fits the evidence?
H5 Give explanations that suggest how an observed effect or situation is brought about and which could be checked?
H6 Show awareness that all explanation are tentative and never proved beyond doubt?

Predicting

Do students:

P1 Attempt to make a prediction relating to a problem even if it is not derived from the evidence?
P2 Make some use of evidence in making a prediction, rather than basing it on preconceived ideas?
P3 Make reasonable predictions that fit the evidence without necessarily being able to make the justification explicit?
P4 Explain how the evidence has been used in making predictions?
P5 Perceive and use patterns in information or observations to make justified interpolations or extrapolations?
P6 Justify a prediction in terms of a pattern in the evidence or in terms of an idea that might explain it?

Raising Questions

Do students:

Q1 Readily ask a variety of questions that include investigable and non-investigable ones?
Q2 Participate effectively in discussing how their questions can be answered?
Q3 Recognize a difference between an investigable question and one that cannot be answered by investigation?
Q4 Suggest how answers to questions of various kinds can be found?
Q5 Generally, in science, ask questions which are potentially investigable?
Q6 Help in turning their own questions into a form that can be tested?

Planning and Conducting Investigations

Do students:

I1 Start with a useful general approach even if details are lacking or need further thought?
I2 Have some ideas of the variable that has to be changed or what different things are to be compared?
I3 Keep the same the things that should not change for a fair test?
I4 Have some idea beforehand of what to look for to obtain a result?
I5 Choose a realistic way of measuring or comparing things to obtain a result?
I6 Take steps to ensure that the results obtained are as accurate as they can reasonably be?

Interpreting/Concluding

Do students:

Int 1 Discuss what they find in relation to their initial questions?
Int 2 Compare their findings with their earlier predictions?
Int 3 Notice associations between changes in one variable and another?
Int 4 Identify patterns or trends in their observations or measurements?
Int 5 Check any patterns or trends against all the evidence?
Int 6 Draw conclusions that summarize and are consistent with all the evidence?

Communicating

Do students:

C1 Talk freely about their activities and the ideas they have, with or without making a written record?
C2 Listen to others' ideas and look at their results?
C3 Report events in drawings, writing, models, paintings?
C4 Use tables, graphs and charts to record and report results when these are suggested?
C5 Regularly and spontaneously use information books to check or supplement their investigations?
C6 Choose a form for recording or presenting results that is both considered and justified?

Generic Indicators for Assessing the Development of Students' Ideas

These generic indicators are expressed in very general terms, but can be "translated" to apply to any scientific concept.

When giving an explanation or making a prediction, do students:

1. Do no more than describe the situation rather than explaining it?
2. Use their own preconceived ideas rather than the relevant scientific ones?
3. Refer to relevant ideas without showing how they apply?
4. Apply the relevant ideas only in situations similar to those already encountered?
5. Apply the relevant ideas in situations different from those encountered before?
6. Bring several relevant ideas together to give a reasoned explanation or prediction?

Examples of Indicators for Assessing Scientific Attitudes

Curiosity

Do students:

CY1 Give some attention to new things but are easily distracted and ask few questions?
CY2 Show interest in new things through asking factual questions, "what" rather than "why" or "how"?
CY3 Explore things and ask questions about them in response to invitations to do so?
CY4 Examine things carefully and ask questions about "how" and "why" as well as "what"?
CY5 Explore and investigate things around to answer their own questions?
CY6 Spontaneously seek information from books or other sources to satisfy their own curiosity?

Respect for Evidence

Do students:

RE1 Report results that are supported by evidence even if the interpretation is influenced by preconceived ideas.
RE2 Realize when the evidence doesn't fit a conclusion based on expectations, although they may challenge the evidence rather than the conclusion?
RE3 Check parts of the evidence that don't fit an overall pattern or conclusions?
RE4 Accept only interpretations or conclusions for which there is supporting evidence?
RE5 Show a desire to collect further evidence to check conclusions before accepting them?
RE6 Recognize that no conclusion is so firm that it can't be challenged by further evidence?

Flexibility

Do students:

FL1 Readily change what they say they think, though this may be due to a desire to please rather than the force of argument or evidence?
FL2 Change ideas when there is considerable evidence against the existing ones and little in their favor?
FL3 Show willingness to consider alternative ideas that may fit evidence, even if they prefer their own in the end?
FL4 Relinquish or change ideas after considering evidence?
FL5 Spontaneously seek other ideas that may fit the evidence rather than accepting the first that seems to fit?
FL6 Recognize that ideas can be changed by thinking and reflecting about different ways of making sense of the same evidence?

Critical Reflection

Do students:

CR1 Review what they have done after an investigation even though they may only justify rather than criticize it?
CR2 Consider some alternative procedures that could have been used without necessarily realizing their advantages and disadvantages.
CR3 Discuss ways in which what they have done could have been improved even if only in detail?
CR4 Consider, when encouraged, the pros and cons of alternative ways of approaching a problem to the one they have used?
CR5 Initiate review of a completed investigation to identify how procedures could have been improved?
CR6 Spontaneously review and improve procedures at the planning stage and in the course of an investigation as well as completion.

Adapted from Chapter 9 of *Teaching, Learning and Assessing Science 5–12* by Wynne Harlen (Sage 2000)