WORKSHOP V: SUBTLE SHIFTS
Adapting Activities for Inquiry

A Professional Development Curriculum from the
Institute for Inquiry®

The fifth in a set of five workshops for teacher professional development.
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⚠️ Caution: The experiments in this guide were designed with safety and success in mind. But even the simplest activity or the most common materials can be harmful when mishandled or misused. Use common sense whenever you’re exploring or experimenting.

You can download your own copy of this guide at www.exploratorium.edu/ifi/subtleshifts. 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 Fundamentals of Inquiry workshop guides at www.exploratorium.edu/ifi/workshops/fundamentals.
Welcome
For more than thirty years, the Exploratorium Institute for Inquiry has been educating teachers, administrators, and professional developers about the theory and practice of inquiry-based teaching and learning. We have witnessed firsthand the power of science coming alive and having real meaning for students and teachers when they learn to focus on the questions of science, rather than just the answers.

In 2000, we received a major grant from the National Science Foundation to make what we have learned 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 professional developers and teacher educators can present these workshops on their own.

This workshop, Subtle Shifts: Adapting Activities for Inquiry, introduces teachers to a strategy they can use to make small changes in existing classroom activities in order to help students develop their abilities to do inquiry. We hope you find this workshop useful in establishing a vibrant setting for teachers to learn and extend their practice. And we hope that, like us, you will be inspired by seeing teachers become enthused about science, eager to bring the very best ideas and approaches to their students.

—LYNN RANKIN
Director
Institute for Inquiry

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ABOUT THIS WORKSHOP

• Workshop Overview
• The Workshop in Context
Workshop Overview

A Quick Summary
This is the fifth in a set of five guides in the Fundamentals of Inquiry curriculum. The guides are designed to help facilitators present professional-development workshops for educators interested in developing an understanding of inquiry-based science instruction.

In Inquiry and the National Science Education Standards, the authors state that “developing the ability to understand and engage in this kind of activity [inquiry] requires direct experience and continued practice with the processes of inquiry.” To develop strong science process skills, learners need the opportunity to actually use those skills, and they need the teacher’s support during that practice. This workshop does not provide teachers with activities they can take back to the classroom. Instead, it provides teachers with strategies to make “subtle shifts” in existing activities (from kits and hands-on science materials) in order to give learners responsibility for using the various process skills.

Both teachers and students will need time to develop the skills and knowledge necessary for effective inquiry learning. And although one of the goals of this workshop is to have teachers give students more responsibility for their own learning, this doesn’t have to happen all at once. Subtle Shifts focuses on developing learners’ science process skills by making gradual changes that shift responsibility for using these skills from the teacher to the learner. By taking these small steps, teachers can help their students develop the skills necessary for inquiry in a manner that is manageable for both the teacher and the student. In this way, students can focus on building a few particular skills rather than building all of them at once, all the while moving toward the increased learner responsibility necessary for doing classroom inquiry.

Subtle Shifts is not meant to be used as a stand-alone workshop. In order for the workshop to be effective, participants must have had a first-hand experience of doing inquiry themselves, such as in the preceding workshop, Stream Table Inquiry. Having a substantive inquiry experience is essential for providing teachers with both practical knowledge about inquiry and a vision of inquiry learning and teaching in action. Without this vision, teachers will not be able to understand the power of inquiry learning and teaching, nor will they realize that making subtle shifts is not an end in itself, but rather a way of moving toward inquiry.

Goals
- To help teachers recognize that students need to be given more responsibility for aspects of their own learning in order to develop science process skills necessary for inquiry.
- To help teachers recognize that they can prepare students for doing inquiry by making small changes in activities they already do.

**The Goals of the Workshop**

*Subtle Shifts* provides participants with a strategy for gradually moving their science teaching in the direction of inquiry. In order to help learners develop the science process skills that they need for doing inquiry, teachers gradually shift to giving learners more responsibility for using those skills in science activities. For example, instead of giving students a predesigned experiment to carry out, a teacher can modify an activity to give students more of a say in designing the experimental procedure. This gives students the opportunity to practice their investigation planning skills.

By moving toward more learner responsibility for using the science process skills, teachers can make activities more engaging and give students more ownership over their own learning. This way of working also provides the opportunity for teachers to observe and evaluate students’ ability to use process skills. For example, having given students more of a say in designing the experimental procedure, the teacher can ask, “Can they control variables? Can they design a data collection format?” If students need to improve their planning skills, giving them more responsibility for designing the experimental procedure provides them with the opportunity for practicing those skills. It also allows teachers to assess various aspects of students’ planning skills, identifying where they may need help and providing that help.

Moving toward inquiry by making subtle shifts in existing science lessons and activities takes time and work. But it is time well spent: Even before students are able to do complete inquiries—where they take full responsibility for raising the question, planning and carrying out the investigation, interpreting the data, and communicating the results—they are developing the skills that will serve them well in doing hands-on science of all kinds.

**How the Workshop Works**

This workshop takes about 2 hours and 45 minutes and is designed to be led by two facilitators working. Typically, planning takes about 4 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.

The workshop begins with the facilitator setting the context. Participants then form pairs, do a chemistry activity, and discuss their findings. The directions for the activity have been “shifted” from the original, more directive worksheet to give the learner more choice about experimental procedure and more responsibility for determining results.

After the pairs complete the activity, the facilitator works with participants to examine the degree of learner responsibility in the activity. Participants compare the shifted chemistry activity with the original version to see how the shifted activity gives the learner more responsibility.
This portion of the workshop ends with participants and the facilitator identifying the learning benefits that the shifted activity offers to students. Doing this helps teachers realize that their students can experience benefits from shifted activities even before they have moved all the way to doing inquiry.

The next part of the workshop helps teachers recognize that they can make subtle shifts to accomplish particular purposes. (For example, in helping young students with the science process skill of raising questions, a specific purpose might be to develop fluency in raising a lot of questions.) To begin, partners identify the purposes of shifts made in a shadow-measuring activity. Then they work together to create a shift in the same activity that accomplishes a particular purpose.

Although this activity can only serve as an introduction to making shifts for particular purposes, it does give participants a model for applying the subtle shifts strategy in their classrooms and for what they can accomplish by doing so.

Subtle Shifts: Adapting Activities for Inquiry provides teachers with new pedagogical understanding that will inform their classroom practice. It is not intended for use with students in the classroom.

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 take-home 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 that participants have constructed.
The Workshop in Context

**FUNDAMENTALS OF INQUIRY**

*Subtle Shifts: Adapting Activities for Inquiry* is the fifth of five workshops in the FUNDAMENTALS OF INQUIRY curriculum, designed to introduce teachers to the benefits of inquiry-based teaching. Though most of the workshops can be used individually, the series is best presented as a comprehensive whole. Below are brief descriptions of the five workshops.

The FUNDAMENTALS OF INQUIRY curriculum is organized into three areas:

**Elements of Inquiry**

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

**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
PLANNING AND PREPARATION

- Workshop at a Glance
- Essential Planning Steps
- Sample Room Setup
- Materials
- Overheads and Handouts
- Background Science for the Changes Chemistry Activity
Workshop at a Glance

Workshop Time: Approximately 2 hours and 45 minutes
Facilitators Needed: 2
Participants Accommodated: 36

Special Materials Note
The chemistry activity in this workshop requires the use of some chemicals, such as phenol red, that you may need to order ahead of time. Information about where to order chemicals can be found on page 18 of this guide.

Arranging Work Groups
Participants first work in pairs, then pairs join to form groups of four. Later discussions involve the group as a whole.

Presenting the Workshop Part 1: Introducing Subtle Shifts

Introducing the Workshop
Facilitators set the tone and put the workshop in context. 10 Minutes

Doing a “Shifted” Science Activity
Participants do a ‘shifted’ chemistry activity. Groups work in pairs, then pairs join to work in groups of 4. 40 Minutes

Examining Learner Responsibility for Direction of Activities
Participants identify the level of control they think students have in the Changes activity. 10 Minutes

Comparing Shifted and Unshifted Activities
Participants compare the shifted chemistry activity with an unshifted original version and determine the benefits of the changes. 35–40 Minutes

Break
15 minutes

Presenting the Workshop Part 2: Using Subtle Shifts

Identifying the Purpose for Shifts
Participants compare a shifted and unshifted shadow activity and identify the value of the shifted version. 25 Minutes

Making Shifts for a Particular Purpose
Participants make their own changes to the shadow activity. 20 Minutes

Concluding the Workshop
Facilitators review the take-home messages and bring the workshop to a close. 5 Minutes

Reviewing the Workshop
Facilitation Review. Time as needed.
Essential Planning Steps

Overview

The Subtle Shifts 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.

It’s important that you and your co-facilitator 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, ordering materials, arranging for an appropriate space, and preparing overheads 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. Learn the guide well so that you can refer to it later as you begin to think about how you will implement it. 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. View a brief online preview of the workshop. This preview, which introduces the workshop with sound and images, can be viewed by both facilitators and participants. It’s available on the Web at www.exploratorium.edu/ifi/subtleshifts.

3. Become familiar with the safety requirements of this workshop. In this workshop, people will be working with chemicals, including phenol red and calcium chloride. Before the workshop, be sure to read the Material Safety Data Sheets (MSDS), which will be provided when you buy the chemicals. Also, check your district policy to determine if you need safety gloves.

Although these materials pose a very low level of risk, it’s good to know exactly what the potential hazards may be before working with any chemical. Keep these data sheets handy during your workshop for anyone who has questions regarding safety, spills, or disposal.

4. Gather and organize materials. Materials are either commonly available or may be ordered from the sources given on page 18.

   • To prepare for the chemistry activity in this workshop, you’ll need to make a dilute solution of phenol red. Instructions are on page 19.

   • For this workshop, you’ll use 36 small containers (e.g., empty pill bottles) to store some of the chemicals needed. Label 18 of the containers “Calcium Chloride” and the other 18 “Sodium Bicarbonate.” Fill them with the appropriate chemicals (see the Materials list on page 17). NOTE: Put the calcium chloride in the containers on the day of the workshop (rather than before) to help avoid clumping.

   • Duplicate and prepare all handouts and over-
heads. Masters begin on page 49. They are identified by the letter M (for Master) and numbered in order of use.

- To simplify setup on the day of the workshop, organize handouts and overheads according to when and where they will be used. Store materials so you can set them out quickly.

- You’ll need to prepare small amounts of materials so that you and your co-facilitator can do a run-through before presenting the workshop to participants (see Step 5, below).

5. Do the workshop as learners. When you’re done gathering materials and preparing enough for this run-through, meet together and go through the entire workshop as if you were participants. During the run-through, it’s very important that you become familiar with the pedagogical concepts the workshop intends to teach. It’s also important to get a personal feel for what participants will be doing in the workshop, in order to gain insight into their experiences and to anticipate the questions they may ask.

- Go through every section, step by step, starting with Introducing the Workshop on page 24.

- You’ll probably need more than the 2 hours and 45 minutes allotted for the actual workshop. Take all the time you need to gain a thorough understanding of all the concepts and activities.

- If possible, conduct your practice workshop in the room where the workshop will take place.

- Prepare overheads and handouts for facilitators to use.

- It’s important to do everything that participants will be asked to do, including the full chemistry activity (see page 27), being sure to complete both Option A and Option B in Part II of handout M3: “Changes Activity (Shifted).”

6. Review the workshop as facilitators. Go through the whole workshop again, taking time to discuss each section.

- Decide which tasks each of you will do. While you both need to be involved in all aspects of the workshop, you might want to assume different roles for presentation. For example, you could take primary and secondary responsibility for different segments of the workshop. Or one facilitator might introduce a step and lead a discussion while the other passes out materials and records information.

- Practice presenting scripted instructions (set in italics and marked with gray arrows). It’s important to convey the scripted information in a way that’s as close as possible to what is written, but it will probably work best for you to say it in your own words rather than read the script.

- Familiarize yourself with all the overheads and handouts, and make sure you know at which

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 activity, 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.
point you will hand out or refer to these tools.

- Note that the chemistry activity requires minimal facilitation because the instructions are straightforward and the task is fairly simple. Facilitation for the whole-group discussion is also relatively straightforward.

7. **Be prepared to set the context.** Setting the context for the workshop is crucial. The facilitator who introduces the workshop should study the information and scripts in Step 1 of Introducing the Workshop (page 24) and practice setting the context in his or her own words.

- As you set the context, be prepared to explain to participants why you chose to present this workshop. How does it fit with other professional development experiences they’ve had? How is it related to district and state goals for science education? What do you want teachers to take away from the experience? Information about how this workshop connects with the National Science Education Standards is available on page 47 of this guide.

8. **Plan time and space carefully**

- Decide where the workshop will take place.

   You’ll need one large room with space for materials, a sink, and workspace. See Sample Room Setup on page 16 for more information.

- Create a detailed schedule for facilitators to refer to during the workshop. Note the beginning and ending times for each step (e.g., Introductions and Setting the Context, 9:00–9:05; Address Take-Home Messages, Standards, and Schedule, 9:05–9:10). Be sure to include times for breaks.

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

- Remember that times given in this workshop are approximate. As you prepare to lead the workshop, going over each step in advance, you may find that you need more time than is suggested. Build this extra time into your schedule.

9. **Assess the need for additional information.** For more on the Institute for Inquiry’s ap-

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### Sample Schedule for Subtle Shifts Participants

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00–9:10</td>
<td>Introducing the Workshop</td>
</tr>
<tr>
<td>9:10–9:50</td>
<td>Doing a “Shifted” Activity</td>
</tr>
<tr>
<td>9:50–10:00</td>
<td>Examining Learner Responsibility for Direction of Activities</td>
</tr>
<tr>
<td>10:00–10:40</td>
<td>Comparing Shifted and Unshifted Activities</td>
</tr>
<tr>
<td>10:40–10:55</td>
<td>Break</td>
</tr>
<tr>
<td>10:55–11:20</td>
<td>Identifying the Purpose for Shifts</td>
</tr>
<tr>
<td>11:20–11:40</td>
<td>Making Shifts for a Particular Purpose</td>
</tr>
<tr>
<td>11:40–11:45</td>
<td>Concluding the Workshop</td>
</tr>
</tbody>
</table>

---

### A Note About Scripts

The scripts in this guide 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.
approach to inquiry learning, as well as information on how this workshop supports the *National Science Education Standards*, see pages 47–48. You may want to copy these sections for participants.

**On the Day of the Workshop**

1. **Prepare the room.** Consult the Materials list on page 17 and the Sample Room Setup on page 16. Make sure the phenol red dilution has been prepared and the MSDS sheets for all workshop chemicals are on hand.

   • Prepare a supply table specifically for the Changes activity. The materials used in that activity can be stored there until they are used, and returned there after use.

   • Optional: You might want to put the materials for each working pair on a cafeteria-type tray, if they are available. The trays will also make it easier for cleanup after the Changes activity.

2. **Watch your schedule.** Refer to the schedule you created to keep things on track. (See Step #8, above.)

**After the Workshop**

When the workshop has ended, you and your co-facilitator 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 43) will allow you to assess the results of your work and identify the successes and challenges that can help guide subsequent workshops.
Sample Room Setup

This diagram shows a sample setup for 36 people. You will need to set up the room so that pairs can comfortably work together on the chemistry activity. Be sure that everyone can see the screen where the overheads are projected and can participate in whole-group discussions.

**Essential features**

- A sink for disposing of nontoxic chemicals
- Tables that will accommodate one or more groups of four (for discussions after the chemistry activity)
- A place for facilitators to store additional materials that will be passed out
- A place to mount charts where all can see
- A place for the overhead projector
- A screen or wall (viewable to all) on which to project overheads
The Changes Activity in this workshop requires a few supplies you may have to order. The table on the next page provides tips on finding and using these materials. Also make sure to have plenty of paper and pencils for creating data collection sheets and recording data.

Note: Quantities are based on 36 people working in groups of 2 (18 pairs).

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount for Each Pair</th>
<th>Total</th>
<th>When Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>overhead projector</td>
<td>—</td>
<td>1</td>
<td>For preparing phenol red dilution used in Changes activity (page 19)</td>
</tr>
<tr>
<td>distilled water</td>
<td>1 liter</td>
<td></td>
<td>For use in Changes activity; prepared before day of session (see page 19 for instructions)</td>
</tr>
<tr>
<td>phenol red dilution *</td>
<td>50 ml</td>
<td>1 liter</td>
<td>For preparing and storing phenol red dilution</td>
</tr>
<tr>
<td>plastic soda bottle or mayonnaise jar</td>
<td>—</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>100-ml graduated cylinder</td>
<td>—</td>
<td>1</td>
<td>For preparing phenol red dilution</td>
</tr>
<tr>
<td>apron (optional)</td>
<td>—</td>
<td>2</td>
<td>For facilitators when they prepare phenol red dilution, which can stain fabric.</td>
</tr>
<tr>
<td>safety goggles*</td>
<td>2 pairs</td>
<td>1 box (100)</td>
<td>For preparing phenol red dilution to set out on supply table before workshop begins: For use in Changes activity</td>
</tr>
<tr>
<td>nitrile safety gloves (optional) *</td>
<td>2 pairs</td>
<td>1 box (100)</td>
<td>For preparing phenol red dilution and to set out on supply table before workshop begins: For use in Changes activity. See the Material Safety Data Sheets (which will be provided when you buy the chemicals), and check your district policy to determine if you need safety gloves.</td>
</tr>
<tr>
<td>cafeteria-type tray (optional)</td>
<td>1 per pair</td>
<td>18</td>
<td>For setting out and clearing up materials in Changes activity</td>
</tr>
<tr>
<td>small (6-9 oz) plastic cups (for phenol red dilution)</td>
<td>—</td>
<td>18</td>
<td>Changes activity</td>
</tr>
<tr>
<td>sodium bicarbonate (baking soda)</td>
<td>35 grams</td>
<td>630 grams</td>
<td>Changes activity</td>
</tr>
<tr>
<td>calcium chloride*</td>
<td>30 grams</td>
<td>540 grams</td>
<td>Changes activity</td>
</tr>
<tr>
<td>small containers with caps (e.g., pill bottles) (for sodium bicarbonate and calcium chloride); labeled appropriately</td>
<td>1 sod. bic. and 1 cal. chlor. per pair</td>
<td>36 (18 of each)</td>
<td>Changes activity</td>
</tr>
<tr>
<td>set of measuring spoons</td>
<td>—</td>
<td>18</td>
<td>Changes activity</td>
</tr>
<tr>
<td>plastic medicine cups (1 oz. graduated) *</td>
<td>6</td>
<td>108</td>
<td>Changes activity</td>
</tr>
<tr>
<td>ziplock sandwich bags (use good quality to avoid leaks)</td>
<td>—</td>
<td>108</td>
<td>Changes activity</td>
</tr>
<tr>
<td>paper for data collection sheet</td>
<td>1 sheet</td>
<td>18 sheets</td>
<td>Changes activity</td>
</tr>
<tr>
<td>sponges</td>
<td>—</td>
<td>4-5</td>
<td>For cleanup</td>
</tr>
<tr>
<td>rolls of paper towels</td>
<td>—</td>
<td>2</td>
<td>For spills during activity and for cleanup</td>
</tr>
<tr>
<td>marking pen (for recording comments on “Evidence of Chemical Change” on blank overhead, if used)</td>
<td>—</td>
<td>1</td>
<td>For Examining Learner Responsibility for Direction of Activities (page 29)</td>
</tr>
</tbody>
</table>

* See following page for ordering information
### Finding and Using Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Source, Cost (2005 Prices)</th>
<th>Notes &amp; MSDS Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenol red</td>
<td>Science Kit &amp; Boreal Laboratories 1-899-828-7777 <a href="http://www.sciencekit.com">www.sciencekit.com</a></td>
<td>Available from science supply companies. Order in the powdered form for least-expensive shipping. Powdered phenol red is sold by the gram. You may also be able to find premixed phenol red at a swimming pool or hot tub supply stores, if there is one near you. Note: The Changes activity uses a diluted solution of phenol red. See the box on the next page for instructions.</td>
</tr>
<tr>
<td>calcium chloride</td>
<td>Science Kit &amp; Boreal Laboratories 1-899-828-7777 <a href="http://www.sciencekit.com">www.sciencekit.com</a> Calcium chloride (anhydrous), lab-grade flakes (4–8 mesh), about $6 for 500 grams. Item number: 9407606</td>
<td>Available in hardware stores in snowy areas or from chemical- or school-supply houses. (Many high school chemistry teachers have a supply.) Order powdered calcium chloride if you can get it. The granulated form is chunky, and workshop participants may confuse the formation of a precipitate with undissolved chunks of calcium chloride.</td>
</tr>
<tr>
<td>safety goggles</td>
<td>Educational Innovations 1-888-912-7474 <a href="http://www.teachersource.com">www.teachersource.com</a> or <a href="http://abcsafetymart.com/sglasses/goggles.html">http://abcsafetymart.com/sglasses/goggles.html</a> Prices vary from about $4 to $6 each, depending on how many goggles you buy.</td>
<td>Most high school chemistry teachers have goggles on hand that you could borrow, or they can be ordered from a supply house.</td>
</tr>
<tr>
<td>nitrile safety gloves (optional)</td>
<td>Educational Innovations 1-888-912-7474 <a href="http://www.teachersource.com">www.teachersource.com</a> or Professional Equipment 1-800-334-9291 or <a href="http://absolutesci.com/shopexd.asp?id=21264">http://absolutesci.com/shopexd.asp?id=21264</a> Prices vary from $6-10 / 100 pairs</td>
<td>Some schools require the use of nitrile safety gloves when handling chemicals, so check your district’s policies. (Note that some people are allergic to latex gloves, which is why nitrile is recommended.)</td>
</tr>
<tr>
<td>plastic medicine cups</td>
<td><a href="http://www.edlpmed.com/prpS1-500.html">www.edlpmed.com/prpS1-500.html</a> About $2 per 100</td>
<td>1 oz graduated</td>
</tr>
</tbody>
</table>
Making the Phenol Red Dilution

Before presenting the workshop, you’ll have to prepare a diluted solution of phenol red, which is used in the Changes activity on page 27.

To prepare this dilution, add 1 liter distilled water to 1 gram phenol red and shake or stir. Dilute with an additional 250 mL of water and mix again. Mix the phenol red in advance and store in a plastic container, such as a soda bottle or mayonnaise jar.

Because phenol red can cause a slight irritation to skin and eyes, we suggest that you wear safety goggles and perhaps gloves (see previous page for sources). You may also want to wear an apron, as phenol red can stain fabric.

Disposal of phenol red in a standard drain is considered safe.

Using Material Safety Data Sheets

The chemicals used in this workshop are standard household chemicals:

- **Phenol red**, a sodium salt, is an acid/base indicator used for testing water in hot tubs and swimming pools.
- In snowy areas, **calcium chloride** is used to melt ice on roads, sidewalks, and driveways.
- **Sodium bicarbonate** is baking soda; it can be purchased in large quantities at grocery and warehouse stores.

When you buy phenol red and calcium chloride, you’ll be provided with Material Safety Data Sheets. Make sure to consult and save these sheets, and note that both chemicals can cause slight irritation to the skin and eyes. Therefore, we recommend that facilitators and participants wear goggles; safety gloves are optional unless your district requires them.
### Overheads, Charts, and Handouts

Masters begin on page 49. They are identified by the letter M (for Master) and numbered in order of use.

#### Overheads

Photocopy the masters onto transparencies. If you prefer, or if an overhead projector is not available, you can make wall charts or handouts instead.

<table>
<thead>
<tr>
<th>Item</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Science Education Standards’ “Science as Inquiry: Content Standard A”</td>
<td>M1</td>
</tr>
<tr>
<td>Take-Home Messages</td>
<td>M2</td>
</tr>
<tr>
<td>Evidence of Chemical Change</td>
<td>M4</td>
</tr>
<tr>
<td>Teacher and Learner Responsibility in Science Activities</td>
<td>M5</td>
</tr>
<tr>
<td>Teacher-Identified Shifts</td>
<td>M8</td>
</tr>
<tr>
<td>Teacher-Identified Benefits of Shifts</td>
<td>M10a&amp;b</td>
</tr>
<tr>
<td>The Abilities to Do Scientific Inquiry - Process Skills</td>
<td>M11a-c</td>
</tr>
<tr>
<td>Measuring Shadows Activity (Unshifted)</td>
<td>M12</td>
</tr>
</tbody>
</table>

#### Charts

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 facsimiles onto chart paper or poster paper approximately the same size.

<table>
<thead>
<tr>
<th>Item</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifts</td>
<td>M7</td>
</tr>
<tr>
<td>Benefits of Shifts</td>
<td>M9</td>
</tr>
</tbody>
</table>

#### Handouts

Photocopy these handouts in the quantities indicated.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Science Education Standards “Science as Inquiry: Content Standard A”</td>
<td>Make one copy for each participant</td>
<td>M1</td>
</tr>
<tr>
<td>Take-Home Messages</td>
<td>Make one copy for each participant</td>
<td>M2</td>
</tr>
<tr>
<td>Changes Activity (Shifted)</td>
<td>Make one copy for each pair</td>
<td>M3</td>
</tr>
<tr>
<td>Teacher and Learner Responsibility in Science Activities</td>
<td>Make one copy for each participant</td>
<td>M5</td>
</tr>
<tr>
<td>Changes Activity (Unshifted)</td>
<td>Make one copy for each pair</td>
<td>M6</td>
</tr>
<tr>
<td>The Abilities to Do Scientific Inquiry - Process Skills</td>
<td>Make one copy for each participant</td>
<td>M11a-c</td>
</tr>
<tr>
<td>Measuring Shadows Activity (Unshifted)</td>
<td>Make one copy for each pair</td>
<td>M12</td>
</tr>
<tr>
<td>Measuring Shadows Activity (Shift 1)</td>
<td>Make one copy for each pair</td>
<td>M13</td>
</tr>
<tr>
<td>Measuring Shadows Activity (Shift 2)</td>
<td>Make one copy for each pair</td>
<td>M14</td>
</tr>
</tbody>
</table>
Background Science for the Changes Chemistry Activity

**Overview**

You don’t need to know chemistry in order to facilitate the Changes activity. The information here will let you know what the activity is about and what to expect.

**What Happens When There’s a Chemical Change?**

This activity asks participants to propose ways to tell whether a chemical change is taking place.

Substances can change in two different ways: chemically and physically. Physical change involves a change in physical properties, such as mass, length, and volume, as well as the state of matter (liquid, solid, gas).

But changing a physical property doesn’t change the chemical identity of a substance—it’s still made up of the same molecules. When water freezes, for instance, a physical change takes place (that is, a change of state from liquid to solid), not a chemical change, because both water and ice consist of H₂O molecules.

During a chemical change, however, atoms are rearranged to form different molecules—which means that different substances are created. Water (H₂O), for instance, is the result of a chemical change when hydrogen gas (H₂) and oxygen gas (O₂) are ignited.

Sometimes it’s tricky to tell whether a chemical or physical change has taken place. Mix yellow paint with blue paint, and a greenish color will result, but no new substance has been formed; the molecules are the same as in the original paints.

**What Happens in the Changes Activity?**

The Changes activity asks participants to combine three standard household chemicals—a phenol red solution, calcium chloride, and sodium bicarbonate—in a closed ziplock bag. When participants mix these chemicals together, they’re likely to see four of the ten most common signs of chemical change:

- Bubbles form.
- The color changes (the liquid changes from pink to yellow).
- The temperature changes (it feels warmer).
- Precipitates, or bits of solids, form (not always observed in this experiment).

All these changes are signs that a chemical change is taking place.

- The bubbles are a sign that a gas has been formed. (It’s carbon dioxide.)
- The color change to yellow indicates that the solution is more acidic. Phenol red is an acid-base indicator (like the more familiar litmus paper).
Increased temperature indicates that the reaction has released energy. Such a reaction is called exothermic or exoergic.

The precipitate indicates that a new substance has formed, one that is solid at room temperature. (It’s calcium carbonate, more commonly known as chalk.)

In the activity’s Option A, when calcium chloride and the phenol red solution are combined, the temperature increases, indicating that energy is being emitted—another exothermic reaction. And when sodium bicarbonate and the phenol red solution are combined, the temperature decreases—this indicates that energy is being absorbed, rather than emitted. This type of reaction is known as an endothermic, or endoergic, reaction.

Participants may see some or all of these signs of chemical change in Option B, depending on the proportions of the three chemicals used.

Recognizing Signs of Chemical Change

Although you probably won’t see the other six signs of chemical change in this activity, it’s interesting to know what they are. Here’s the whole list:

1. Bubbles form
2. Colors change
3. Temperature changes
4. Precipitates (solids) form
5. Light is emitted
6. A change in volume occurs
7. A change in electrical conductivity occurs
8. A change in the melting point or boiling point occurs
9. A change in smell or taste occurs
10. A change in any distinctive chemical or physical property occurs

While you might not rely on one sign as indication of a chemical change, during the Changes activity several actually occur, offering strong evidence of a chemical reaction.

For more information on the ten signs of chemical change, go to http://antoine.frostburg.edu/chem/senese/101/reactions/symptoms.shtml.
PRESENTING
THE WORKSHOP

Part 1: Introducing Subtle Shifts

• Introducing the Workshop
• Doing a “Shifted” Science Activity
• Examining Learner Responsibility for Direction of Activities
• Comparing Shifted and Unshifted Activities
Introducing the Workshop

Overview

At the beginning of the workshop, the facilitator establishes the tone by stating the purpose of the workshop and explaining how participants will work together. Being open about intentions and transparent about purpose are important in order to build trust and demonstrate respect for the participants as learners.

6 Steps • 10 Minutes

1. Ask the participants to introduce themselves. Begin the workshop by introducing the facilitators and asking the participants to introduce themselves.

2. Set the context for the workshop. Display overhead M1: “National Science Education Standards Content Standard A” and distribute the corresponding handout. Say:

   ▶ Inquiry is a powerful means of teaching science. The National Science Education Standards has focused on inquiry as a standard in its own right. It states that “as a result of activities in grades K–8, all students should develop the abilities to do scientific inquiry.”

Point to the overhead and say:

   ▶ For grades K–4, the Standards lists these abilities as . . .

Read the bulleted items under grades K–4 on overhead M1: National Science Education Standards Content Standard A.

   ▶ For grades 5–8, the Standards lists these abilities as . . .

Read the bulleted items under grades 5–8 on overhead M1: National Science Education Standards Content Standard A.

These abilities are the science process skills. In order to learn scientific concepts through inquiry, learners must become adept at using the science process skills, including formulating good questions, planning investigations to test ideas, interpreting data, and forming explanations based on data. It is important for teachers to help students develop these skills.

The more that learners have the opportunity for actually using the process skills, the more adept they will become. To get good at questioning, they need to have opportunities for asking their own questions. To become better at planning investigations and interpreting results, they need to be allowed to practice those skills.

Many science curriculum materials, including kits and other hands-on materials, do not provide opportunities for practic-
ing several of the science process skills. For example, they often establish the question to investigate and specify the steps of the procedure for investigation. However, as a teacher, you can gradually move toward giving your students more opportunities—and responsibility—for practicing the process skills. At the same time, you can shift your teaching to support and guide students in taking more responsibility for their use of the process skills.

This workshop lasts about 2 hours and 45 minutes. During that time, we’ll introduce you to a strategy you can use to develop the skills your students need for inquiry-based learning. The strategy involves making small changes in lessons and activities you already do. These shifts serve to give students more responsibility for using particular process skills. In the workshop, you’ll have an opportunity to experience a science activity that has been modified, and then you’ll compare it with the original, unmodified version. You’ll look at simple changes that have been made in an activity and identify the purpose of those changes. Finally, you’ll change an activity yourself in ways that are intended to accomplish specific learning purposes.

3. Refer to the take-home messages. Display overhead M2: “Take-Home Messages.” Tell participants:

▶ This workshop explores the concept of what we call “subtle shifts”—small changes in existing lessons and activities that prepare teachers and students to do inquiry. Let’s look at the main points we hope you’ll take away from this workshop.

Note: Below, the bold script represents the take-home messages as they appear on the overhead. The nonbold script represents comments you might make about the messages. Say:

▶ To help learners develop the abilities to do scientific inquiry, teachers need to give students responsibility for using the process skills of science.

In this workshop, you’ll learn a strategy for giving students more of that kind of responsibility.

Teachers can make small shifts in existing activities to help learners strengthen the process skills needed for scientific inquiry.

You’ll find that you can make a big difference for a learner by simply making small changes in the activities you already do. As we go through this workshop, you’ll see that by taking small steps, you and your students can move toward inquiry at a comfortable pace.

Lessons can be modified in specific ways to achieve particular purposes.

We’ll go over how small changes can be used to strengthen student inquiry skills. You’ll be able to gain experience with some aspects of inquiry teaching and find ways to give more responsibility for learning to your students.

4. Tell participants why you chose to present this workshop, describing how the workshop relates to the specific goals, standards, and other professional development activities of your district. You may also
want to talk about how the workshop relates to state and national standards. For more on how Subtle Shifts connects to the National Science Education Standards, see page 47.

5. **Explain that this workshop is designed for professional development.** Tell participants:

   - The chemistry activity in this workshop serves as a concrete example of a shifted science activity. It was designed with teachers, not students, in mind. If you wish to use the activity in the classroom, keep in mind that you’ll want to relate it to particular learning goals you have for your students. Also, please be aware that working with chemicals is potentially hazardous and that the activity may not be appropriate for younger students.

6. **Address the workshop schedule.** Tell participants that the workshop will take about 2 hours and 45 minutes. If you chose to post a simplified Workshop Schedule, refer to it here.
Doing a “Shifted” Science Activity

Overview
In this part of the workshop, participants work in pairs on a chemistry activity called Changes. The activity has been modified from its original version to be less prescriptive and to give students more opportunities to determine how they will practice the process skills of predicting, planning investigations, and interpreting results.

6 Steps • 40 minutes
1. Have participants form working pairs.
   Ask participants to choose partners. Then have one person from each pair go to the supply table to get their pair’s supplies, including handout M3: “Changes Activity (Shifted)” and a blank piece of paper for recording data.

2. Explain the Changes activity. Tell participants:
   - You’re about to do a standard science activity that has been modified to give learners more practice in using various process skills. Then you’ll compare it with the original version of the same activity.
   - You’ll combine some chemicals and carefully observe what happens. Then you’ll record what you saw that might indicate that a chemical change has taken place.

   - Before you begin working with the chemicals, put on safety goggles and gloves [if you have provided them]. Don’t smell or taste the materials.
   - You’ll have about 20–25 minutes to do a number of trials. Start by reading the directions on the activity sheet.

3. Circulate and provide assistance. Both facilitators should circulate, providing assistance as needed.
   - Remind participants to squeeze air out of the bag before sealing it.
   - If the calcium chloride has clumped (it often does), suggest that participants break up the clumps.
   - Suggest that participants touch the bag to check for changes in temperature.

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

- Have materials for the Changes Activity (Shifted) on the supply table, separated into one set for each pair (see the Materials list on page 17)
- Place handout M3: “Changes Activity (Shifted)” on supply table, one for each pair
- Display overhead M4: “Evidence of Chemical Change” (or blank overhead or chart) for recording participants’ responses
4. **Give a 5-minute warning.** After 20 minutes, let participants know that they have about 5 minutes left to complete their work.

5. **Bring work to a close.** When time is up, have participants stop experimenting and bring all their materials back to the supply table. (Note: After the workshop is over, you can dispose of the chemicals by pouring them down the sink along with extra running water. This is a safe and approved method of disposal for these materials.)

6. **Have participants discuss and share observations (15 minutes).** Ask each pair to get together with another pair and take a few minutes to discuss what they observed that they think indicates chemical change.

Reconvene the whole group and ask:

- What did you see that you think might indicate that a chemical change was taking place?

Record responses on the transparency, and briefly discuss any disagreements. If no one mentions these indications, you can tell participants:

- Some things you may have observed that could indicate chemical changes include
  - change in temperature
  - bubbles forming/expansion of the plastic bag
  - change in color
  - precipitates, or bits of solids, form

It’s hard to be sure if a chemical reaction has taken place if you only observe one sign. But several signs, as we observed in this activity, are fairly strong evidence. When you combined the sodium bicarbonate and calcium chloride with the phenol red solution, the chemical change resulted in salt, calcium carbonate, and carbon dioxide.
Examining Learner Responsibility for Direction of Activities

Overview

After participants have done the chemistry experiment and discussed their findings, the facilitator introduces the chart in overhead/handout M5: “Teacher and Learner Responsibility in Science Activities.”

Participants use the chart to identify where in the Changes activity students take responsibility for how they utilize various process skills. The chart suggests a continuum, moving from less to more responsibility for students. Teachers can make changes that locate parts of lessons (the question/problem; the procedure/design; the results/analysis) at various places along that continuum, depending on where students are in the practice of their process skills and where having more responsibility will help them continue to develop those skills.

The chart also allows teachers to analyze and reflect on their own teaching and consider where and how they might be able use less directed instruction by turning some responsibility over to students.

3 Steps • 10 Minutes

1. Introduce the Teacher and Learner Responsibility in Science Activities.

Display the overhead and pass out the handout M5: “Teacher and Learner Responsibility in Science Activities.” Tell participants:

> In preparing for inquiry you need to give students increased responsibility for the practice of the science process skills. Many educators have found it useful to think about the degree of student responsibility as a continuum, as illustrated on the “Teacher and Learner Responsibility in Science Activities” overhead and handout.

While this is a simplified version of reality, it’s useful to look at the chart to gain some understanding of the range of learner responsibility. As we look at activities today, we will be asking:

- Who determines the question or problem posed in the activity?
- Who determines the procedure or design of the activity?
- Who determines the results or analysis of the findings?

Materials Reminder

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

- Make sure participants still have handout M3: “Changes Activity (Shifted)”
- Display overhead and distribute handout M5: “Teacher and Learner Responsibility in Science Activities”
cides, we mark the chart in the Learner column.
In many activities, the teacher determines part
and the learner part of what goes on. In those
cases, we mark the chart in the Teacher/Learner
column.

You might think that every part of every activity
would go in the Teacher/Learner column since
both teacher and learner almost always play
some role in whatever goes on in hands-on learn-
ing. To make this chart a useful tool, we’ll mark
the Teacher column in cases where learners play
only a minor role and we’ll mark the Learner
column in cases where teachers play only a
minor role.

2. Have groups of four quickly decide who
determines each of the three questions.

Tell participants:

► In your groups of four, determine who makes the
decision in each of the chart’s categories for the
Changes activity you just did. Explain the reasons
for your choices. We’re not looking for deep analy-
sis. Just make a quick decision. You’ll have about a
minute or two to do so.

3. Have groups report out. After about a
minute, pick one of the small groups and ask:

► Who determines the question in the Changes ac-
tivity?

When this group answers, ask:

► Why do you think it’s ________________?

After they answer, ask:

► Did anyone else choose something different?
  Why?

Pick another small group and ask:

► Who did you say determines the procedure in the
Changes activity?

When this group answers, ask:

► Why do you think it’s ________________?

After their answer, ask:

► Did anyone else choose something different?
  Why?

Pick another small group and ask:

► Who did you say determines the results/analysis
  in the Changes activity?

When this group answers, ask:

► Why do you think it’s ________________?

After their answer, ask:

► Did anyone else choose something different?
  Why?

Tell the whole group:

► Although it is possible to reasonably identify dif-
erent answers, the teacher who made these
shifts had the following in mind.

Mark the Teacher column for “Who determines
the question?” and tell the participants:

► In the Changes activity, the worksheet/teacher
  poses the major question, “What indicates the
  occurrence of a chemical change?”

Mark the Teacher/Learner column for “Who de-
termines the procedure?” and tell the partici-
pants:
In the Changes activity, the teacher and learner each determine part of the procedure. The learner is required to plan the data collection sheet, choose an experimental option, and make additional choices about what do within each option. The teacher/worksheet determine the other parts of the procedure: for example, the steps and the amounts of chemicals to use in Exploration Part I.

Mark the Learner column for “Who determines the results?” and tell the participants:

In the Changes activity, the learner determines the results. The learner has to list what he or she saw that appeared to be evidence of a chemical change.
Comparing Shifted and Unshifted Activities

Overview

In this section, participants examine a more traditional version of the Changes activity that gives less responsibility to the student. They compare the Changes activity they did (the “shifted” activity) with the traditional version (the “unshifted” activity) by identifying and discussing the differences between the two.

By examining a concrete example of the ways an activity has been shifted, participants begin to understand how they can make changes for the purpose of giving students more choice and responsibility in using particular process skills. This increased responsibility helps students develop the abilities to do scientific inquiry.

7 Steps • 40 Minutes

Steps 1–4 • 25 Minutes


   Now, as you just did for the shifted Changes activity, in your groups of four, read over this handout of the unshifted version of the activity and determine who makes the decision in each of the Teacher and Learner Responsibility categories. Be prepared to explain the reasons for your choices. You have a few minutes to do this.

2. Ask participants to identify where the lesson falls on the continuum for each part of the lesson. After a few minutes, ask the group:

   Who do you think determines the question or problem?

Repeat for procedure/design and for results/analysis. (Note: Most people will say that the teacher/lesson determines the question and the procedures and design; and that the learner has some choice over the results/analysis.)
After a few people have responded, say:

▶ Now take about 5 minutes within your groups to identify what shifts were made to the unshifted version of the Changes activity to produce the shifted version you did earlier. For example, in the original activity, learners were told exactly what to investigate, while in the shifted activity, learners had some choice about what to investigate.

Have someone in your group record your ideas. After 5 minutes, we'll share some of your ideas.

3. **Have groups share.** After about 5 minutes, ask groups to share one shift they identified. Have the co-facilitator record these ideas on chart M7: “Shifts.” Take about 10 minutes to do this, having as many groups as possible share in that time.

**Steps 5–8 • 15 Minutes**

4. **Display overhead M8:** “Teacher-Identified Shifts.” Say:

▶ Now let’s look at some shifts that other groups of teachers identified in this activity. Look to see what similarities there are to your own lists, and what differences there are.

As you read the overhead aloud, point out shifts that the group identified in the previous step.

5. **Talk about benefits of the shifts.** Say:

▶ We’re going to take a few minutes now to talk about the benefits of various shifts that were made in this activity. As an example, one of the identified shifts is that in the new version, “the language of instruction is more open-ended” than the directive language of the original worksheet. Compare the statement, “Careful observations will help you gather evidence,” with the statement, “A chemical detective watches out for these four indicators (among others) of a chemical reaction:

1. change of color
2. change of temperature
3. formation of solids
4. formation of gases.”

These passages exemplify a shift from directing learners to allowing them to make discoveries. The shifted activity gives students the chance to find their own answers; the original one tells students what to look for.

Now, take 5 minutes to think about what benefits there might be to these shifts. In your group, discuss the question, “What might students gain by having more responsibility for their learning?” Have one group member record your ideas.

6. **Have groups share.** After 5 minutes, ask groups to share one benefit they identified, and have the co-facilitator record the responses on chart M9: “Benefits of Shifts.” Take 5 minutes to do this, having as many groups as possible share in that time.

7. **Display overhead M10a&b:** “Teacher-Identified Benefits of Shifts.” Tell
participants:

▶ Let’s look now at what other groups of teachers identified as some of the benefits of the shifts that were made. Again, look for similarities and differences with your own lists.

Read the first comment, then say:

▶ One benefit teachers have identified is that shifting gives students a sense of freedom and focus when they were asked to design their own data sheets.

Choose another of the teacher-identified benefits to read. You don’t have to read all the benefits on both pages. You might want to select only those that the group has not identified.

8. Tell people to take a 15-minute break.
Let them know what time to reconvene after the break.
PRESENTING THE WORKSHOP

Part 2: Using Subtle Shifts

- Identifying the Purposes for Shifts
- Making Shifts for a Particular Purpose
- Concluding the Workshop
Identifying the Purpose for Shifts

Overview

In this part of the workshop, participants examine subtle shifts made in a different sample activity, then discuss what the teacher was trying to accomplish by making those shifts. Examining a shifted activity in this way prepares them for the next part of the workshop, in which they will practice making their own shifts.

7 Steps • 25 Minutes

1. Introduce this part of the workshop.

Tell participants:

▶ We've just finished looking at some of the learning benefits that shifts can provide. As a teacher, you can make shifts in the activities your students do to achieve those benefits.

In this part of the workshop, you'll look at a shifted activity to see if you can identify the teacher's purpose in making the shift. And in the following part of the workshop, you'll design your own shifts for the same activity.

2. Pass out handout M11a–c: “The Abilities to Do Scientific Inquiry–Process Skills,” and display the corresponding overhead. The abilities listed on the handout and overhead are from the National Science Education Standards. The descriptions of students using the abilities are taken from the work of British science educator and author Wynne Harlen. Tell participants:

▶ The National Science Education Standards identifies the abilities necessary to do inquiry in grades K-4 and 5-8. On this overhead and handout, we provide descriptions of what students actually do when they practice the process skills. The descriptions are listed in developmental order, with higher numbers indicating more advanced skills.

We'll examine Raising Questions together, and you can look more closely at the other skills when you make your own shifts.

Read the Raising Questions category from the overhead aloud. Then tell par-
As you can see, this skill includes identifying questions that can be investigated and turning those that cannot be investigated into something that lends itself to investigation. The descriptions of the other science process skills give a similar level of detail.

In this part of the workshop, you’ll practice identifying how shifts in activities can help students develop these science inquiry skills.

3. Distribute handout M10: “Measuring Shadows (Unshifted)” and display the corresponding overhead.

Tell the group to take a few minutes to read through the activity. When they have finished, distribute handout M11: “Measuring Shadows (Shift 1)” and handout M12: “Measuring Shadows (Shift 2),” one copy to each pair.

4. Have participants identify shifts and their purposes. Tell participants:

   - With your partner, look at the two shifted versions of the Measuring Shadows activity. The shifted parts should be clear. Spend a few minutes identifying what you think the teacher was trying to accomplish by making each shift.

5. Have the group discuss the shifts (10 minutes). Reconvene the whole group and ask one pair:

   - What do you think the teacher was trying to accomplish in the Measuring Shadows (Shift 1) activity?

After that pair responds, ask:

- Did anyone come up with anything different?

6. Explain the shift. When everyone has had a chance to respond, explain the following (Note: If people mention planning, begin the following with “As was mentioned . . . ”)

   - The teacher’s purpose in making the shift was to give students more opportunity to practice and improve their skills in planning and conducting investigations. The unshifted activity gives distances that make the pattern in the data apparent. In the Measuring Shadows (Shift 1) activity, students have to determine what distances will help them see the pattern.
If participants identify purposes other than the one the teacher intended, acknowledge that:

- Although a shift may be intended to accomplish a particular purpose, there may be other results of that shift as well.

7. Ask for comments about the Measuring Shadows (Shift 2) activity.

When everyone has had a chance to respond, explain the following. (Note: Again, if people mention planning, begin the following with “As was mentioned . . .”)

- With this activity, the teacher wanted to give students more opportunity to practice and improve their planning and conducting investigations skills. When asked to make their own recording sheet, students have to learn how to design such a sheet—a planning and conducting investigations skill. Although Shift 2 is aimed at the same general skill area as Shift 1, it gives more responsibility to the student and requires a more developed level of this skill.
Making Shifts for a Particular Purpose

Overview

In this part of the workshop, participants work in pairs to practice making subtle shifts for the purpose of developing particular science process skills. Then, in a whole group discussion, they share the shifts they made, as well as the specific purpose for those shifts. Through this sharing, everyone can see the many and varied ways that shifts can be used to modify activities to fit students’ needs.

2 Steps • 20 Minutes

1. Tell participants they'll be working in pairs to make their own shifts in the original (unshifted) version of the Measuring Shadows activity. Explain:

- This part of the workshop gives you the opportunity to practice designing shifts in activities to help students develop the inquiry skills described in the Standards.

Using handout M12: “Measuring Shadows Activity (Unshifted),” work with your partner to devise a shift that gives students the opportunity to practice either a questioning skill or a predicting skill. Each of these skills has various levels of development, as described on “The Abilities to Do Scientific Inquiry” handout, so be specific about what part of that skill you are focusing on.

For example, let's say you want students to work on the process skill of questioning at Level 2, in order to be able to “participate effectively in discussing how their questions can be answered.” You might add a fifth step to the activity that asks them to write at least one question that they still have about the size of shadows and talk with a partner about how they might go about investigating that question.

Or maybe you want students to get better at predicting at Level 2: “Make some use of evidence from experience in making a prediction.” You might add steps at the beginning of the activity that ask them first to explore the materials. Then, before the first step, you could ask them to predict if the shadow will get bigger, smaller, or stay the same size if they move only the object further from the light (closer to the screen.)

Before the third step, you could ask them to predict if the shadow will get bigger, smaller, or stay the same size if they move only the light source further away from the object.

Write down your ideas so you can share them later. You'll have about 10 minutes to work on this.

2. After 10 minutes, have groups discuss their shifts. Display overhead M12: “Measuring Shadows Activity (Unshifted)”
Facilitation Hints for Making Shifts for a Particular Purpose

- **Relate Shifts to Purposes**
  Encourage participants to be explicit about how their shifts accomplish their purposes. Sharing the thinking behind a shift highlights the multiplicity of ways shifts can be made to accomplish a specific purpose and gives participants ideas that can help them as they begin making changes to the activities they normally do in the classroom.

- **Point Out Different Approaches**
  Point out that there are many different shifts that can be made for any activity. However, there should be a specific reason for making any shift.

- **Be Sure You’re Familiar with Some Examples**
  As a facilitator it is useful to have an idea of the kinds of subtle shifts that participants could make for both skills. Below are some examples:

  **Raising Questions**
  
  Purpose (Level 1): Readily ask a variety of questions that include investigable and noninvestigable ones.
  
  Shift 1: At the end of the activity, ask students to write down as many questions as they can think of about the size of shadows.
  
  Purpose (Level 3): Recognize the difference between an investigable question and one that cannot be answered by investigation.
  
  Shift: At the end of the activity, ask each student to write one question they still have about shadow. As a class, go through these questions and determine which could be investigated in a classroom and which could not. After sorting the questions, discuss what makes a question investigable or not.
  
  Purpose (Level 5): Ask questions which are potentially investigable.
  
  Shift: Ask students to write down a question about shadows that they think they can find the answer to using available materials.

  **Predicting**
  
  Purpose (Level 1): Attempt to make a prediction relating to a problem, even if the prediction is based on preconceived ideas.
  
  Shift: Before the activity, show the class the arrangement of light source, object, and screen. With the light source turned off, show moving the object away from the light without moving anything else and ask the group, “Who thinks the shadow will get bigger, who thinks the shadow will get smaller, and who thinks the shadow will stay the same?” Ask students to raise their hands in response and record the tally for each category. Do the same for moving the light source as in step 3 in Measuring Shadows (Unshifted).
  
  Purpose (Level 4): Explain how a prediction relates to a pattern in observations.
  
  Shift: After step 2, ask students, “Approximately how big do you think the shadow would be if you made the distance from light to object 40 cm? Explain how this prediction relates to the pattern in the size of the shadow.” After step 4, ask students, “Approximately how big do you think the shadow would be if you made the distance from light to screen 270 cm? Explain how this prediction relates to the pattern in the size of the shadow.”
  
  Purpose (Level 5): Use patterns in information or observations to make justified interpolations or extrapolations.
  
  Shift: Change step 2 and step 4 to, “Graph your results. Use your graph to predict the size of the shadow if you increased the distance by 30 cm.”
Concluding the Workshop

Overview
At the close of the workshop, it’s helpful to go back to the take-home messages introduced at the beginning of the workshop. Go over each one to help participants review their work and reflect on the experiences they’ve just had.

3 Steps • 5 Minutes

1. Go over the take-home messages once again. Display the overhead and distribute the corresponding handout. Read through the take-home messages point by point, so participants can review along with you.

   NOTE: Below, the bold script represents the take-home messages as they appear on the overhead and handout. The regular script represents comments you might make about the messages. Say:

   ▶ To help learners develop the abilities to do scientific inquiry, teachers need to give students responsibility for using the process skills of science.

   By taking additional responsibility for how to use the process skills, students can practice skills they might not otherwise have a chance to develop.

   Teachers can make small shifts in existing activities to help learners strengthen the process skills needed for scientific inquiry.

   Making these small shifts can have large impacts on students’ abilities to use the process skills effectively.

   Lessons can be modified in specific ways to achieve particular purposes.

   In this workshop, you practiced making changes to a relatively simple activity and found that you could accomplish specific purposes by doing so. However, many activities—particularly those from kits—can be more complex. Making subtle changes to those activities can be more difficult, but the practice you’ve had here will give you a good place to start.

2. Remind participants that the workshop is for professional development only. Say:

   ▶ The workshop you’ve just experienced was created especially for professional development; it was not intended for you to take back as-is to the classroom. However, if you choose to do the chemistry activity with your students, you’ll need to find ways to relate it to particular parts of your science curriculum.

3. As appropriate, let participants know the subjects of 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 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 adapting activities to move students toward inquiry developed during the workshop, and where you would like this group to go next in exploring the teaching of science.

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 enthusiastic about applying some of their new ideas in their own classrooms? Is there anything you could do to help engender more enthusiasm for trying out some of those new ideas?

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?
   • 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
• *Subtle Shifts* and the *National Science Education Standards*
• *Subtle Shifts* and Inquiry
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 Institute for Inquiry (IFI), a group of Exploratorium 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.

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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 five-part FUNDAMENTALS OF INQUIRY curriculum, Institute for Inquiry staff have also developed this five-part curriculum. Created with noted British researcher and educator Wynne Harlen, ASSESSING FOR LEARNING covers topics in both formative and summative assessment for teachers and professional developers. It’s available online at www.exploratorium.edu/ifi.

**ASSESSING FOR LEARNING**

**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)
At the Institute for Inquiry, we view inquiry as a way of learning that involves exploring the natural or material world, and that leads to asking questions, making observations, developing explanations, rigorously testing those explanations, and discussing and debating results with others. *Subtle Shifts: Adapting Activities for Inquiry* provides a way to help students strengthen their science process skills while at the same time helping teachers develop their abilities to support students learning science through inquiry.

Although inquiry is a natural human endeavor, students need to develop their inquiry skills—the process skills of science—in order to learn how to think and problem-solve in ways that can help them build a scientific understanding of the world. Well-developed process skills are necessary if student investigations are to lead to learning science content.

This workshop is built upon the idea that teachers can provide opportunities for the kind of practice that leads to the development of stronger science process skills by giving students more responsibility for using those skills. In many hands-on science curricula, the questions to investigate, the procedures for experimenting, and the problems to solve are already decided for the student. But to develop strong science process skills, students need opportunities to practice them on their own, with continual feedback and support from teachers, rather than using their skills only in ways determined by teachers or curriculum materials.

For example, students will never learn how to ask questions (a science process skill) that lead to productive investigations unless they get the chance to practice. When students raise their own questions, they become responsible for engaging with a material or topic, articulating questions based on their curiosity, and determining which of those questions can be investigated.

In this case, a teacher’s main responsibility is to support the students by observing and assessing their questioning skills and providing guidance where and when it can best assist them. When they have the responsibility to formulate questions, plan investigations to test ideas, interpret data, and form explanations based on data, students—with the help of their teachers—can more effectively develop their abilities to carry out inquiries that lead to an understanding of science concepts.

*Subtle Shifts: Adapting Activities for Inquiry* provides teachers with a strategy for moving their science teaching in the direction of inquiry, toward the goals described in the *National Science Education Standards* (see box, page 48). The strategy introduced in this workshop offers guidelines for making “subtle shifts”—strategic changes to existing activities that gradually give students more responsibility for using the process skills of science on their own. Teachers don’t have to turn entire lessons and activities over to students without any guidance or support; instead, they can give responsibility for particular parts of activities or lessons to students in order to give them practice in specific process skills.

Developing students’ abilities to become profi-
cient inquirers happens gradually, over time. Teachers must decide on the optimal balance between the amount of student responsibility versus the amount of teacher direction or instructional materials. But by making subtle shifts to activities they already use in the classroom, teachers can modify lessons to provide different degrees of student self-direction and teacher direction. When done gradually, the shifts can provide the necessary scaffolding to help students become more independent and effective learners, and can help teachers support learning through inquiry.

This workshop can serve not only to help students meet the National Science Education Standards’ goals for learning content, it can also help teachers make progress in meeting goals for teaching. In making subtle shifts toward increased student responsibility, a teacher makes gradual changes in his or her role as well, becoming more of a facilitator, observing and assessing students as they work in order to provide the guidance and support they need.

### Notes on Inquiry from the National Science Education Standards

**Content Standards**

“The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.”


**Teaching Standards**

“Teachers of science plan an inquiry based science program,”

2. Ibid., p. 30.

“...focus and support inquiries [and] encourage and model the skills of scientific inquiry.”

3. Ibid., p. 32.

The *Standards* refer to teaching through inquiry as “the central strategy for teaching science.”

4. Ibid., p. 31.
# Reproducible Masters

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**National Science Education Standards**

**Science as Inquiry: Content Standard A**

As a result of activities in grades **K–4**

all students should develop the abilities necessary to do scientific inquiry, including the following:

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations (spoken, drawn, or written).  

As a result of activities in grades **5–8**

all students should develop the abilities necessary to do scientific inquiry, including the following:

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.  


2. Ibid., pp. 145 & 148.
Take-Home Messages

■ To help learners develop the abilities to do scientific inquiry, teachers need to give students responsibility for using the process skills of science.

■ Teachers can make small shifts in existing activities to help learners strengthen the process skills needed for scientific inquiry.

■ Lessons can be modified in specific ways to achieve particular purposes.
Changes Activity (Shifted)

In this activity, you’ll try to determine whether or not a chemical change has taken place by investigating the question, “What indicates the occurrence of a chemical change?” Careful observations will help you gather evidence.

Exploration: Part I
Read all of Part I. Then design a data-collection sheet on which you can record what you do and what you observe. Be sure that it is in a format that is easy to follow and can be shared with others. Then do the activity.

- Put on your safety equipment.
- Place ¼ teaspoon of sodium bicarbonate (NaHCO₃) and ½ teaspoon of calcium chloride (CaCl₂) into a ziplock bag.
- Fill a medicine cup with 5 mL of phenol red solution. Carefully place the cup in the bag, keeping it upright until after you zip the bag closed.
- Squeeze out as much air as possible and seal the bag.
- Keeping the bag sealed, tip the cup over, mix the chemicals together, and observe the result.
- Record what you did and what you observed on your data-collection sheet. Record the evidence you think indicates a chemical change.

Exploration: Part II
Choose Option A or Option B (below) to continue your investigation. Design a new data-collection sheet for that option. Complete the second option if time permits, using another data collection sheet.

OPTION A
- Predict what would happen if you tried the experiment again but left out one of the chemicals.
- Test your prediction. Record what you did and what you observed.
- Repeat this experiment, leaving out a different chemical.

OPTION B
- Predict what would happen if you varied the amount of one of the chemicals.
- Test your prediction. Record what you did and what you observed.
- Repeat this experiment several times, each time varying a different chemical.

Summary
1. Analyze and summarize the results of your experiments on your data-collection sheets.
2. List any questions you still have on your data-collection sheets.
3. Describe what you have discovered about chemistry from this activity.

Adapted from an activity created by the Earth System Implementation Project of Anchorage, Alaska. Presented at the Kits to Inquiry Graduate Seminar at the Exploratorium’s Institute for Inquiry, March 1999.
Evidence of Chemical Change
Teacher and Learner Responsibility in Science Activities

<table>
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<th>Who determines the question/problem?</th>
<th>Learner</th>
<th>Teacher / Learner</th>
<th>Teacher</th>
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<td>Who determines the procedure/design?</td>
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<tr>
<td>Who determines the results/analysis?</td>
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**Learner**
The learner determines. The teacher may have a small role. (Note that, in this context, “Teacher” may also refer to lessons from science kits and other curriculum materials.)

**Teacher/Learner**
The teacher determines some parts and the learner determines some parts. There are a number of ways in which teachers and learners can share responsibilities. The following are some examples:

**The question/problem**
The students raise a number of questions after exploring materials. The teacher chooses one of these questions for the students to investigate.

**The procedure/design**
The teacher provides the procedure. The students decide how to record the data.

**The results/analysis**
The teacher tells students to expect to find a pattern in the data. The students figure out what the pattern is.

**Teacher**
The teacher determines. The learner may have a small role.

**NOTE:** This chart draws upon ideas from the following:
In this activity, you’ll experiment with chemical reactions that take place in a ziplock sandwich bag. The sealed bag prevents any chemicals from escaping before you have a chance to observe the reactions.

Chemists gather evidence by observing. A chemical detective watches out for these four indicators (among others) of a chemical reaction:

- change of color
- change of temperature
- formation of solids
- formation of gases

A good chemist must be careful and take the time to look for each of these kinds of evidence.

**Procedure**

- Put on your safety equipment.
- Place ¼ teaspoon of sodium bicarbonate (NaHCO₃) and ½ teaspoon of calcium chloride (CaCl₂) into the ziplock bag.
- Pour 5 mL of phenol red into the medicine cup.
- Place the cup carefully in the baggie so that it stays upright, squeeze out as much air as possible, and seal the bag.
- Tip over the cup and mix the contents together.

*Use the back of this sheet if you need more room to record your observations and discoveries.*

**Questions**

1. Write detailed observations of the changes you see.

2. What evidence have you gathered that a chemical reaction took place?

3. Predict what would happen if you left out the calcium chloride (CaCl₂). Try the experiment again, make careful observations of the changes you see and record them below. Predict what would happen if you left out the sodium bicarbonate (NaHCO₃). Try this, and record your observations and results.

4. What happens when you use ¼ teaspoon of sodium bicarbonate (NaHCO₃)? What if you use 1 teaspoon of calcium chloride (CaCl₂)? Record everything that happens and the amount of each chemical added.

5. What have you discovered about chemistry from this experiment?

*Adapted from an activity created by the Earth System Implementation Project of Anchorage, Alaska. Presented at the Kits to Inquiry Graduate Seminar at the Exploratorium’s Institute for Inquiry, March 1999.*
Shifts
Teacher-Identified Shifts

■ Language of instruction is more open-ended.

■ Learners design their own data sheets.

■ Learners choose what they investigate.

■ Learners are asked to report what they think is significant.

■ There’s no assumption that there’s a “right” answer.

■ There’s an expectation that learners will have new questions when they’re finished.
Benefits of Shifts
Teacher-Identified Benefits of Shifts

- Designing their own data sheets gives students a sense of freedom and also helps them focus.

- Because students aren’t told what to look for, they have to observe and interpret their results very carefully.

- Students have to use higher-order thinking skills to interpret and analyze what they are seeing.

- Students have to describe in detail what they observe, then analyze and summarize what they did very carefully.

- To explain their results, students have to write more than just brief notes.
Teacher-Identified Benefits of Shifts (continued)

- Students have ownership of what they do.
- Students are encouraged to make discoveries.
- It’s empowering to make your own discoveries.
- Having choices gives students confidence.
- Students have to think for themselves.
- Anticipating what results they might get keeps students involved.
The Abilities to Do Scientific Inquiry

In this chart, the list of abilities necessary to do scientific inquiry are from the *National Science Education Standards*. Each is followed by descriptions of the ability in action, based on the work of Wynne Harlen in *Teaching, Learning, and Assessing Science, 5–12*. The numbered entries describe progressively more sophisticated learner use of each skill.

### Raising Questions

<table>
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<th>Students in grades K–4 should be able to ask a question about objects, organisms, and events in the environment.</th>
<th>Students in grades 5–8 should be able to identify questions that can be answered through scientific investigation.</th>
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When raising questions, do the students:

1. Readily ask a variety of questions that include investigable and noninvestigable ones?
2. Participate effectively in discussing how their questions can be answered?
3. Recognize a difference between an investigable question and one that cannot be answered by investigation?

4. Suggest how answers to questions of various kinds can be found?
5. Generally, in science, ask questions which are potentially investigable?
6. Help in turning their own questions into a form that can be tested?

### Planning

<table>
<thead>
<tr>
<th>Students in grades K–4 should be able to plan and conduct a simple investigation.</th>
<th>Students in grades 5–8 should be able to design and conduct a scientific investigation.</th>
</tr>
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</table>

When planning, do the students:

1. Start with a useful general approach even if details are lacking or need further thought?
2. Identify the variable that has to be changed and the things that should be kept the same for a fair test?
3. Identify what to look for or what to measure to obtain a result in an investigation?
4. Succeed in planning a fair test using a given framework of questions?

5. Compare their actual procedures after the event with what was planned?
6. Spontaneously structure their plans so that independent, dependent, and controlled variables are identified and steps taken to ensure that the results obtained are as accurate as they can reasonably be?
### Observing and Interpreting

<table>
<thead>
<tr>
<th>Students in grades K–4 should be able to employ simple equipment and tools to gather data and extend the senses.</th>
<th>Students in 5–8 should be able to use appropriate tools and techniques to gather, analyze, and interpret data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>When observing, do the students:</td>
<td>When interpreting, do the students:</td>
</tr>
<tr>
<td>1. Succeed in identifying obvious differences and similarities between objects and materials?</td>
<td>1. Discuss what they find in relating to their initial questions?</td>
</tr>
<tr>
<td>2. Make use of several senses in exploring objects or materials?</td>
<td>2. Compare their findings with their earlier predictions?</td>
</tr>
<tr>
<td>3. Identify differences of detail between objects or materials?</td>
<td>3. Notice associations between changes in one variable and another?</td>
</tr>
<tr>
<td>4. Identify points of similarity between objects where differences are more obvious than similarities?</td>
<td>4. Identify patterns or trends in their observations or measurements?</td>
</tr>
<tr>
<td>5. Use their senses appropriately and extend the range of sight using a hand lens or microscope as necessary?</td>
<td>5. Draw conclusions that summarize and are consistent with all the evidence that has been collected?</td>
</tr>
<tr>
<td>6. Distinguish from many observations those that are relevant to the problem at hand?</td>
<td>6. Recognize that any conclusions are tentative and may have to be changed in the light of new evidence?</td>
</tr>
</tbody>
</table>

### Hypothesizing and Predicting

<table>
<thead>
<tr>
<th>Students in grades K–4 should be able to use data to construct a reasonable explanation.</th>
<th>Students in grades 5–8 should be able to • develop descriptions, explanations, predictions, and models using evidence • think critically and logically to make the relationships between evidence and explanations • recognize and analyze alternative explanations and predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>When hypothesizing, do the students:</td>
<td>When hypothesizing, do the students:</td>
</tr>
<tr>
<td>1. Attempt to give an explanation that is consistent with evidence, even if only in terms of the presence of certain features or circumstances?</td>
<td>4. Show awareness that there may be more than one explanation that fits the evidence?</td>
</tr>
<tr>
<td>2. Attempt to explain things in terms of a relevant idea from previous experience even if they go no further than naming it?</td>
<td>5. Give explanations that suggest how an observed effect or situation is brought about and which could be checked?</td>
</tr>
<tr>
<td>3. Suggest a mechanism for how something is brought about, even if it would be difficult to check?</td>
<td>6. Show awareness that all explanations are tentative and never proved beyond doubt?</td>
</tr>
</tbody>
</table>
When communicating, do the students:
1. Talk freely about their activities and the ideas they have, with or without making a written record?
2. Listen to others’ ideas and look at their results?
3. Use drawings, writing, models, paintings to present their ideas and findings?
4. Use tables, graphs, and charts when these are suggested to record and organize results?
5. Regularly and spontaneously use information books to check or supplement their investigations?
6. Choose a form for recording or presenting results, which is both considered and justified in relation to the type of information and the audience?

Communicating

| Students in grades K–4 should be able to communicate investigations and explanations (spoken, drawn, or written). |
| Students in grades 5–8 should be able to communicate scientific procedures and explanations. |

When predicting, do the students:
1. Attempt to make a prediction relating to a problem even if it is based on preconceived ideas?
2. Make some use of evidence from experience in making a prediction?
3. Make reasonable predictions based on a possible explanation (hypothesis) without necessarily being able to make the justification explicit?
4. Explain how a prediction that is made relates to a pattern in observations?
5. Use patterns in information or observations to make justified interpolations or extrapolations?
6. Justify a prediction in terms of a pattern in the evidence or an idea that might explain it?

References
Measuring Shadows Activity (Unshifted)

**Procedure**

1. Keep the light source in the same spot and move the object. Measure and record the size of the shadow with the object at the listed positions.

<table>
<thead>
<tr>
<th>Distance from light to screen</th>
<th>Distance from light to object</th>
<th>Size of object</th>
<th>Size of shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 cm</td>
<td>60 cm</td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>240 cm</td>
<td>80 cm</td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>240 cm</td>
<td>120 cm</td>
<td>15 cm</td>
<td></td>
</tr>
</tbody>
</table>

2. What patterns do you see in the sizes of the shadows?

3. Move the light source and keep the object in the same place. Measure and record the size of the shadow with the light source at the listed positions.

<table>
<thead>
<tr>
<th>Distance from light to screen</th>
<th>Distance from object to screen</th>
<th>Distance from light to object</th>
<th>Size of object</th>
<th>Size of shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 cm</td>
<td>120 cm</td>
<td>40 cm</td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>180 cm</td>
<td>120 cm</td>
<td>60 cm</td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>240 cm</td>
<td>120 cm</td>
<td>120 cm</td>
<td>15 cm</td>
<td></td>
</tr>
</tbody>
</table>

4. What patterns do you see in the sizes of the shadows?

*Adapted from a commonly used classroom activity.*
Measuring Shadows Activity (Shift 1)

**Note:** Gray areas indicate shifts in the activity.

**Procedure**

1. Keep the light source in the same spot and move the object. Measure and record the size of the shadow with the object at different positions. Choose positions that will help you see patterns in your result.

<table>
<thead>
<tr>
<th>Distance from light to screen</th>
<th>Distance from light to object</th>
<th>Size of object</th>
<th>Size of shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td>240 cm</td>
<td></td>
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</tr>
<tr>
<td>240 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
</tbody>
</table>

2. What patterns do you see in the sizes of the shadows?

3. Move the light source and keep the object in the same place. Measure and record the size of the shadow with the light source at different positions. Choose positions that will help you see patterns in your result.

<table>
<thead>
<tr>
<th>Distance from light to screen</th>
<th>Distance from object to screen</th>
<th>Distance from light to object</th>
<th>Size of object</th>
<th>Size of shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
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<tr>
<td></td>
<td>120 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
</tbody>
</table>

4. What patterns do you see in the sizes of the shadows?

*Adapted from a commonly used classroom activity.*
Measuring Shadows Activity (Shift 2)

Procedure

1. Use an object 15 cm high. Keep the light 240 cm from the screen and move the object. Measure and record the size of the shadow when the distance from the light to the object is:

   - 60 cm
   - 80 cm
   - 120 cm

   **Make your own recording sheet.** Record your experiment and results in a way that will help you see patterns in the sizes of the shadows.

2. What patterns do you see in the sizes of the shadows?

3. Use an object 15 cm high. Move the light source and keep the object 120 cm from the screen. Measure and record the size of the shadow when the distance of the light source from the screen is:

   - 160 cm
   - 180 cm
   - 240 cm

   **Make your own recording sheet.** Record your experiment and results in a way that will help you see patterns in the sizes of the shadows.

4. What patterns do you see in the sizes of the shadows?

*Adapted from a commonly used classroom activity.*