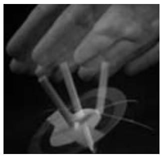
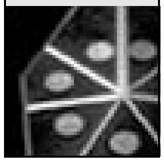
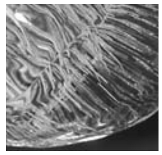
Workshop I 

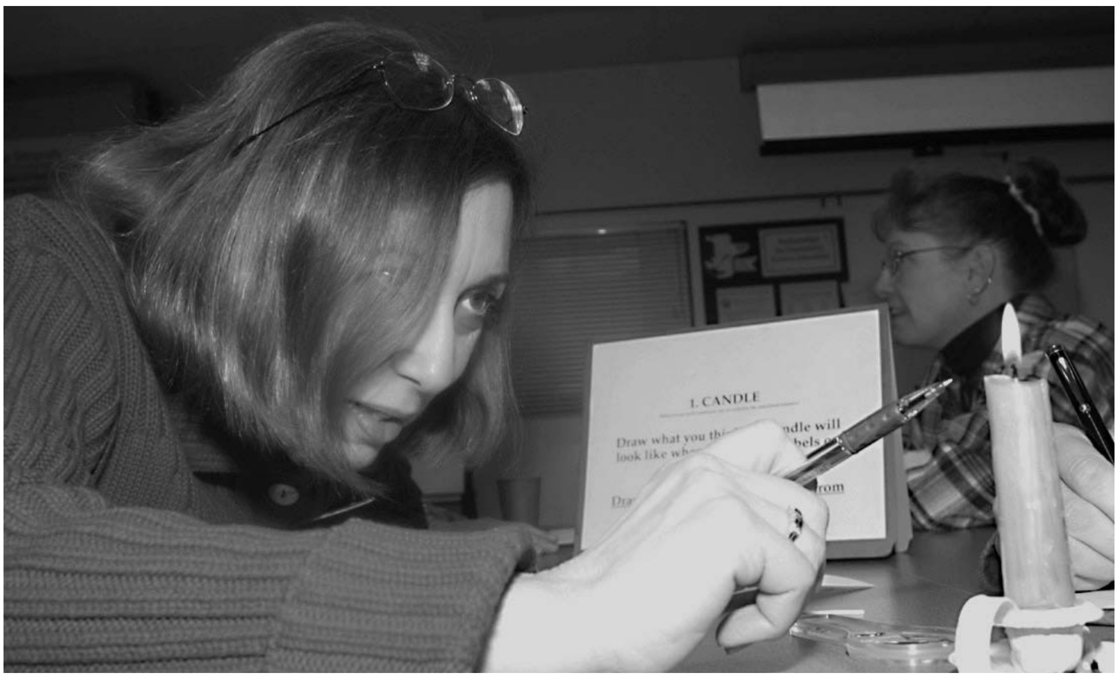
Workshop II 

Workshop III 

Workshop IV 

Workshop V 

Fundamentals of Inquiry Facilitator's Guide



WORKSHOP II: PROCESS SKILLS

A Professional Development Curriculum from the
Institute for Inquiry®

The second in a set of five workshops for teacher professional development.

exploratorium®
the museum of science,
art and human perception

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The initial ideas for *Process Skills* came from Wynne Harlen, noted British science educator and author or editor of such books as *The Teaching of Science in Primary Schools, UNESCO Sourcebook for Science in the Primary School,* and *Primary Science: Taking the Plunge.* Dr. Harlen has worked with the Exploratorium Institute for Inquiry for a number of years, facilitating workshops for professional developers and engaging in an ongoing dialogue with us about inquiry-based science instruction. Her thinking infuses this workshop and we are grateful for her generosity in sharing her ideas.

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/processskills.
A wealth of background material, for this and the other guides in the series, can be found at www.exploratorium.edu/ifi/library.

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.

Process Skills

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 this 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.

In the *Process Skills* workshop, participants work to develop their understanding of the central role of the process skills of science in learning scientific concepts. They see what those skills look like in action as students use them at various developmental levels and they consider how to make changes in science activities that will help students develop their skills to higher levels.

We hope you find this workshop useful in establishing a vibrant setting for participants to learn and extend their practice. And we hope that, like us, you will be inspired by seeing teachers enthused about science, eager to bring the very best ideas and approaches to their students.

—LYNN RANKIN
Director
Institute for Inquiry

Contents

Acknowledgments

Project Directors
Lynn Rankin, Barry Kluger-Bell

Curriculum Developers
Lynn Rankin, Barry Kluger-Bell, Fred Stein, Marilyn Austin, Karen Wilkinson, Mike Petrich, Candice Brown

Project Producer
Ruth Tepper Brown

Project Designer
Kristina Hooper Woolsey, Woolsey & Associates

Project Writer
Buff Whitman-Bradley

Project Evaluators
Barbara Heenan, Inverness Research Associates
Mark St. John, Inverness Research Associates

Series Editor
Erin Van Rheenen

Project Editors
Judith Brand, Martha Nicholson Steele, Laura Jacoby, Buff Whitman-Bradley

Graphic Designers
Gary Crounse, Alisa Lowden, Esther Kutnick, Barbara Del Rio, John Mavroudis, Steve Kearsley

Photographers
Lily Rodriguez, Amy Snyder, Mike Petrich, Karen Wilkinson

Web Designers
Karen Wilkinson, Mike Petrich

Web Developers
Jenny Villagrán, Rob Rothfarb, Adrian Van Allen, Robin Marks

Project Managers
Avon Swofford, Pat Koblenz

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Workshop Reviewers
Many educators participated in the testing and refinement of the Fundamentals of Inquiry curriculum. We are grateful for their exceptional contributions.

Althea Chow
Seattle Public Schools, Seattle, WA

Ana Crossman
Seattle Public Schools, Seattle, WA

Thelma Davis
Clark County School District, Las Vegas, NV

Linda Gregg
TERC, Cambridge, MA

David Hartney
First Hand Learning, Inc., Buffalo, NY

Erica Ingber
Pasadena Unified School District, Pasadena, CA

Kelly Lawson
Pasadena Unified School District, Pasadena, CA

Laura MacDonald
Clark County School District, Las Vegas, NV

Pat McGlashan
First Hand Learning, Inc., Buffalo, NY

Kirsten Nesholm
Seattle Public Schools, Seattle, WA

Gail Paulin
Tucson Unified School District, Tucson, AZ

Steve Piccinicci
Clark County School District, Las Vegas, NV

Harold Pratt, President
Educational Consultants, Inc., Littleton, CO

Wayne Ransom
Franklin Institute, Philadelphia, PA

Alex Rubalcaba
Pasadena Unified School District, Pasadena, CA

Paula Schachtel
Seattle Public Schools, Seattle, WA

Katherine Show
Seattle Public Schools, Seattle, WA

Kristina Wentdorf
Seattle Public Schools, Seattle, WA

Elaine Woo
Seattle Public Schools, Seattle, WA

Karen Worth
Education Development Center, Newton, MA

Jennifer Yuré
Pasadena Unified School District, Pasadena, CA

ABOUT THIS WORKSHOP

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

Workshop Overview

A Quick Summary

This is the second in a set of five guides in the FUNDAMENTALS OF INQUIRY curriculum. The guides are designed to help facilitators plan and present professional development workshops for educators who want to develop an understanding of inquiry-based science instruction.

The *Process Skills* workshop provides new pedagogical understandings and skills, rather than activities participants can take back to their classrooms. The workshop helps participants develop an understanding of the science process skills—skills needed to generate and test new ideas, build new knowledge, and learn scientific concepts. *Process Skills* lets teachers "think together" about the ways they understand the process skills of science (observing, questioning, hypothesizing, and so on), what the skills look like as students practice them at various developmental levels, and how to create opportunities for students to bring their skills to higher levels.

The process skills are ways of thinking about and interacting with materials and phenomena that can lead to an understanding of new scientific ideas and concepts. By using these skills, students can gather information, test their ideas, and construct scientific explanations of the world. Process skills are especially important in inquiry-based learning; they are tools that students use to carry out scientific investigations and build an understanding of scientific concepts from the results of those investigations.

This workshop uses seven categories of process skills: observing, questioning, hypothesizing, predicting, planning and investigating, interpreting, and communicating. There are other, longer lists that are equally acceptable, but a shorter list is more manageable. See "Process Skills: Definitions and Examples" (pages M13a–c) for additional information.

Goals

- **To enable teachers to construct a more complete and accurate understanding of the process skills of science and the central role these skills play in the learning of science concepts.**
- **To further teachers' abilities to identify the developmental levels of the process skills and to redesign science activities in ways that will promote students' continuing development of these skills.**

The Goals of the Workshop

As much as they need a firm grasp of science content, teachers must have a solid working knowledge of the process skills of science—and understand the critical role they play in student learning—in order to help their students get the most out of hands-on science experiences. The stronger the students' science process skills, the better they'll learn science content.

This professional development workshop provides the opportunity, through hands-on activities and carefully crafted discussions, for participants to clarify and deepen their understanding of what the process skills of science are and how students use them. In addition, the workshop gives participants the chance to practice ways of helping their students develop their process skills more fully.

During the *Process Skills* workshop, participants are strongly encouraged to be reflective and analytical—to think about the role of process skills in their teaching and in their students' learning. Some participants may have given very little thought to the process skills before this workshop. Others will find the views they bring to the workshop challenged by the very different views of others. Most will find that they have to rethink and expand their understanding of the process skills.

How the Workshop Works

This workshop takes approximately three-and-a-half hours and is designed to be presented by two facilitators. Typically, planning takes about five 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.

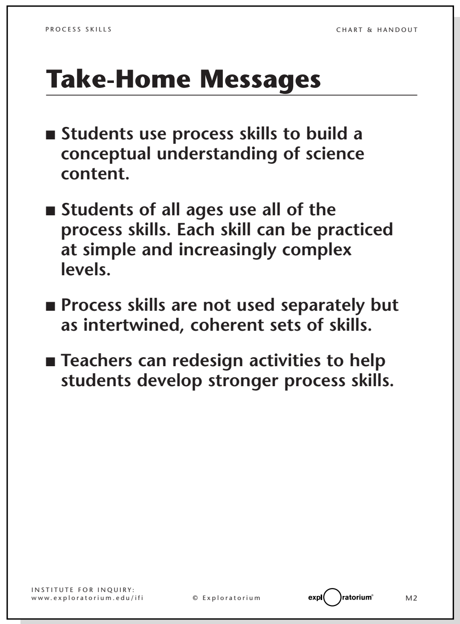
We recommend 12 to 36 participants for our workshops. Having fewer than 12 does not allow for the lively group interaction that is such an important component of the workshop. Having more than 36 makes whole group discussions unwieldy and can necessitate an additional facilitator.

In the first part of the workshop, participants work in pairs as they rotate through six stations where they do science activities and identify the principal process skill used in each. Afterward, first in groups of four, then as a whole group, they discuss their findings and any differences of opinion they have. Attempting to understand and resolve these differences in identifying process skills can lead to useful and important changes in the way participants understand the skills.

These discussions prepare participants to compare the way they understand the process skills with the definitions of these skills presented by the facilitator. Participants sometimes find that their understandings are incomplete or incorrect, in which case they must shift or enlarge their ideas to bring them into line with the standard definitions of the skills. But without first connecting with their prior understandings and experience, they are unlikely to change their thinking. In working with partners to identify the process skills in action, they must discuss their ideas about process skills with each other. Partners may find that they have different ideas, but they usually come to agreement without too much trouble.

When the pairs join to form groups of four, they often find that the other pair has identified some of the process skills differently. As they discuss these differences, participants begin to question the correctness and completeness of their own understanding of the process skills. Finally, in the large group discussion, people see that these differences in opinion are not unique to their groups of two or four. They get the opportunity to compare their ideas with those they hear from others and to look at some of the arguments for these alternative ideas. As a group, they begin to develop a common perspective on which skills are the most difficult to define.

After participants have had these several opportunities to discuss their ideas about process skills, they are given standard definitions of the skills in the second part of the workshop. Providing them with definitions too early in the process could lead participants to merely accept or reject what they've been told rather than developing their own understanding of the skills. In small group discussions, participants work to reconcile their own understandings of the process skills with the definitions they've been given. Then, they read and discuss an anecdote that describes students using the process skills to learn science content.



PROCESS SKILLS CHART & HANDOUT

Take-Home Messages

- Students use process skills to build a conceptual understanding of science content.
- Students of all ages use all of the process skills. Each skill can be practiced at simple and increasingly complex levels.
- Process skills are not used separately but as intertwined, coherent sets of skills.
- Teachers can redesign activities to help students develop stronger process skills.

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M2

In the third part of the workshop, participants examine what students do when they practice particular process skills at various developmental levels. To be effective in helping students develop their use of process skills, teachers need to be able to identify students' current skill levels and provide activities that help advance them to the next level. So next, participants examine a science activity and identify the level of the skills required. And finally, they redesign an activity to increase the developmental level of particular process skills, much as they would do 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 messages deepens as the workshop progresses, and as participants become intellectually engaged in building new ideas based on their firsthand experiences and their conversations with each other. The take-home messages are revisited at the end of the workshop as a way to summarize and reinforce the understandings participants have constructed.

The Workshop in Context

FUNDAMENTALS OF INQUIRY

Process Skills is the second 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.

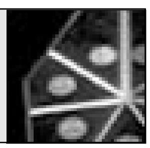
The FUNDAMENTALS OF INQUIRY curriculum is organized into three areas:

Elements of Inquiry

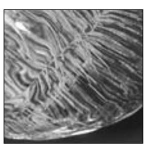
A set of workshops that serve as building blocks for an immersion into inquiry by focusing on various hands-on approaches and process skills related to inquiry learning.

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



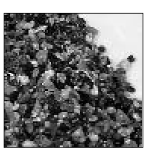
Workshop II: Process Skills
Participants identify the tools needed to carry out inquiry—the process skills—and examine the role of these skills in learning (about 3.5 hours).
Preview the workshop at www.exploratorium.edu/ifi/skills



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

Immersion in Inquiry

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



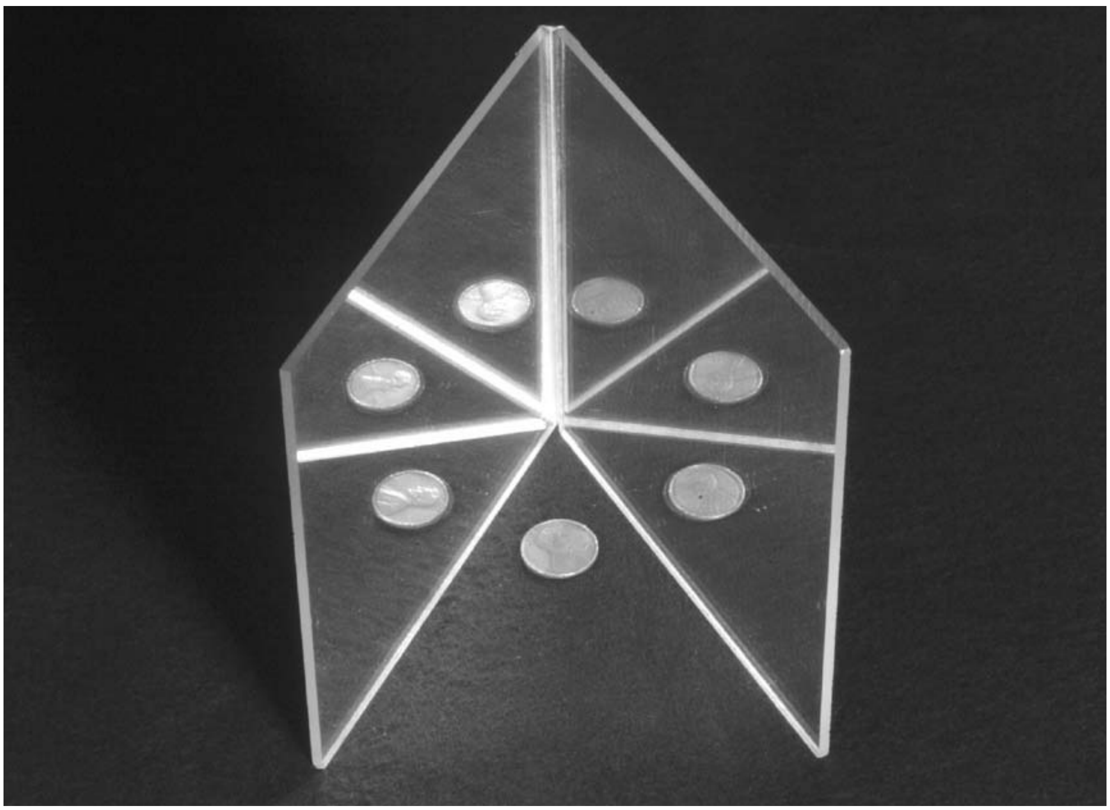
Workshop IV: Stream Table Inquiry
Participants experience inquiry firsthand, learning scientific process and content through an extended investigation (about 6 hours).
Preview the workshop at www.exploratorium.edu/ifi/streamtable

Connections to the Classroom

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

Workshop V: Subtle Shifts: Adapting Activities for Inquiry
Participants examine how current classroom activities can be modified to incorporate elements of inquiry (about 3 hours).
Preview the workshop at www.exploratorium.edu/ifi/subtleshifts

PLANNING AND PREPARATION



- **Workshop at a Glance**
- **Essential Planning Steps**
- **Sample Room Setup**
- **Materials**
- **Charts, Task Cards, Overheads, and Handouts**
- **Preparing the Materials**

Workshop at a Glance

Workshop Time: Approximately 3½ hours

Facilitators Needed: 2

Participants Accommodated: 36

Planning and Preparation
5 hours + materials prep

Presenting the Workshop Part 1: Identifying Process Skills

Introducing the Workshop
Facilitator sets the context for the workshop. **15 minutes**

Exploring Process Skills
Pairs rotate through six hands-on stations and identify the main process skill in each activity. 18 groups; 2 people each. **30 minutes**

Small-Group Discussions
Groups of four discuss the process skills needed at each station. 9 groups; 4 people each. **20 minutes**

Whole-Group Discussion
Facilitator guides a whole-group discussion, which exposes participants to new ideas about the process skills. **25 minutes**

Break — 10 minutes

Presenting the Workshop Part 2: How Students Use Process Skills

Process Skill Definitions
Facilitator presents some generally agreed-on definitions of the process skills. **25 minutes**

Process Skills and Student Learning
Participants consider how students use process skills to learn new science concepts. **20 minutes**

Presenting the Workshop Part 3: Helping Develop Process Skills

Developmental Levels of Process Skills
Pairs identify the developmental levels of process skills needed in an activity, then revise an activity to increase the skill levels. 18 groups; 2 people each. **55 minutes**

Concluding the Workshop
Facilitator summarizes the main ideas of the workshop. **5 minutes**

Reviewing the Workshop
time as needed

Essential Planning Steps

Planning Time Needed

Planning typically takes about 5 hours, not including the time necessary to gather and prepare materials.

Overview

The *Process Skills* 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 and agreeing on how much time you'll need to accomplish all the necessary planning and preparation. There's a lot to do, including reading through this entire guide, preparing to lead discussions, trying the workshop yourselves, arranging for an appropriate space, and collecting, ordering, or constructing a wide array of materials. 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 in subsequent workshops.

Before the Workshop

1. Read this guide all the way through. It is essential for you to read through this guide before you do any of the planning steps that follow. 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/skills.

3. Prepare materials. Gather and prepare all materials for participants (see complete list on page 17). Materials are all common and easily available.

• Duplicate and prepare all handouts, charts, overheads, and task cards (see page 18). Prepare hinged mirrors and mount the task cards on file folders or card stock as shown on page 20.

• To make it easy to set up on the day of the workshop, organize the handouts, charts, and overheads according to when and where they'll be used. Organize the materials and mounted task cards by activity.

4. Do the workshop as learners. Once you have gathered the materials, meet with your co-facilitator and go through the workshop as if you were participants, so you can get a feel for how the participants will experience it.

• Read the task cards, do the activities, and fill in a copy of the M9: "Process Skills Identification" handout. You might want to take more than the designated time when you do this part of the workshop, in order to feel confident in your understanding of which process skill is required at each station. You may find that you and your facilitation partner have some disagreements about how you filled in the form—the same kinds of disagreements that are likely to come up when you present the workshop to a group of teachers. Exploring these differences of opinion is a good way to help shared understandings take shape. You don't have to resolve the disagreements, just discuss them.

• After you have identified the main process skills at all of the stations, read through the M11a&b: "Observing Process Skills in Action" handout and consider your identification of the main process skills in light of what you read. Typically, participants have the most difficulty fully understanding or agreeing about the definitions of and differences among hypothesizing, predicting and interpreting. Carefully read the sidebar, "How Hypothesizing and Predicting and Interpreting Differ" on page 33 and be sure you feel confident in your understanding of each skill and the differences among the skills.

• Read through the M13a–c: "Process Skills: Definitions and Examples" handout.

• Read through M14: "Student Learning: Condensation," which illustrates how students use process skills to learn science content. Look over the M15a–c: "Learning about Condensation" diagrams.

• Try M17: "Identifying the Levels of Process Skills (Windup Toy Activity)," and experiment with M18: "Changing the Levels of Process Skills (Penny and Water Drops Activity)." Again, give yourself plenty of time to do the activities in order to thoroughly ground yourself in what participants will be doing, so you'll be able to anticipate some of their questions and responses.

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.

5. Review the workshop as facilitators.

• Decide on which tasks each of you will do. You both need to be involved in all aspects of the workshop, but you might want to take primary and secondary responsibility for different sections. For example, one of you might introduce a section and lead a discussion while the other distributes handouts and keeps time.

• Practice presenting the scripted information (shown *in italics*, and marked with arrows). While it's important to convey the scripted information in a way that's close to what is written, it will probably work best for you to say it in your own words, rather than reading the scripts.

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.

6. Familiarize yourselves with each section. You should read through the steps carefully, studying the prompts and facilitation hints and becoming familiar with the information and the instructions.

• For most of the workshop, the facilitation is quite simple. When the participants are working in small groups, both facilitators need to circulate and be available to answer questions.

• The 25-minute Whole-Group Discussion section requires careful and skillful facilitation that will help participants work toward a richer and more complete understanding of the process skills. There is extensive facilitation advice to help guide you and to help you be aware of some of the questions and issues that might arise as the workshop proceeds.

• When participants are practicing identifying and changing skill levels, the whole-group discussion should be brief. Since it is only intended to illustrate the process of adjusting the skill level of activities, it does not require a lot of give-and-take between participants or with the facilitator.

7. Be prepared to set the context. Setting the context for the workshop is crucial. Study the information in Introducing the Workshop (page 22), and practice setting the context in your own words.

• In setting the context, be prepared to explain why you chose to present this workshop. How does it fit with other professional development experiences the participants have had? How is it related to district and state goals and standards? What do you want participants to get from the experience? You might also want to relate the workshop to the *National Science Education Standards* (see page 53).

8. Be prepared to give presentations. There are three presentations that should be practiced in advance. You'll find them in Process Skill Definitions (page 36), in Process Skills and Student Learning (page 38), and in Developmental Levels of Process Skills (page 43).

9. Plan time and space carefully.

• Decide where the workshop will take place. See the 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 Context, 9:00–9:05; Review Process Skills Chart and Explain Workshop Design, 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 below.

• Remember that times given for 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.

Sample Schedule for *Process Skills* Participants

9:00–9:15	Introducing the Workshop
9:15–9:45	Exploring Process Skills
9:45–10:05	Small-Group Discussions
10:05–10:30	Whole Group Discussion
10:30–10:40	Break
10:40–11:05	Process Skills Definitions
11:05–11:25	Process Skills and Student Learning
11:25–12:20	Developmental Levels of Process Skills
12:20–12:25	Concluding the Workshop

10. Assess needs for additional information. Be sure to read *Process Skills* and the *National Science Education Standards,* and *Process Skills* and Inquiry Learning on pages 53–55. These sections offer background information about the Institute for Inquiry's approach to inquiry learning, as well as information on how this workshop supports the *Standards*. You may want to copy this section for participants.

On the Day of the Workshop

1. Prepare the room. Consult the Materials list on page 17. Set out the necessary materials and mounted task cards on the tables where groups will be working. Put the handouts, charts, and overheads near where you will be using them.

- Post the M1: "Process Skills" and M2: "Take-Home Messages" charts where all can see.
- Keep ice cubes or crushed ice in the freezer or ice chest until the last minute.

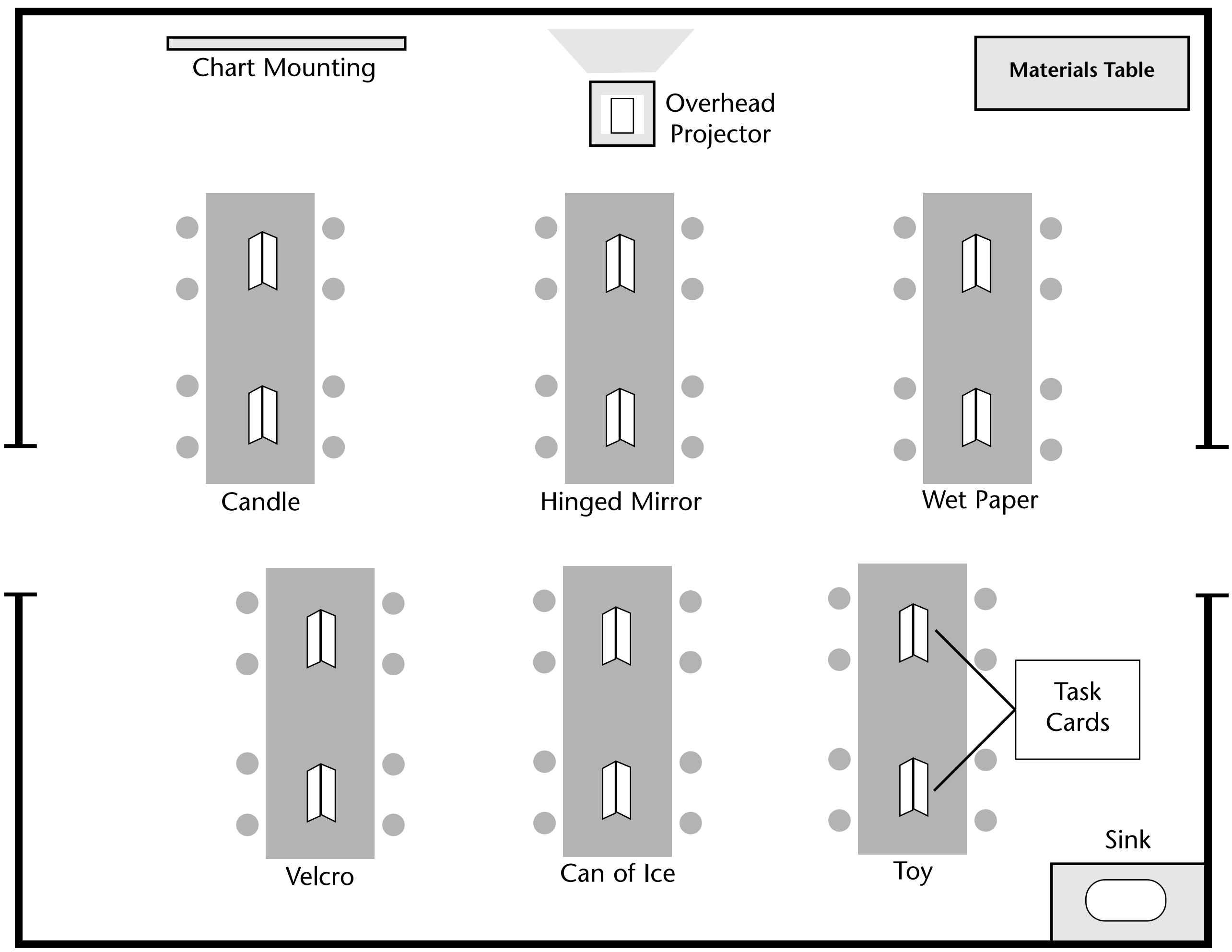
2. Watch your schedule. Refer to the facilitator schedule you created to keep things on track. (See #9 above.)

After the Workshop

You and your co-facilitator should take time to reflect on your experiences and address issues of logistics, communication, outcomes, and expectations. The Facilitation Review (page 49) 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

The diagram shows one possible way to set up for 36 people. You'll need a space that can accommodate whole-group discussions, small-group discussions for nine groups of four people, and 24 activity stations with space at each for two people to work. Note that there are four stations for each of the six tasks, with room for two people at each station. With four stations set up for each activity, there will always be a station available if some groups finish earlier than others.



Essential features

- A freezer or ice chest for storing ice cubes
- A sink or other source of water
- An overhead projector

Materials

To accommodate 36 people, you'll need four stations for each of the six tasks. This allows for open stations for those who finish a task early and need to move on to the next.

Setups For Each Station	Total for Four Setups at Each Table	When Needed
Task 1: Candle		
❑ 1 votive candle on a four-inch-square piece of foil	4 votive candles 4 four-inch-square pieces of foil	Exploring Process Skills (page 25)
❑ 1 book of matches	4 books of matches	
❑ 1 cup of water (for fire safety)	4 cups of water	
❑ 9 sheets of blank paper	36 sheets of paper	
❑ 2 pencils	8 pencils	
Task 2: Velcro		
❑ 2 paired two-inch pieces of Velcro	8 two-inch pieces of Velcro (4 paired)	Exploring Process Skills
❑ 1 hand lens (magnifying glass)	4 hand lenses	
❑ 9 sheets of blank paper	36 sheets of paper	
❑ 2 pencils	8 pencils	
Task 3: Hinged Mirrors		
❑ 2 mirrors approximately four inches square (preferably Plexiglas) joined vertically with a duct-tape hinge	8 four-inch-square mirrors duct tape	Exploring Process Skills
❑ 1 protractor	4 protractors	
❑ 1 penny	4 pennies	
Task 4: Can of Ice		
❑ 1 clean, empty, shiny food can—stripped of label—without lid (15 oz. to 28 oz.) NOTE: Be sure inside edges of can are smooth.	4 shiny food cans	Exploring Process Skills
❑ 1 container of ice cubes (enough to fill the can, above)	4 containers of ice cubes	
❑ 8 paper towels	32 paper towels	
Task 5: Wet Paper		
❑ 1 clear plastic cup (8–9 ounces) filled with water	4 clear plastic cups filled with water	Exploring Process Skills
❑ 8 strips of filter paper, approx. ½″ x 3″ (may be cut from coffee filters)	32 strips of filter paper, ½″ x 3″	
Task 6: Windup Toy		
❑ 1 windup toy, optional (it is not essential to include the toy because the point at this station is planning, not doing)	4 windup toys, optional	Exploring Process Skills
Miscellaneous		
❑ 24 file folders or card stock		For mounting task cards in preparation for the workshop

Charts, Task Cards, Overheads, and Handouts

Masters begin on page 54. They are identified by the letter *M* (for Master) and numbered in order of use. Note that some masters fulfill two separate functions (i.e., a handout is also an overhead) and are used in different parts of the workshop.

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

Chart	Page	When Needed
❑ Process Skills	M1	Post before the workshop begins; leave up throughout the workshop
❑ Take-Home Messages	M2	Post before the workshop begins; leave up throughout the workshop

Task Cards

Make four photocopies of each activity and mount them on 12 file folders or card stock.
Directions for mounting them can be found in Preparing the Materials, page 20.

Task Cards	Page	When Needed
❑ Candle	M3	For Exploring Process Skills
❑ Velcro	M4	
❑ Hinged Mirror	M5	
❑ Can of Ice	M6	
❑ Wet Paper	M7	
❑ Toy on Different Surfaces	M8	

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.

Overheads	Page	When Needed
❑ Process Skills Identification	M9	For Whole-Group Discussion
❑ Observing Process Skills in Action	M11a&b	For Small-Group Discussion
❑ Separating Process Skills	M12	For Whole-Group Discussion
❑ Learning About Condensation A, B, and C	M15a–c	For Process Skills and Student Learning
❑ Indicators of Development of Process Skills	M16a–c	For Developmental Levels of Process Skills

Handouts

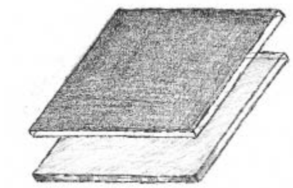
Photocopy the handouts, making one copy for each participant.

Handouts	Page	When Needed
❑ Take-Home Messages	M2	For Concluding the Workshop
❑ Process Skills Identification	M9	For Exploring Process Skills
❑ Directions for Activities at Stations	M10	For Small-Group Discussions
❑ Observing Process Skills in Action	M11a&b	For Small-Group Discussion
❑ Process Skills: Definitions and Examples	M13a–c	For Process Skills Descriptions
❑ Student Learning: Condensation	M14	For Small-Group Discussion and Levels of Process Skills
❑ Learning about Condensation A, B, and C	M15a–c	For Process Skills and Student Learning
❑ Indicators of Development of Process Skills	M16a–c	For Development Levels of Process Skills
❑ Identifying the Level of Process Skills (Windup Toy Activity)	M17	For Development Levels of Process Skills
❑ Changing the Level of Process Skills (Penny and Water Drops Activity)	M18	For Development Levels of Process Skills
❑ (Optional) “The Process Skills of Inquiry” http://www.nsf.gov/pubs/2000/nsf99148/ch 7.htm	on the Internet	For Concluding the Workshop

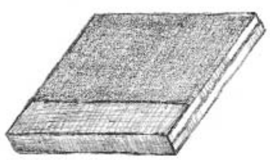
Preparing the Materials

Hinged Mirrors

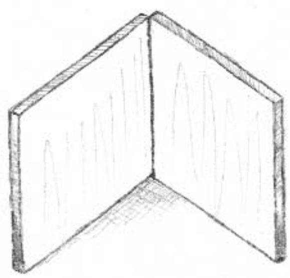
• Make four hinged mirrors as shown:



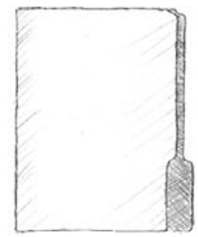
Place two four-inch-square mirrors with their reflective sides facing each other. Add a hinge of duct tape to one outside edge.

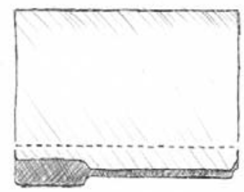


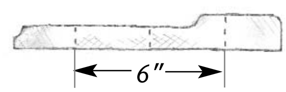
Open the mirrors and stand them up like this.



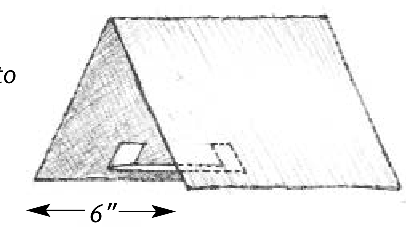
Cut an 8 1/2″ x 11″ file folder as shown to make a tent.







Make a brace out of one of the cut-off strips. Fold the ends up, and fold the center down. Tape the folded ends to the inside bottom of the tent. The center fold will let you close the tent for storage.



Mounted Task Cards

Mount the photocopies of the task cards on file folders or card stock. If you are using file folders, trim them so the horizontal edges are even, then tape a copy of the activity directions to both sides of the folder. (Two pairs of participants, sitting on opposite sides of a table, will share a folder.) To make sure the folders will stay upright, use one of the strips you trimmed off as a brace: Tape it to the inside base of both sides of the folder, as shown in the illustration, allowing about six inches between the sides. Colored file folders will make setup easier and will help participants identify the different stations.

PRESENTING THE WORKSHOP

Part 1: Identifying Process Skills

- **Introducing the Workshop**
- **Exploring Process Skills**
- **Small-Group Discussions**
- **Whole-Group Discussion**

Introducing the Workshop

Materials Reminder

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

- **Post chart M1: "Process Skills"**
- **Post chart M2: "Take-Home Messages"**
- **(Optional) Post workshop schedule for participants (see page 14)**

Overview

The facilitator explains the purpose of the workshop, what participants will be doing, how long it will take, and how the workshop fits with district goals.

8 Steps ◆ 15 Minutes

1. Ask 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. Relate the following information to participants:

► *The process skills of science are the tools for gathering information, generating and testing new ideas, for building new knowledge, and for learning scientific concepts and constructing scientific explanations of the world. Process skills are especially important in inquiry-based learning because they are the tools that students use to carry out scientific investigations.*

The purpose of this workshop is to give you the opportunity to:

• develop a richer and more complete understanding of the process skills of science

• see what they look like when students use them

• think about how to help students develop their skills to higher levels

There are three parts to this workshop. In part one, you'll begin by working in pairs, rotating through six very short hands-on activities that require the use of a variety of process skills.

You will do just enough of each activity to identify the main process skill that it requires.

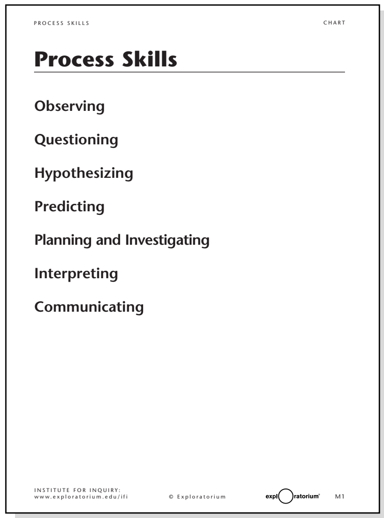
Then, you and your partner will discuss your conclusions with another pair. Even though you have all come into this workshop having used process skills terminology before, you will likely find that you have differences of opinion. After groups of four talk, the conversation continues in the whole group.

We'll begin part two by giving you the standard definitions of the process skills. We wait to give you these definitions until you have had the opportunity to experience using the process skills and to thoroughly discuss with each other your own ideas about them. Those discussions serve as a kind of scaffolding for building your own understanding rather than just memorizing definitions handed to you. We will talk more about this in a few minutes.

You can also think about process skills by looking at what students actually do when they are using them. So you'll examine what process skills look like in action, as students practice them at various developmental levels.

In part three, you'll practice modifying science activities to help your students raise their skills to higher levels.

3. Call attention to chart M1: "Process Skills." Give the group a chance to read it. Explain that for the purpose of manageability, there are only seven basic categories of skills used in this workshop. There are other equally valid lists with more categories, but they include skills that can be subsumed under one or another of these seven. For instance, comparing can be considered a subskill of observing; controlling variables can be considered a subskill of planning and investigating.


PROCESS SKILLS CHART

Process Skills

Observing

Questioning

Hypothesizing

Predicting

Planning and Investigating

Interpreting

Communicating

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M1

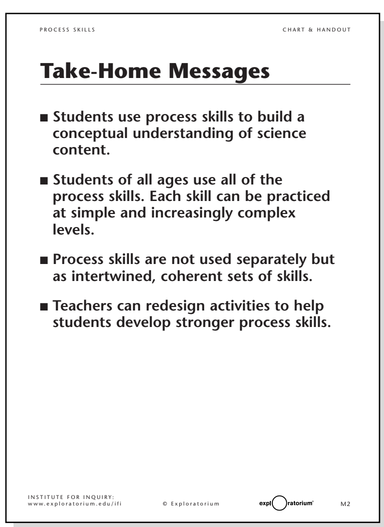
the definitions that differed from your own. Some of the definitions will be very close to your own and may simply broaden your thinking. However, in some cases, the definitions we give may challenge your own ideas and move you consider changing them. Having the opportunity to examine your current understanding and compare it with the way other people think about the process skills can foster changes in how you understand them.

4. Explain further the reasons behind the design for the workshop. Tell participants:

▶ *As we mentioned earlier, there are generally accepted definitions of the process skills terms. But you may be surprised to find that you won't always agree with each other about your own understandings of the skills. There can be a number of reasons for these disagreements:*

- *your own definitions may be incomplete*
- *in some cases, there are subtle differences between one skill and another*
- *in practice, the process skills are usually not practiced discretely—when students do science activities, they may use two or more of the process skills simultaneously.*

Some people might ask, "Why don't you just give us the definitions up front?" We could do that, but you probably wouldn't look at them very closely and might be less likely to accept


PROCESS SKILLS CHART & HANDOUT

Take-Home Messages

- Students use process skills to build a conceptual understanding of science content.
- Students of all ages use all of the process skills. Each skill can be practiced at simple and increasingly complex levels.
- Process skills are not used separately but as intertwined, coherent sets of skills.
- Teachers can redesign activities to help students develop stronger process skills.

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M2

5. Call attention to chart M2: "Take-Home Messages." Tell participants:

▶ *You'll be working, through direct experience and discussion, to develop your own understanding of the ideas that these messages express.*

Read the take-home messages aloud.

6. Explain to 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 *Process Skills* connects to the *National Science Education Standards,* see page 53.

7. Explain that this workshop is designed for professional development only. Tell participants:

▶ *Remember that this workshop is designed to develop and deepen your own understanding of the* *process skills of science. The activities at the stations are not intended to be replicated in the classroom. If you were to use any of the workshop's very brief science activities with students, it would be important to connect them to related science topics in your curriculum.*

8. Address the workshop schedule. Tell participants that the entire workshop will take approximately 3 1/2 hours, including 10 minutes for a break.

Exploring Process Skills

Materials Reminder

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

- **Place mounted task cards (pages M3–M8) and materials at each station**
- **Distribute handout M9: "Process Skills Identification"**

Overview

In this first part of the workshop, participants do brief science activities that require the use of various science process skills. They do so in order to have a concrete, experiential reference for identifying, discussing, and refining their understanding of the skills in subsequent parts of the workshop. Doing the tasks and using the skills help participants think about the process skills in terms of actions rather than abstract definitions. One of the central aims of the workshop is to have participants describe skills *in action*. This will help them recognize the process skills when they see students using them.

There are six activities in all, with four stations for each one. (Note that one of the stations requires the identification of two skills.) At each station there are the simple materials the activity requires and a "task card" with directions for doing the activity. It's important that participants focus on process skills, not on learning about the scientific phenomena the activities address. After doing each activity, participants fill in handout M9: "Process Skills Identification," indicating the primary process skill required by the activity.

6 Steps ◆ 30 Minutes

1. Tell participants that they will be working in pairs to identify the main process skill used in each of six tasks. Point out that there are four stations for each activity in order to accommodate everyone. Say to participants:

▶ *You can go to the stations in any order, but it's important that you keep moving quickly so that you get to all of the activities. It isn't necessary to finish doing every activity. Just do enough to get a good idea of the main skill that's required.*

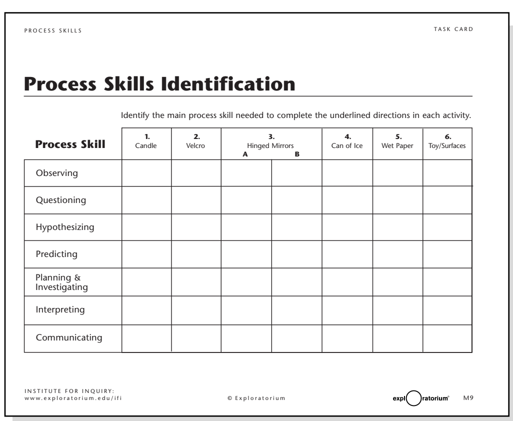
(NOTE: The time allotted to complete the tasks is adequate, as long as groups keep moving.)

2. Distribute handout M9: "Process Skills Identification." Explain:

▶ *Use this form to indicate the main process skill required at each station. You don't need to indicate all the skills used, just the main ones.*

3. Tell participants that they'll have about 25 minutes to sample the six activities. Have them choose partners and go to their first station.

4. Remind people to concentrate on the main skill required of each activity. Circulate among groups and if you see any identifying more than one skill (except at the Hinged Mirror station) remind participants to



PROCESS SKILLS TASK CARD

Process Skills Identification

Identify the main process skill needed to complete the underlined directions in each activity.

Process Skill	1. Candle	2. Velcro	3. Hinged Mirrors A	3. Hinged Mirrors B	4. Can of Ice	5. Wet Paper	6. Toy/Surfaces
Observing							
Questioning							
Hypothesizing							
Predicting							
Planning & Investigating							
Interpreting							
Communicating							

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M9

focus on the underlined part of the task card and identify only the main skill required. Identifying only the primary skill demands that participants think more carefully about what they understand that skill to be.

Participants may find the activity at a particular station very engaging and want to remain at that station. However, encourage them not to linger at any one station.

5. Give a 5-minute warning. About five minutes before time is up, let participants know how much time they have to complete their work.

6. Announce when time is up. Go on to the small-group discussions.

Facilitation Hints for Exploring Process Skills

■ **Know the Intended Skills**
Knowing the tasks and the intended main skill at each station will help you facilitate both the work at the stations and the subsequent discussions. (See "Process Skills at the Stations" below, which shows the main skill each activity was intended to represent.) Participants, however, may identify different skills, either because of inaccurate understandings of the process skills or because of legitimate differences of opinion about which process skills are actually required to complete these tasks. Since the point of this part of the workshop is to uncover participants' initial ideas, it's not important that they identify the process skills needed exactly as they appear in the sidebar below.

Process Skills at the Stations

The process skills listed are the main skills needed to carry out the underlined directions on the task cards.

1. **Candle**
   Intended main skill: observing
   Other skills: communicating and predicting

2. **Velcro**
   Intended main skill: communicating
   Other skills: observing and hypothesizing

3. **Hinged Mirror**
   A. **Intended main skill:** interpreting
   B. **Intended main skill:** predicting

4. **Can of Ice**
   Intended main skill: hypothesizing

5. **Wet Paper**
   Intended main skill: questioning

6. **Toy on Different Surfaces**
   Intended main skill: planning

Small-Group Discussions

Materials Reminder

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

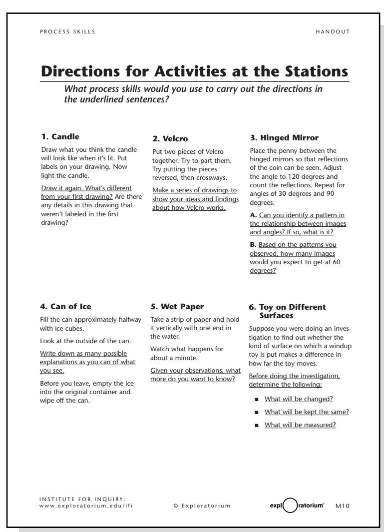
- **Distribute handout M10: "Directions for Activities at the Stations"**
- **Distribute handout M11a&b: "Observing Process Skills in Action" and display corresponding overhead**

Overview

Participants meet in groups of four to discuss which process skills they've identified for the six activities. Grounding the discussion in the concrete experience at the stations encourages participants to discuss process skills as they are actually practiced, rather than in the abstract.

Participants often differ in their identification of the main process skill for each activity. For example, some people may think the main skill of the Candle activity is communicating, since they are asked to draw what they think that they will see; others think it is predicting, since their initial drawing is of something that has not yet happened; and others think it is observing, since the required task makes them focus in on the details of what they see.

These differences in identification may arise for a number of reasons. First, many people may have incorrect or incomplete understandings of how to define the process skills. Also, when you do any activity, you inevitably use a number of skills, often simultaneously. For instance, observing is part of just about anything you do. So it may be difficult to "pull apart" the skills being used in order to identify the primary one. And finally, people may have legitimate differences of opinion about what actions actually indicate the use of particular skills.



PROCESS SKILLS HANDOUT

Directions for Activities at the Stations

What process skills would you use to carry out the directions in the underlined sentences?

1. Candle

Draw what you think the candle will look like when it's lit. Put labels on your drawing. Now light the candle.

Draw it again. What's different from your first drawing? Are there any details in this drawing that weren't labeled in the first drawing?

2. Velcro

Put two pieces of Velcro together. Try to part them. Try putting the pieces reversed, then crossways.

Make a series of drawings to show your ideas and findings about how Velcro works.

3. Hinged Mirror

Place the penny between the hinged mirrors so that reflections of the coin can be seen. Adjust the angle to 120 degrees and count the reflections. Repeat for angles of 30 degrees and 90 degrees.

A. Can you identify a pattern in the relationship between images and angles? If so, what is it?

B. Based on the patterns you observed, how many images would you expect to get at 60 degrees?

4. Can of Ice

Fill the can approximately halfway with ice cubes.

Look at the outside of the can.

Write down as many possible explanations as you can of what you see.

Before you leave, empty the ice into the original container and wipe off the can.

5. Wet Paper

Take a strip of paper and hold it vertically with one end in the water.

Watch what happens for about a minute.

Given your observations, what more do you want to know?

6. Toy on Different Surfaces

Suppose you were doing an investigation to find out whether the kind of surface on which a windup toy is put makes a difference in how far the toy moves.

Before doing the investigation, determine the following:

- What will be changed?
- What will be kept the same?
- What will be measured?

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M10

Participants' disagreements prompt them to probe their own thinking about process skills as they try to articulate their reasons for choosing the skills they did.

2 Steps ◆ 20 Minutes

1. Have participants compare their findings in groups of four (10 minutes). Ask each pair to join another pair, then distribute handout M10: "Directions for Activities at the Stations" to help participants recall the six activities. Tell the small groups:

► *Discuss what you identified as the main process skill at each station, noting areas of agreement and disagreement. Take 10 minutes.*

As participants conduct their discussions, facilitators can collect the materials from the tables. Doing so quickly will not interfere with discussion.

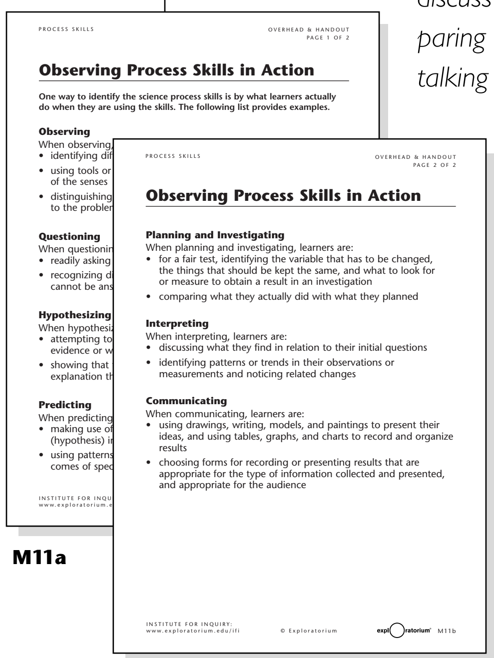
2. Have participants review the descriptions of process skills on the handout M11a&b: "Observing Process Skills in Action" (10 minutes). Ask for everyone's attention in order to distribute the handout. Display the corresponding overhead and tell participants:

► *Now, we'd like to give you a tool that can help you think about the skills in terms of what they look like when learners are using them. On this sheet are descriptions of some of the things students actually do when they are using the process skills. The list is not intended to be exhaustive, but these descriptions do provide you with ideas to consider as you develop your own understanding of the skills. Being able to identify process skills in action allows you to guide students' use of the process skills in very focused ways.*

In presenting the descriptions, you can also say:

► *These are not definitions of process skills. Rather, they are descriptions that focus on what students do as they practice each of the process skills. For example, if students are sorting leaves into groups based on how smooth or fuzzy they are, the students are "identifying obvious differences between objects," an observation skill. For another example, students wind up spring-driven cars and see how far they travel. After seeing her car go one meter with one wind and three meters with four winds, a student said, "I think my car will go four meters if I give it five winds." She is "making use of evidence from experience to make an extrapolation," a predicting skill. These operational descriptions of process skills are important for recognizing the skills in students' actions.*

Now you'll have a little less than 10 minutes to discuss the skills further by comparing the way you have been talking about the process skills with the way the skills are described on the "Observing Process Skills in Action" handout. Again, note agreements and disagreements. And remember, these are descriptions, not definitions. We're using them here to serve as a way to expand your thinking by introducing another way to think of the process skills.



M11a

M11b

Facilitation Hints for Small-Group Discussions

▪ Listen for Interesting Conversations
Circulate among groups, assist any that need help, and listen for interesting discussions or disagreements that you can refer to during the whole group discussion. You may want to make notes as you move around the room.

▪ Keep Discussions Going
Groups sometimes finish their conversations very early. They may say that they agreed on everything. To get their conversations restarted, you can ask:

► *Was there anything you initially disagreed about? If so, how did you come to agreement?*

You can also ask:

► *What did you do at (a particular station) that indicated you were using the process skill you identified?*

continued

Facilitation Hints for Small-Group Discussions (continued)

Asking about actions participants took helps move their thinking about process skills out of the abstract and also encourages them to examine the reasoning behind their choices.

■ Uncover Reasons for Opinions
If groups are stuck in disagreement, encourage each group member to articulate the thinking underlying his or her opinion.

■ Defer Giving Definitions
Sometimes groups will ask you for a definition of one of the process skills. Remind them that at this point in the workshop, you want them to clarify and examine the ideas they bring to the discussion from their previous experiences. Giving them a definition would short-circuit that process. Ask them to note their ideas and differences of opinion so they can bring them to the whole group discussion where they can work at coming to some resolution.

■ Expect Some Agreement with the Process Skills in Action
Participants may recognize elements of the "Process Skills in Action" that confirm their own views but are stated in a different way (e.g., "Make use of several senses in exploring objects or materials" will agree with most people's idea of observing). They may also find descriptions that expand their thinking (e.g., "Distinguish from many observations those which are relevant to the problem in hand" clearly has to do with observation, but will not have been considered previously by most people). For many people, the "Observing Process Skills in Action" handout gives them a way of thinking about describing process skills with more precise and concrete language.

■ Also Expect Some Disagreement
On the other hand, participants may find that they disagree with the way certain behaviors are described (e.g., "Use patterns in information or observations to make justified interpolations or extrapolations" is given as a prediction skill, but many participants may regard using patterns as an interpretation skill). Whether they agree or disagree with the descriptions, participants will have examined their current thinking in light of the new information presented in the handout.

Whole-Group Discussion

Materials Reminder

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

- **Display overhead M12: "Separating Process Skills"**
- **Display overhead M9: "Process Skills Identification"**

Overview

As the discussion moves to the entire group, participants may be exposed to additional ways of thinking about the process skills that hadn't occurred to them before. In the small-group discussions, participants compared their ideas with just one other pair. Any differences could be seen simply as variations of personal opinion. The exposure to new ideas from the larger group opens participants up to questioning their own thinking. And the fact that they are working as a whole group with the meanings of the process skills terms helps them understand the need to use common terminology to communicate effectively with colleagues.

During the whole-group discussion, the facilitator takes on a more central role: guiding the conversation, eliciting opinions about the skills, asking participants to explain their thinking, inviting expression of differences of opinion, and encouraging participants to compare their views with those of others. Through this whole-group dialogue, participants begin to experience changes in their own thinking. In some instances, they shift from defining process skills abstractly to describing them in action. In others, they may actually change their understanding of the meaning of the process skill terms. In both cases, participants develop a more complete and accurate understanding of the science process skills, preparing them to adopt commonly held definitions of the process skills that will be presented later in the workshop.

6 Steps ◆ 25 Minutes

1. Reconvene the whole group. Explain what will happen next:

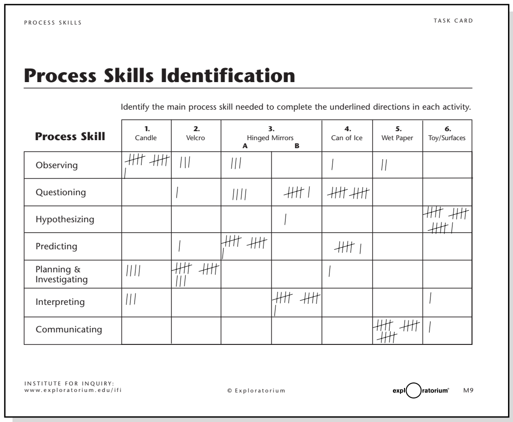
► *Now we're going to have a whole-group conversation similar to the ones you've been having in your groups of four. In the large group, you will be able to hear a broader range of ideas about process skills than you heard from talking in groups of four. You'll get a chance to ask questions of groups with different ideas and work to figure out meanings together.*

At this stage, it's important to compare your own thinking about the process skills as they are practiced when doing science activities with what others think. This can lead to a deeper understanding of your own ideas and can help you see where those ideas may need expanding or changing. Since new ideas are built by this process of expanding and changing existing ideas, these discussions lay the foundation for you to adopt the standard definitions of the process skills that we will look at later. Let's begin with a quick survey of the group.

2. Display overhead M9: "Process Skills Identification" and survey the group. (5 minutes). Tally the responses on the overhead. Start by saying:

► *Let's begin with the Candle task. Raise your hand if you identified Observing as the main process skill here. Hypothesizing? Planning?*

Continue through the list of skills, placing tally marks in the appropriate spaces. Do the same for each of the tasks. (You may want to have the other facilitator record the tally.)


PROCESS SKILLS TASK CARD

Process Skills Identification

Identify the main process skill needed to complete the underlined directions in each activity.

Process Skill	1. Candle	2. Velcro	3. Hinged Mirrors A	3. Hinged Mirrors B	4. Can of Ice	5. Wet Paper	6. Toy/Surfaces
Observing	11	3	3		1	2	
Questioning		1	4	6	10		
Hypothesizing				1			11
Predicting		1	11		6		
Planning & Investigating	4	13			1		
Interpreting	3			11			1
Communicating						15	1

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M9, with examples of typical responses

▶ *First, we will examine those areas of disagreement (or the skills that were particularly difficult to identify).*

Choose one of the tasks about which a group disagreed, or had some confusion or difficulty in identifying the skill. Ask one of the groups:

▶ *What did you identify as the main skill at (a particular station)?*

Why did you identify the skill as ______(e.g, hypothesizing) and not ______(e.g., interpreting) or ______(e.g., predicting)?

• Ask another group that named a different skill for the same task the same question:

Why did you identify the skill as ______(e.g., interpreting) and not ______(e.g., predicting) or ______(e.g., hypothesizing)?

• Encourage these groups to respond to each other's ideas.

• Ask others why they agree or disagree.

To extend the discussion, you can ask about the skills one at a time:

▶ *Did anyone find ______(e.g., planning) to be the main skill at any of the stations? Which stations? What did you do at that station that indicates ______(e.g., planning) is the main skill?*

Again, encourage groups to respond to each other's ideas and ask others why they agree or disagree.

3. Look for areas of disagreement on the chart (5 minutes).

Remember that disagreements can be illuminating, indicating where there may be confusion, ambiguity, or misconceptions about how to recognize, describe, and understand particular process skills. Paying particular attention to these areas of disagreement keeps the discussion focused on those skills that need further discussion. In addition, disagreements can be fruitful because they lead participants to examine their own ideas and understandings in the light of what others think. Typically, people disagree about the skills of hypothesizing, interpreting, and predicting. See the Facilitation Hints on page 32 for help in sorting out these differences. If there are disagreements, tell participants:

▶ *You can see that there are areas where we are not in agreement.*

If disagreements haven't occurred, you can ask:

▶ *Which process skills were the hardest to identify?*

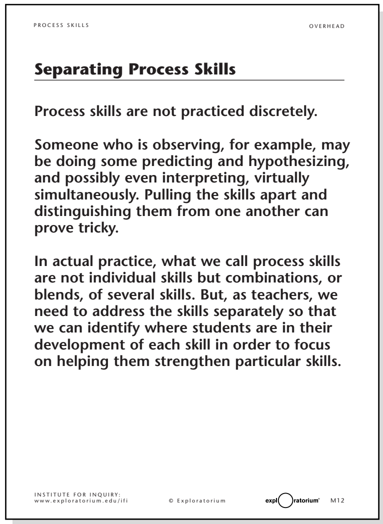
Use participants' responses to determine which of the process skills to discuss further in the following discussion.

4. Talk about areas of disagreement or skills that were difficult to identify. Say:

5. Explain how process skills are inter-

twined. Tell participants:

► *It's not surprising when there are disagreements or difficulties in identifying individual process skills. Sometimes it's hard to identify a single process skill for each of the underlined directions because in practice, process skills are not used discretely, one at a time. As noted in the take-home messages we looked at the beginning of the workshop, the process skills are actually coherent sets of skills that intertwine and overlap. This fact illustrates a basic truth about scientific inquiry—that the science process skills are not applied separately from each other in any prescribed, step-by-step order.*


PROCESS SKILLS OVERHEAD

Separating Process Skills

Process skills are not practiced discretely.

Someone who is observing, for example, may be doing some predicting and hypothesizing, and possibly even interpreting, virtually simultaneously. Pulling the skills apart and distinguishing them from one another can prove tricky.

In actual practice, what we call process skills are not individual skills but combinations, or blends, of several skills. But, as teachers, we need to address the skills separately so that we can identify where students are in their development of each skill in order to focus on helping them strengthen particular skills.

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M12

Next, display overhead M12: "Separating Process Skills" and read it aloud.

6. Wrap up the discussion, and tell participants they'll be taking a 10-minute break. Say:

► *You've thoroughly discussed your own understandings of the process skills and have seen how difficult it can be to define them. Now we'll take a 10-minute break. When we come back, we'll look at the standard definitions of the process skills. Those definitions can help us resolve any remaining disagreements and lead to some new understandings of the process skills.*

Facilitation Hints for Whole-Group Discussion

■ **Be Prepared**
Typically, the conversation and the confusion in the large group discussions center around the skills of hypothesizing, predicting, and interpreting. It is essential that the facilitator of this conversation have a firm grasp of these terms beyond simply how they are defined, so that he or she can help deal with any confusion that arises.

■ **Address the Term *Hypothesis***
The term *hypothesis* may be confusing for participants because there are differences in how science educators use it. Simply put, hypothesizing is an attempt to answer the question "Why . . . ?" In other words, a hypothesis is a *tentative* explanation of an event or phenomenon. A hypothesis is not necessarily correct, but it should be reasonable in terms of available evidence and science concepts. In addition, a hypothesis is testable—there must be a way to prove it wrong. Some people refer to a hypothesis as an "educated guess." Although that's technically correct, using the word *guess* tends to confuse people about how much knowledge and evidence is required to form a good hypothesis.

■ **Address the Term *Predicting***
There may also be a good deal of confusion about the meaning of *predicting*. Many people regard a prediction as "just a guess," in contrast to a hypothesis as an "educated guess." In fact, a prediction is based on knowledge about what has happened before, a pattern of evidence, or a hypothesis. It is a response to the question, "What will happen in this particular instance if . . . ?" When a prediction is based on a hypothesis, it can serve as a test of that hypothesis. An incorrect prediction demonstrates that the hypothesis is incorrect. A correct prediction strengthens confidence that the hypothesis is valid. But it does not prove conclusively the validity of the hypothesis because further predictions based on the hypothesis may turn out to be incorrect.

Facilitation Hints for Whole-Group Discussion (continued)

■ **Address the Term *Interpreting***
Interpreting can get confused with hypothesizing since sometimes interpretations lead to tentative explanations. Interpreting is distinguished by the assessment of data, checking for reliability, and looking for patterns or other meaning. Interpreting may involve organizing, analyzing, and synthesizing data using statistical analysis, tables, graphs, and diagrams. Although interpreting data may result in a set of facts that lead to a hypothesis, it is not the formation of a hypothesis.

■ **Distinguish between Predicting and Hypothesizing**
Making the distinction between predicting and hypothesizing clear generally requires a good deal of discussion with reference to the particular activities that use those skills. On the task card M5: "Hinged Mirror," for example, question B has to do with a particular instance (number of images expected at a 60-degree angle) and it's based on prior knowledge (numbers of images seen at other angles), so the question calls for a prediction. In general, a prediction refers to a particular case. A hypothesis is a proposed explanation that can be applied to a broad range of cases.

■ **Distinguish between Hypothesizing and Interpreting**
As mentioned above, there is often confusion between hypothesizing and interpreting. For instance, some people will say that the main skill required for the M6: "Can of Ice" task is hypothesizing (the intended main skill) because it calls for an explanation. Others will say the main skill is interpreting, because one has to figure out what finding moisture on the outside of the can reveals. In the discussion,

(continued on next page)

How Hypothesizing, Predicting, and Interpreting Differ

Hypothesizing
Answers the question

Why *. . . ?* (E.g., Why does the sweater keep me warm?)

A hypothesis proposes an explanation (based on observation, evidence, and past experience) of events or phenomena. (A hypothesis may or may not be correct.)

Example: Sweaters and other warm things keep me warm because they make heat.

Predicting
Answers the question

What will happen in this particular instance if *. . . ?* (E.g., What will happen if I put a thermometer in my sweater and let it sit there for several hours?)

A prediction takes experience into account and is often based on a hypothesis.

Example: If I put a thermometer in my sweater and leave it there for several hours, it will show an increase in temperature.

Interpreting
Answers the question

What do my data tell me? (E.g., What does the fact that the temperature did not go up after several hours tell me?)

An interpretation is a conclusion based on analysis and assessment of the data.

Example: The fact that the temperature did not go up after several hours tells me that either there was a flaw in my experiment or sweaters don't make heat.

NOTE: For more information, see handout M13a–c: "Process Skills: Definitions and Examples."

Facilitation Hints for Whole-Group Discussion (continued)

it's important to bring to light what people think about different sorts of evidence (or data) and different uses of that evidence in the process of doing science. In general, interpreting involves finding a pattern or other meaning in a collection of data.

■ **Address the "Scientific Method"**
Teachers may bring up the "scientific method," which many people associate with process skill terms. Most textbooks introduce the scientific method near the beginning of the text. Traditionally, this method has been presented as a linear series of steps, starting with a scientist observing a new phenomenon or raising a question based on that observation and then immediately forming a hypothesis. This is followed by investigation based on a prediction derived from the hypothesis, and interpretation of the result as supporting or refuting the hypothesis.

More recently, the introduction of the scientific method is accompanied by statements saying that the steps are often not done in a linear fashion. However, there are teachers who have misconceptions about hypothesizing and often think that investigations start with a hypothesis, and that a hypothesis is a guess.

In most scientific investigations, a hypothesis is actually preceded by a question. A good deal of investigation into that question is usually necessary before the investigator has enough experience and information to produce a tentative answer or explanation—a hypothesis rather than a guess.

Once one has a hypothesis, the scientific method provides a way to test that hypothesis. But even then, the path to a conclusion is rarely very linear. Investigations meant to test hypotheses often involve revisions in planning, looking at a variety of predictions, challenging assumptions, puzzling over interpretations and more, done in no particular order.

PRESENTING THE WORKSHOP

Part 2: How Students Use Process Skills

- **Process Skills Definitions**
- **Process Skills and Student Learning**

Process Skills Definitions

Overview

All of the discussion and activity to this point has prepared participants to think deeply about process skills and to consider whether their previous understandings of these skills are accurate or need to be reconsidered. In this second part of the workshop, the facilitator presents standard definitions of process skills, and participants spend time discussing the definitions and comparing them to their ideas. Doing this helps participants develop a common language about process skills, and to develop a deeper understanding that they will apply to the rest of the workshop and to the work they'll do back in their own classrooms.

4 Steps ◆ 25 Minutes

1. Explain why a common language for the process skills is important. Tell participants:

► *You've done a great deal of thinking and talking so far, exploring your own and each other's ideas about process skills. In doing so, you have likely come to a deeper understanding of these skills and can see why people may have differences in understanding their meaning. However, in order to work effectively with process skills in the classroom, and to create a foundation for discussion of process skills with other teachers, it's important to develop a common language to describe these skills.*

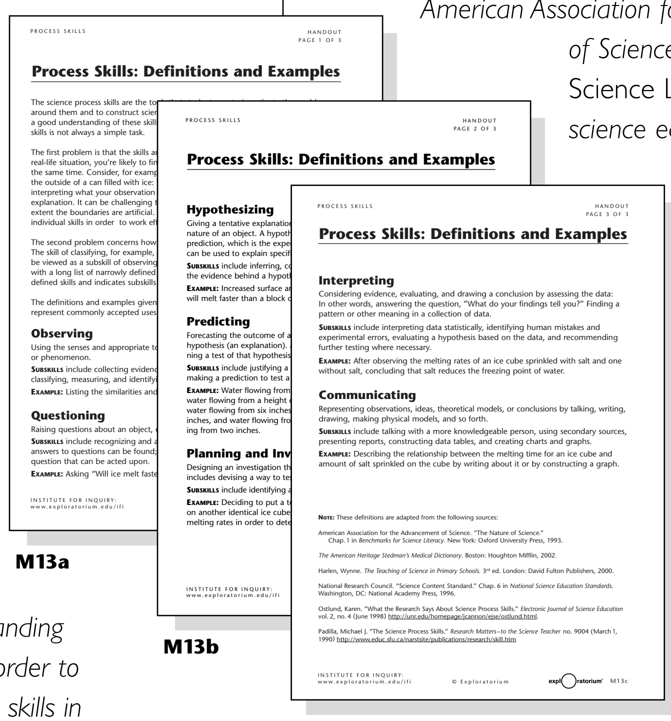
Materials Reminder

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

- **Distribute handout M13a–c: "Process Skills: Definitions and Examples"**

2. Distribute handout M13a–c: "Process Skills: Definitions and Examples" and have participants discuss it (10 minutes). Tell participants:

► *These definitions and examples that we are handing out represent commonly accepted uses of the process skills terms. They are based on a number of sources, including the* National Science Education Standards; *the American Association for the Advancement of Science* Benchmarks for Science Literacy; *noted science educator Wynne Harlen's book* The Teaching of Science in Primary Schools, *and others. In some cases, these definitions will simply expand your current understanding. In other cases, they may challenge you to reconsider your views.*



M13a M13b M13c

Now in your groups of four, spend 10 minutes discussing these definitions and examples.

How do these definitions fit with your own understanding of the skills? In your discussion, pay particular attention to those skills you had disagreements or confusion about.

3. Reconvene the whole group and have participants share ideas and questions from their groups of four (10 minutes). Begin by asking:

► *Do you have any questions or differences of opinion remaining about any of these skills?*

If so, say:

► *Can anyone help resolve these differences or answer these questions?*

It's very common for people to have questions about the definitions of hypothesizing, predicting, and interpreting or the differences among them. If the group has a hard time resolving differences or answering questions about these skills, see the Facilitation Hints and "How Hypothesizing, Predicting, and Interpreting Differ" (page 33) for some background information that can help you address the remaining questions.

4. Explain the next step and remind participants that process skills overlap. Say:

► *What we're going to do now is look at examples of how students use these skills to learn. After that you'll do some exercises that provide a first step in practicing how to identify where your students are in the development of their process skills and how to help them improve their skills. Even after this practice, when you go back to your classrooms, you may find that it is still difficult to identify which skills learners are required to use in particular activities or which skills learners are actually using as they do hands-on science activities. Remember that process skills are almost never practiced separately and that identification is difficult. It takes time and practice to identify skills and skill levels.*

Process Skills and Student Learning

Materials Reminder

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

- **Distribute handout M14: "Student Learning: Condensation"**
- **Distribute handouts M15a–c: "Learning about Condensation," and display corresponding overheads**

Overview

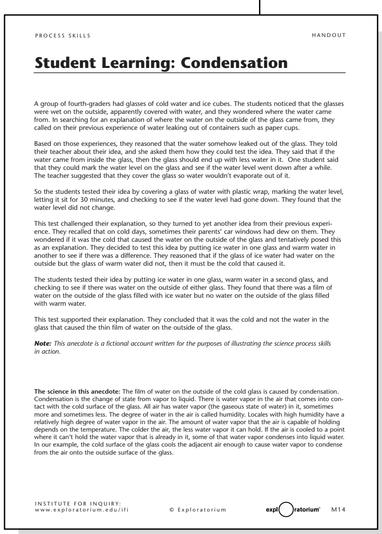
The workshop now moves to a consideration of what process skills look like in action, and the connection between process skills and learning.

The facilitator presents an anecdote to the whole group that shows how a group of students uses the process skills when encountering new ideas and phenomena. This example helps participants see what students do when they are using the process skills. It also helps reinforce the importance of strengthening students' process skills in order to help them build a better understanding of science content.

5 Steps ♦ 20 Minutes

1. Pass out handout M14: "Student Learning: Condensation" (5 minutes). Tell participants:

► *You may be wondering why it is important to spend this much time on the process skills of science. The vignette that we're handing out may help to answer this question. It illustrates how students deal with new phenomena and build new ideas, and shows how process skills are crucial to students' learning of science content and concepts. Take a few minutes to read the vignette and then we'll go over it as a group, looking at how the students used various process skills.*


PROCESS SKILLS HANDOUT

Student Learning: Condensation

A group of fourth-graders had glasses of cold water and ice cubes. The students noticed that the glasses were wet on the outside, apparently covered with water, and they wondered where the water came from. In searching for an explanation of where the water on the outside of the glass came from, they called on their previous experience of water leaking out of containers such as paper cups.

Based on those experiences, they reasoned that the water somehow leaked out of the glass. They told their teacher about their idea, and she asked them how they could test the idea. They said that if the water came from inside the glass, then the glass should end up with less water in it. One student said that they could mark the water level on the glass and see if the water level went down after a while. The teacher suggested that they cover the glass so water wouldn't evaporate out of it.

So the students tested their idea by covering a glass of water with plastic wrap, marking the water level, letting it sit for 30 minutes, and checking to see if the water level had gone down. They found that the water level did not change.

This test challenged their explanation, so they turned to yet another idea from their previous experience. They recalled that on cold days, sometimes their parents' car windows had dew on them. They wondered if it was the cold that caused the water on the outside of the glass and tentatively posed this as an explanation. They decided to test this idea by putting ice water in one glass and warm water in another to see if there was a difference. They reasoned that if the glass of ice water had water on the outside but the glass of warm water did not, then it must be the cold that caused it.

The students tested their idea by putting ice water in one glass, warm water in a second glass, and checking to see if there was water on the outside of either glass. They found that there was a film of water on the outside of the glass filled with ice water but no water on the outside of the glass filled with warm water.

This test supported their explanation. They concluded that it was the cold and not the water in the glass that caused the thin film of water on the outside of the glass.

***Note:** This anecdote is a fictional account written for the purposes of illustrating the science process skills in action.*

The science in this anecdote: The film of water on the outside of the cold glass is caused by condensation. Condensation is the change of state from vapor to liquid. There is water vapor in the air that comes into contact with the cold surface of the glass. All air has water vapor (the gaseous state of water) in it, sometimes more and sometimes less. The degree of water in the air is called humidity. Locales with high humidity have a relatively high degree of water vapor in the air. The amount of water vapor that the air is capable of holding depends on the temperature. The colder the air, the less water vapor it can hold. If the air is cooled to a point where it can't hold the water vapor that is already in it, some of that water vapor condenses into liquid water. In our example, the cold surface of the glass cools the adjacent air enough to cause water vapor to condense from the air onto the outside surface of the glass.

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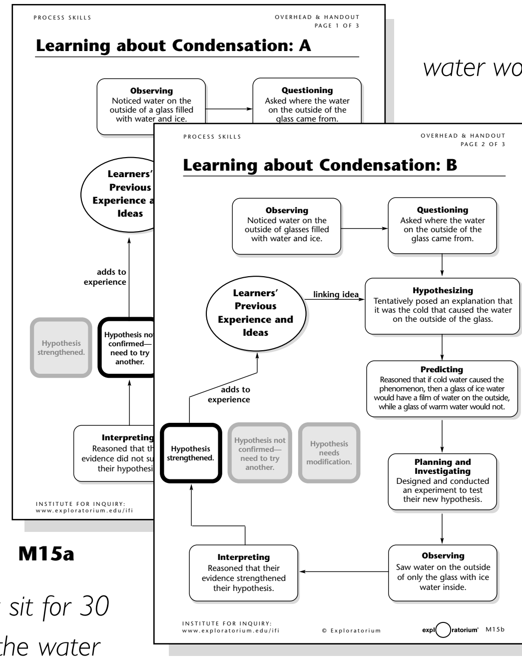
M14

2. Examine the vignette for the use of process skills. Display overhead M15a: "Learning about Condensation: A" and distribute the handouts M15a–c. Use the script below to go back over the anecdote, highlighting the process skills students used at each step while pointing out the appropriate boxes on the overhead. Tell participants:

► *Let's go over the first page in this three-page handout, looking at the role process skills played in this description of learning. We've seen that many process skills are in play simultaneously, but we'll focus only on the main skill in each part. First, the students noticed that water appeared on the outside of the glasses filled with cold water and ice. In noticing that, they were using the skill of **observing**. When they asked where the water on the outside of the glass came from, they were **questioning**. Their previous experience of water leaking out of containers such as paper cups (the "**linking idea**") led them to propose the tentative explanation that somehow the water leaked out of the glass. In doing this, they were **hypothesizing**. When the students talked to their teacher*



M15a

M15b

*about testing their hypothesis, they were **communicating**. One way to test their hypothesis was to assume it was sound and make a prediction based on that assumption.*

*The students **predicted** that the water level in a glass would go down because the water would leak out. They decided they would test this prediction by covering a glass of ice water with plastic wrap, marking the level, letting it sit for 30 minutes, and checking to see if the water level had gone down. In deciding on these steps, they were **planning and investigating**. After 30 minutes had elapsed, they **observed** that the water level hadn't changed. This evidence did not support their explanation. Their **interpretation** was that water was not leaking out of the glass.*

The result of this test—one of three possible outcomes—challenged their explanation. Even though their hypothesis was not confirmed, the results added to the store of experience and ideas that they could use in developing other explanations. Then they turned to another idea from their previous experiences.

3. Display overhead M15b: "Learning about Condensation: B" and continue:

▶ *Now let's look at the second page of the handout. In the vignette, the students recalled that on cold days, sometimes their parents' car windows had dew on them (the **linking idea**). When they posed the tentative explanation that a cold glass might get water on it just because it was cold, they were **hypothesizing**. They decided to test this by putting ice water in one glass and warm water in another. They **predicted** that, if they were right, water would form on the outside of the glass with ice water but not on the one with warm water. When students suggested putting ice water in one glass and warm water in another and then did so, they were **planning and investigating**.*

*Later, they **observed** a film of water only on the outside of the glass with the ice water. They **interpreted** the result as supporting their explanation that it was the cold that caused the water to form. This interpretation strengthened their new hypothesis and added to their store of experience and ideas.*

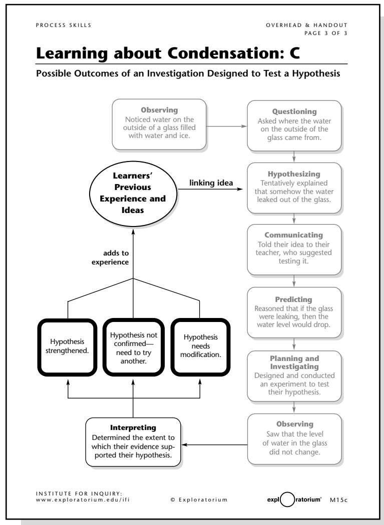
The idea that maybe cold, all by itself, was causing this effect showed significant progress in understanding the elements of science content which are necessary for learning the more complex concept of condensation. However, it was not a complete explanation of condensation. It did not, for instance, say where the water was coming from. However, for fourth graders, this was a big leap in that direction.

The important science content that these students discovered included the following:

- *Taking note that there was a film of water on the outside of a cold glass of water.*
- *Ruling out that water leaks out of glasses of cold water.*
- *Making the connection between the water on the outside of the glass and the water on the windshield of a car on a cold morning. These kinds of connections allow a common explanation of different phenomena.*

• Concluding that temperature was a critical variable in the observed phenomena.

This anecdote gives an example of the role of process skills in the forming of a new idea. In general, when you are going through a process of experimenting to test your hypotheses, there are three possible outcomes when you interpret your results.



M15c

4. Display overhead M15c, "Learning about Condensation: C" and continue:

▶ *Looking at the third page of the handout, we'll consider the three possible outcomes of interpreting your results:*

One, ***the hypothesis is not confirmed and therefore may be eliminated*** *because it led to a completely wrong prediction. This happened in the first part of the anecdote.*

Two, ***the hypothesis may be strengthened*** *because the result was exactly as predicted. This happened in the second part of the anecdote.*

Three, ***the hypothesis needs modification because the result is inconclusive****. Although it did not come out exactly as predicted, it was close and shows you that you might be on the right track. In that case, you can go back and try a modification of your initial hypothesis, then go back and test that modified hypothesis.*

Any of these results adds to the learner's store of experience and ideas, from which he or she builds new concepts. Strong process skills allow learners to arrive at such results efficiently and with confidence that their findings are well founded.

5. Talk to the group about the learning of science concepts and process skills. Tell participants why we emphasize process skills:

▶ *Why do we feel that strong process skills are so important in learning science content? It is because the science process skills are the intellectual tools for generating and testing new ideas and for building new knowledge. We can turn to the anecdote of students learning about condensation to see why this is so.*

Tell participants what the *Standards* say about how students develop new ideas:

▶ *The authors of* Inquiry and the National Science Education Standards *state that "research on learning indicates that students change their ideas when they find these ideas to be unsatisfactory, that is, when they find their present ideas do not sufficiently describe or explain an event or observation."[1] This is exactly what happens in the condensation anecdote, when the idea about leaky cups doesn't explain the water on the outside of the cold glass. These authors also tell us that research shows that "students build new knowledge and understanding on what they already know and believe."[2] Again, the anecdote illustrates this as the students reach into their store of previous experiences and ideas to try to find a linking idea that explains what they observed.*

[1] National Research Council. *National Science Education Standards*. (Washington, DC: National Academy Press, 1996), p. 118.

[2] Ibid., p. 117.

Describe the role process skills play in learning:

- *Strong process skills play a critical role in learning science content. In the anecdote of students learning about condensation, the students needed strong* ***observing*** *skills to notice that there was a film of water on the outside of a cold glass of water and to realize that it was a noteworthy observation. They needed strong* ***questioning*** *skills to pose a question about that observation that could be investigated.. As good observers and questioners, children can efficiently pick out observations that are relevant from those that are not and come up with productive questions rather than those that may take them down dead-end paths.*

  The students needed strong skills in ***planning and investigating*** *and in* ***interpreting*** *the result of their investigation in order to rule out the hypothesis that water leaks out of glasses of cold water. Without such skills, students may do experiments without controlling variables or misinterpret their results and arrive at incorrect conclusions.*

  The students needed strong ***hypothesizing*** *skills to make the connection between the water on the outside of the glass and the water on the windshield of a car on a cold morning. With strong hypothesizing skills, students can dig back into their store of previous experiences and ideas and come up with an idea, a mix of ideas, or an incorporation of things they are finding along the way that will help explain their observations.*

  The students again needed strong skills in ***planning and investigating*** *and in* ***interpreting*** *the result of that investigation, to conclude that temperature was a critical variable in the observed phenomena.*

  As you can begin to see, strong science process skills are necessary in order to generate new explanations (hypotheses) and to rule out those that are wrong. Without strong process skills, the chances of ending up with a scientifically incorrect explanation or none at all are much higher.

Reemphasize the need to develop strong process skills:

- *In the best of cases, learning science content and using process skills are intimately intertwined. When students are doing good science, they are getting a vigorous workout of their process skills in the service of learning the science content. However, you can't expect your students to start with strong process skills. There are times when teachers have to put the development of process skills in the foreground and content in the background in order to develop stronger skills. In the next part of this workshop, we will focus on helping students develop stronger science process skills.*

PRESENTING THE WORKSHOP

Part 3: Helping Develop Process Skills

- **Developmental Levels of Process Skills**
- **Concluding the Workshop**

Developmental Levels of Process Skills

Materials Reminder

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

- **Display overhead M16a–c: "Indicators of Development of Process Skills" and distribute the corresponding handout**
- **Distribute handout M17: "Identifying the Levels of Process Skills (Windup Toy Activity)"**
- **Distribute handout M18: "Changing the Levels of Process Skills (Penny and Water Drops Activity)"**

Overview

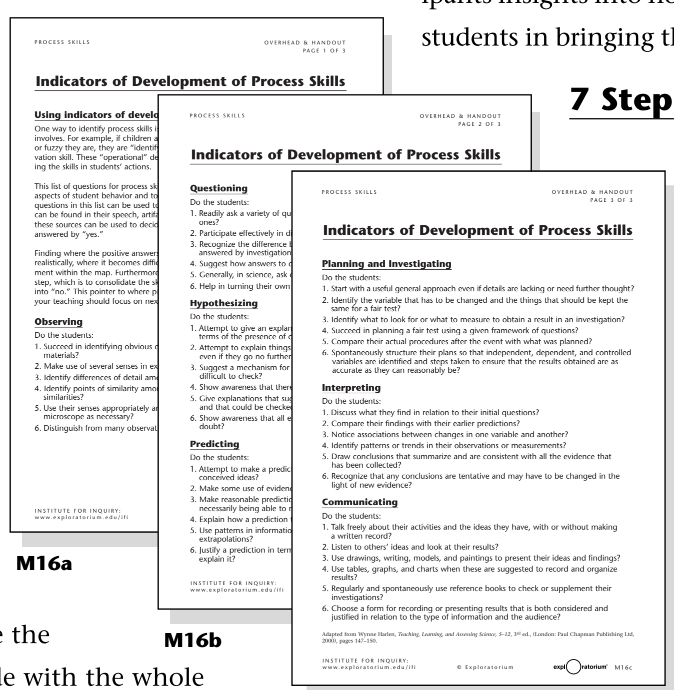
This third part of the workshop focuses on the idea that students of all ages use all of the process skills, and that each of the skills can be practiced at simple and increasingly complex levels. It's important that this fact be made explicit because many participants will have come to the workshop with the mistaken idea that while younger students can use some of the process skills (e.g., observing), other skills (e.g., hypothesizing) are only used by older students.

Participants examine the "Indicators of Development of Process Skills" handout, paying attention to the developmental nature of each process skill. The handout provides simple examples of how all the process skills are practiced at various levels.

Next, participants identify the levels of the process skills needed to complete a given science task. After that, they modify a science activity to raise the level of the process skills required, as they would do in the classroom to help students move to the next developmental skill level.

Participants then share the changes that they made with the whole group. This lets everyone see that there is a variety of ways to alter an activity to increase the developmental level of the process skills involved.

The brief exercises in this section communicate the important idea that simple changes in activities can help students develop and strengthen their process skills. While the exercises don't provide enough practice for teachers to master this technique, they give participants insights into how they can begin to assist students in bringing their skills to higher levels.



M16a

M16b

M16c

7 Steps ◆ 55 Minutes

1. Display overhead M16a–c: "Indicators of Development of Process Skills" and distribute the corresponding handout. Tell participants:

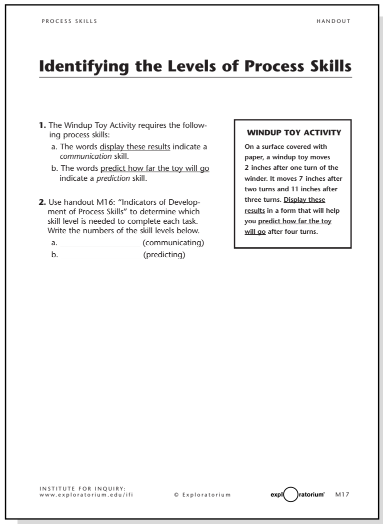
▶ *The "Indicators of Development of Process Skills," from the work of British science educator*

Wynne Harlen, show how each process skill is actually used at lower and higher developmental levels. These indicators describe what you might see students doing at various skill levels. A skill such as observation is often thought of as a "lower level" skill that even young children can master. Certainly young children can "make use of several senses in exploring objects or materials" (Level 2)—for example, in looking at, smelling, feeling, and tasting a piece of candy. But they are not able to "distinguish from many observations those that are relevant to the problem at hand" (Level 6), a high-level observation skill practiced by older, more sophisticated science students (as well as working scientists)—for example, a middle school class studying how frogs swim in a pond recognizing that they have to pay attention to how close the frogs are to the shore but not to the color of a frog's skin.

Similarly, hypothesizing can happen at lower and higher skill levels as well. Even kindergartners hypothesize, by attempting to give an explanation that is consistent with evidence, even if only in terms of the presence of certain features or circumstances (Level 1)—for example, a young child explaining that the wind blows because the trees move the air.

2. Explain how to use the Indicators. Tell participants:

► *You can use the "Indicators of Development of Process Skills" as an assessment tool when you want to get an accurate picture of where students are in developing their process skills. It also provides a map of where to go next in supporting the development of those skills. You can identify students' current skill levels and then design or redesign activities that help develop their skills to the next level.*


PROCESS SKILLS HANDOUT

Identifying the Levels of Process Skills

1. The Windup Toy Activity requires the following process skills:
a. The words display these results indicate a *communication* skill.
b. The words predict how far the toy will go indicate a *prediction* skill.

2. Use handout M16: "Indicators of Development of Process Skills" to determine which skill level is needed to complete each task. Write the numbers of the skill levels below.
a. ____________ (communicating)
b. ____________ (predicting)

WINDUP TOY ACTIVITY
On a surface covered with paper, a windup toy moves 2 inches after one turn of the winder. It moves 7 inches after two turns and 11 inches after three turns. Display these results in a form that will help you predict how far the toy will go after four turns.

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M17

3. Have participants identify the developmental levels of process skills (10 minutes). Ask the participants to find a partner. Distribute handout M17: "Identifying the Levels of Process Skills (Windup Toy Activity)" to each pair. Explain that in the following exercise, they will be determining the level of skill necessary to complete certain tasks. In particular, they will be working to identify the levels of two different process skills—*communicating* and *predicting*—required for completing the windup toy task. They should use the numbers from the "Indicators of Development of Process Skills" handout to indicate the level of each skill. (NOTE: the intended level for *communicating* is Level 4 and for *predicting* is Level 5.)

4. Reconvene the whole group, and ask various pairs to share their conclusions (10 minutes). When people respond, ask:

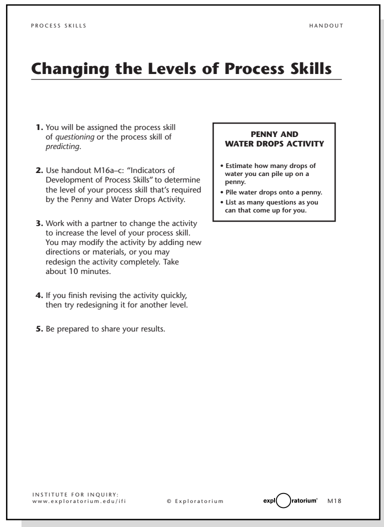
► *Can you explain why you identified that particular developmental level?*

(You might want to point out the level that participants are discussing on the "Indicators of Development of Process Skills" overhead.)

Note that there may be disagreements among participants about the skill levels. Explain that the purpose of this exercise is not to arrive at "correct" answers. Say:

► *I want to emphasize that what's important about identifying skill levels is not to get a "correct" answer, but to use that identification to help you determine what to do next in helping students strengthen their skills.*

5. Have participants practice changing skill levels (10 minutes). Tell participants:



PROCESS SKILLS HANDOUT

Changing the Levels of Process Skills

1. You will be assigned the process skill of *questioning* or the process skill of *predicting*.

2. Use handout M16a–c: "Indicators of Development of Process Skills" to determine the level of your process skill that's required by the Penny and Water Drops Activity.

3. Work with a partner to change the activity to increase the level of your process skill. You may modify the activity by adding new directions or materials, or you may redesign the activity completely. Take about 10 minutes.

4. If you finish revising the activity quickly, then try redesigning it for another level.

5. Be prepared to share your results.

PENNY AND WATER DROPS ACTIVITY

- **Estimate how many drops of water you can pile up on a penny.**
- **Pile water drops onto a penny.**
- **List as many questions as you can that come up for you.**

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M18

► *Now you are going to work with a different activity, one that describes a task requiring the use of skills at a certain level of development. What you will do is modify the activity in order to increase the developmental level of the required skills. This is something you can do in your classrooms. When you know that students are practicing a process skill at particular developmental level, you can consult the "Indicators of Development of Process Skills" handout to see what the next level looks like and redesign activities to advance them to the next level.*

Ask participants to work in the same pairs as previously. Distribute handout M18: "Changing the Levels of Process Skills (Penny and Water Drops Activity)." Divide the room in half. Ask the pairs in one half of the room to work to increase the skill level of *predicting*, and the pairs in the other half of the room to increase the skill level of *questioning*.

Tell participants that they may change the activity any way they want. First, they will need to identify the skill level of the task as it is presently written. Then, using the "Indicators of Development of Process Skills" handout, they should modify the activity to raise the skill level. (NOTE: The intended original level for both *questioning* and *predicting* is Level 1.)

6. Discuss changes in developmental levels with the whole group (20 minutes). Reconvene the group, and ask teams to share the changes they made. They should begin by identifying the original skill level. Explain:

► *We have a limited amount of time available for sharing. But we want to be certain that every group gets to share because we want you to get a sense of the wide range of ways in which activities can be changed to help students develop their skills. In order to hear from all of you, each group will have only about a minute. In your presentations, tell us what you thought was the original skill level, then describe the changes you made to the activity and tell us what the new skill level is.*

- Ask to hear first from all the pairs that worked with *questioning*, one pair at a time, and then from those that worked with *predicting*. While the groups are explaining what changes they made, display the Indicators page that includes the particular skill.

- Invite comments from the group on each pair's changes.

- At the end of the discussion, emphasize that, as has just been demonstrated, there are multiple ways of changing a single activity to raise the skill level.

- You can find examples of changes participants might make in the box on the next page.

7. Remind participants that, in practice, skills intertwine and overlap. Explain:

▶ *In the examples we've been considering, it's fairly easy to distinguish the process skills we are working with. But in practice, in the classroom, it's not always that easy. Remember that process skills are almost never practiced separately, but intertwine and overlap as students use them. So when you go back to your classrooms, you may find that it is still difficult to identify which skills particular activities require, or what skills students are using as they do hands-on science activities. It takes time and practice to become effective at identifying skills and adjusting skill levels.*

Examples of how participants have raised the skill levels

For *questioning*

Add: Ask students, "Which questions do you think you can answer by your own experiments?" *This raises the skill to Level 3.*

Add: Ask students to identify which of their questions are investigable and how they might go about investigating one of those. *This raises the skill to Level 4.*

Add: Ask students to choose a question that isn't investigable and suggest how they might change it to a question that can be investigated. *This raises the skill to Level 6.*

For *predicting*

Add at the beginning: Ask students to see how many drops they can put on a dime and how many drops they can put on a nickel. Then proceed as in the original. *This raises the skill to Level 2.*

Add at the beginning: Ask students to explore piling water drops on waxed paper and on aluminum foil. Then proceed as in the original. *This raises the skill to Level 2.*

Add at the beginning: Ask students to see how many drops they can put on a dime and how many drops they can put on a nickel. Have them explain how they could use a pattern in their observations to predict how many drops they can put on a penny. *This raises the skill to Level 4.*

Facilitation Hints for Developmental Levels of Process Skills

■ **Elicit Reasons for Choices**

The Windup Toy Activity was intended to require Level 4 for the *communicating* skill and Level 5 for the *predicting* skill. However, don't be surprised if you get a range of answers. When participants respond, ask them to explain the reasons for their responses.

■ **Circulate and Offer Help as Needed**

For the Penny and Water Drops Activity, if you notice that any pair is having trouble raising the skill level, you could say:

▶ *Look at the specific actions described at the next level and think about what questions or tasks would require students to take those actions.*

Concluding the Workshop

Materials Reminder

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

- **Distribute handout M2: "Take-Home Messages"**
- **(Optional) Distribute the article "The Process Skills of Inquiry," or let participants know where to get it online at www.nsf.gov/pubs/2000/nsf99148/ch_7.htm**

Overview

The facilitator summarizes and synthesizes the main ideas of the workshop and reviews the take-home messages.

4 Steps ◆ 5 Minutes

1. Distribute handout M2: "Take-Home Messages" and refer to the corresponding chart. Summarize the main ideas that came up during the workshop by reading the take-home messages aloud.

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

▶ *Remember that* Process Skills *wasn't designed to be replicated in the classroom. If you want to use any of the science tasks you did in the first part of the workshop, you'll need to need to find ways to relate them to particular parts of your science curriculum. What's important about this workshop isn't the individual activities, but the new understandings of process skills that you can carry with you and apply to your work with students.*

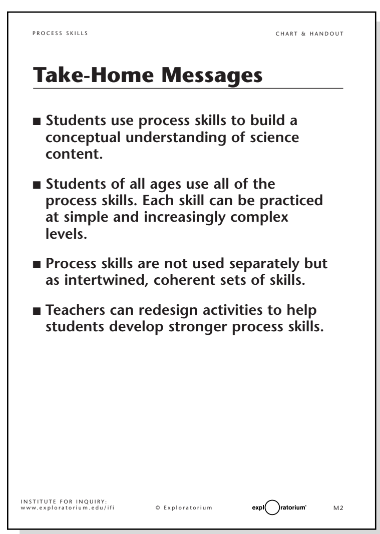
3. (Optional) Distribute copies of "The Process Skills of Inquiry."

Encourage participants to continue the conversation with each other about developing students' process skills to higher levels.

4. Let parti-cipants know about upcoming professional development workshops.

If you are planning to present the next FUNDAMENTALS OF INQUIRY workshop, *Raising Questions*, tell participants:

▶ *In the next workshop in the* FUNDAMENTALS OF INQUIRY *series,* Raising Questions, *you will have the opportunity to examine the kinds of questions learners ask about phenomena and find out how to turn questions that can't be investigated into those that can.*


PROCESS SKILLS CHART & HANDOUT

Take-Home Messages

- Students use process skills to build a conceptual understanding of science content.
- Students of all ages use all of the process skills. Each skill can be practiced at simple and increasingly complex levels.
- Process skills are not used separately but as intertwined, coherent sets of skills.
- Teachers can redesign activities to help students develop stronger process skills.

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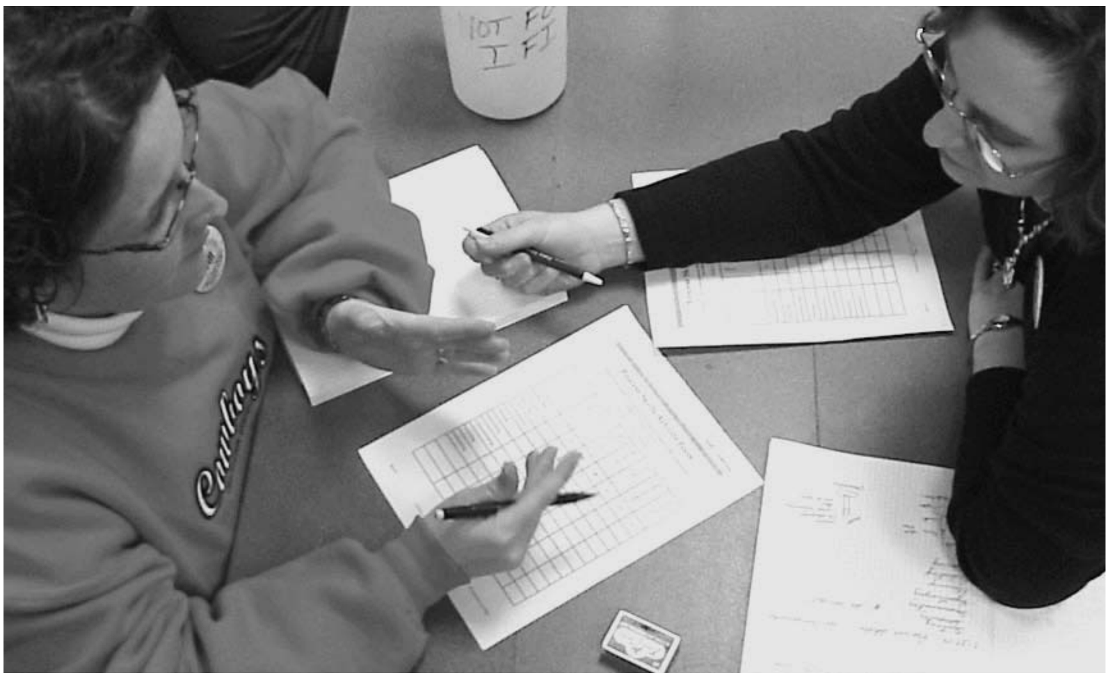
M2

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 process skills 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?

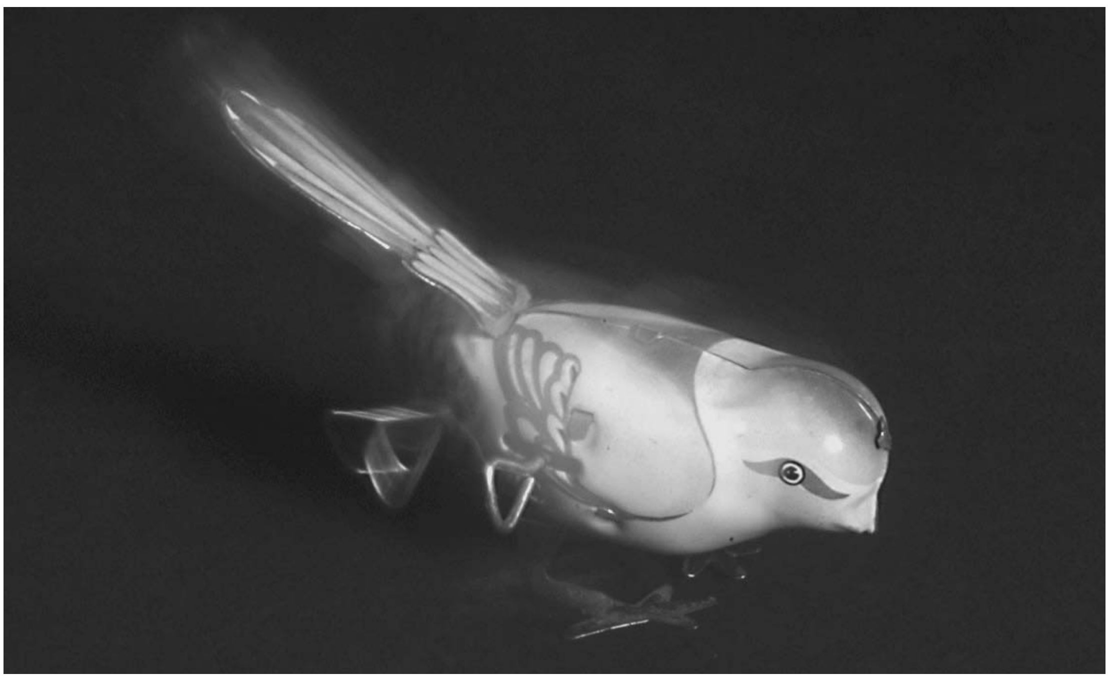
3. Review the logistics of the workshop.

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

MORE FROM THE INSTITUTE FOR INQUIRY



- **About the Exploratorium Institute for Inquiry**
- **More Workshops on the Web**
- ***Process Skills* and the *National Science Education Standards***
- ***Process Skills* and Inquiry Learning**

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.

For more information contact

Exploratorium Institute for Inquiry
3601 Lyon Street
San Francisco, CA 94123-1099
Phone: (415) 561-0330
Fax: (415) 561-0307
E-mail: ifi@exploratorium.edu
Web site: www.exploratorium.edu/ifi

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)

Process Skills and the *National Science Education Standards*

The authors of the *National Science Education Standards* and *Inquiry and the National Science Education Standards* make strong statements about the understanding of and the ability to use the process of inquiry: "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations."[1]

In *Inquiry and the National Science Education Standards,* the authors go further to claim 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. Students do not come to understand inquiry simply by learning words such as 'hypothesis' and 'inference' or by memorizing procedures such as 'the steps of the scientific method.' They must experience inquiry directly to gain a deep understanding of its characteristics.

"Yet experience in itself is not sufficient. Experience and understanding must go together. Teachers need to introduce students to the fundamental elements of inquiry. They must also assist students to reflect on the characteristics of the processes in which they are engaged."[2]

Indeed, in order to learn science content through inquiry, students must develop strong science process skills. These skills are listed in the *Standards* and summarized in *Inquiry and the National Science Education Standards* as shown in the table on the following page.

The skills mentioned in the box on the following page correlate directly onto the process skills discussed in this workshop.

The *Process Skills* workshop was designed to develop teachers' understanding and appreciation of the importance of science process skills. Through this workshop teachers become aware of their responsibility to help students build stronger process skills. The workshop supports the goals of the *Standards* in helping teachers to further their students' understanding of and the ability to use the inquiry process.

1. National Research Council. *National Science Education Standards*. (Washington, DC: National Academy Press, 1996), p. 23.

2. National Research Council. *Inquiry and the National Science Education Standards*. (Washington, DC: National Academy Press, 2000), p. 14.

Fundamental Abilities Necessary to Do Scientific Inquiry:

Grades K–4

- 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.

Grades 5–8

- 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.
- Use mathematics in all aspects of scientific inquiry.

Grades 9–12

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. (Washington, DC: National Academy Press, 2000), p. 19.

Process Skills and Inquiry Learning

When learners do inquiry they are making observations, raising questions, planning and carrying out investigations, proposing tentative explanations (hypotheses), testing these explanations by making predictions, interpreting results, and communicating those results to others. Students don't use process skills merely to be using them. Instead, they use them for the prupose of learning by connecting previous knowledge with current experience. Learners use the process skills to identify and investigate novel experiences, and, from this inquiry, build new ideas.

However, according to Wynne Harlen, noted teacher educator and author, when process skills are not developed to a sufficient degree, learners may "ignore contradictory evidence in interpreting findings and hold on to their initial ideas even though these do not fit the evidence. Thus the extent to which ideas become more scientific (by fitting more phenomena) depends on the way in which the testing of possible explanatory ideas is carried out; that is, on the use of process skills. The development of understanding in science is thus dependent on the ability to carry out process skills in a scientific manner."[1]

Children are natural inquirers. Driven by curiosity, they will instinctively raise questions and begin to investigate things. However, in order for these investigations to lead to productive development of the understanding of science concepts, learners' must be able to use the process skills effectively. Teachers who are charged with teaching science content must pay attention their student's process skills. Student inquiry becomes a powerful means of learning science concepts only when the students' process skills are well developed.

1. Harlen, Wynne. *The Teaching of Science in Primary Schools*, 2nd ed. (London: David Fulton Publishers, 1996), p. 14.

REPRODUCIBLE MASTERS

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Process Skills

Observing

Questioning

Hypothesizing

Predicting

Planning and Investigating

Interpreting

Communicating

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Take-Home Messages

- Students use process skills to build a conceptual understanding of science content.
- Students of all ages use all of the process skills. Each skill can be practiced at simple and increasingly complex levels.
- Process skills are not used separately but as intertwined, coherent sets of skills.
- Teachers can redesign activities to help students develop stronger process skills.

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1. Candle

What process skill would you use to carry out the directions in the underlined sentences?

Draw what you think the candle will look like when it's lit. Put labels on your drawing.

Now light the candle.

<u>Draw it again. What's different from your first drawing?</u>

Are there any details in this drawing that weren't labeled in the first drawing?

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2. Velcro

What process skill would you use to carry out the directions in the underlined sentence?

Put two pieces of Velcro together.

Try to part them.

Try putting the pieces reversed, then crossways.

<u>Make a series of drawings to show your ideas and findings about how Velcro works.</u>

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3. Hinged Mirror

What process skills would you use to answer the underlined questions?

Place the penny between the hinged mirrors so that reflections of the coin can be seen. Adjust the angle to 120 degrees and count the reflections. Repeat for angles of 30 degrees and 90 degrees.

A: <u>Can you identify a pattern in the relationship between images and angles? If so, what is it?</u>

B: <u>Based on the patterns you observed, how many images would you expect to get at 60 degrees?</u>

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4. Can of Ice

What process skill would you use to carry out the directions in the underlined sentence?

Fill the can approximately halfway with ice cubes.

Look at the outside of the can.

<u>Write down as many possible explanations as you can of what you see.</u>

Before you leave, empty the ice into the original container and wipe off the can.

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5. Wet Paper

What process skill would you use to answer the underlined question?

Take a strip of paper and hold it vertically with one end in the water.

Watch what happens for about a minute.

<u>Given your observations, what more do you want to know?</u>

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6. Toy on Different Surfaces

What process skill would you use to carry out the directions in the underlined sentences?

Suppose you were doing an investigation to find out whether the kind of surface on which a windup toy is put makes a difference in how far the toy moves.

Before doing the investigation, determine the following:

- **What will be changed?**
- **What will be kept the same?**
- **What will be measured?**

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Process Skills Identification

Identify the main process skill needed to complete the underlined directions in each activity.

Process Skill	**1.** Candle	**2.** Velcro	**3.** Hinged Mirrors **A**	**B**	**4.** Can of Ice	**5.** Wet Paper	**6.** Toy/Surfaces
Observing							
Questioning							
Hypothesizing							
Predicting							
Planning & Investigating							
Interpreting							
Communicating							

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Directions for Activities at the Stations

What process skills would you use to carry out the directions in the underlined sentences?

1. Candle

Draw what you think the candle will look like when it's lit. Put labels on your drawing. Now light the candle.

Draw it again. What's different from your first drawing? Are there any details in this drawing that weren't labeled in the first drawing?

2. Velcro

Put two pieces of Velcro together. Try to part them. Try putting the pieces reversed, then crossways.

Make a series of drawings to show your ideas and findings about how Velcro works.

3. Hinged Mirror

Place the penny between the hinged mirrors so that reflections of the coin can be seen. Adjust the angle to 120 degrees and count the reflections. Repeat for angles of 30 degrees and 90 degrees.

A. Can you identify a pattern in the relationship between images and angles? If so, what is it?

B. Based on the patterns you observed, how many images would you expect to get at 60 degrees?

4. Can of Ice

Fill the can approximately halfway with ice cubes.

Look at the outside of the can.

Write down as many possible explanations as you can of what you see.

Before you leave, empty the ice into the original container and wipe off the can.

5. Wet Paper

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Before doing the investigation, determine the following:

- What will be changed?
- What will be kept the same?
- What will be measured?

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Observing Process Skills in Action

One way to identify the science process skills is by what learners actually do when they are using the skills. The following list provides examples.

Observing

When observing, learners are:

- identifying differences and similarities between objects or materials
- using tools or instruments as necessary to extending the range of the senses
- distinguishing from many observations those which are relevant to the problem at hand

Questioning

When questioning, learners are:

- readily asking a variety of questions about phenomena
- recognizing differences between questions that can and cannot be answered by investigation

Hypothesizing

When hypothesizing, learners are:

- attempting to give explanations which are consistent with evidence or with ideas from prior experiences
- showing that they are aware that there may be more than one explanation that fits the evidence

Predicting

When predicting, learners are:

- making use of evidence from experience or a possible explanation (hypothesis) in forecasting the outcome of a specific future event
- using patterns in information or observations in forecasting outcomes of specific events that go beyond the data (extrapolations)

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Observing Process Skills in Action

Planning and Investigating

When planning and investigating, learners are:

- for a fair test, identifying the variable that has to be changed, the things that should be kept the same, and what to look for or measure to obtain a result in an investigation
- comparing what they actually did with what they planned

Interpreting

When interpreting, learners are:

- discussing what they find in relation to their initial questions
- identifying patterns or trends in their observations or measurements and noticing related changes

Communicating

When communicating, learners are:

- using drawings, writing, models, and paintings to present their ideas, and using tables, graphs, and charts to record and organize results
- choosing forms for recording or presenting results that are appropriate for the type of information collected and presented, and appropriate for the audience

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Separating Process Skills

Process skills are not practiced discretely.

Someone who is observing, for example, may be doing some predicting and hypothesizing, and possibly even interpreting, virtually simultaneously. Pulling the skills apart and distinguishing them from one another can prove tricky.

In actual practice, what we call process skills are not individual skills but combinations, or blends, of several skills. But, as teachers, we need to address the skills separately so that we can identify where students are in their development of each skill in order to focus on helping them strengthen particular skills.

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Process Skills: Definitions and Examples

The science process skills are the tools that students use to investigate the world around them and to construct science concepts, so it's essential for teachers to have a good understanding of these skills. However, identifying and defining the process skills is not always a simple task.

The first problem is that the skills aren't practiced discretely. When you look at a real-life situation, you're likely to find several related skills being used more or less at the same time. Consider, for example, trying to explain why water drops appear on the outside of a can filled with ice: You're observing the phenomenon, you're interpreting what your observation means, and you're proposing a hypothesis, or explanation. It can be challenging to tease out separate skills because to a certain extent the boundaries are artificial. But it's necessary to be able to distinguish individual skills in order to work effectively with students.

The second problem concerns how broadly or narrowly the skills should be defined. The skill of classifying, for example, while often found listed as a separate skill, can also be viewed as a subskill of observing. Because it can be quite cumbersome to work with a long list of narrowly defined skills, this document presents seven broadly defined skills and indicates subskills where appropriate.

The definitions and examples given below are based on a number of sources and represent commonly accepted uses of the process skill terms.

Observing

Using the senses and appropriate tools to gather information about an object, event, or phenomenon.

Subskills include collecting evidence, identifying similarities and differences, classifying, measuring, and identifying relevant observations.

Example: Listing the similarities and differences of a cube of ice and a ball of ice.

Questioning

Raising questions about an object, event, or phenomenon.

Subskills include recognizing and asking investigable questions; suggesting how answers to questions can be found; and turning a noninvestigable question into a question that can be acted upon.

Example: Asking "Will ice melt faster with or without salt sprinkled on it?"

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Process Skills: Definitions and Examples

Hypothesizing

Giving a tentative explanation, based on experience, of a phenomenon, event, or the nature of an object. A hypothesis is testable. A hypothesis is *not* the same thing as a prediction, which is the expected outcome of a specific event. However, a hypothesis can be used to explain specific events.

Subskills include inferring, constructing models to help clarify ideas, and explaining the evidence behind a hypothesis.

Example: Increased surface area causes faster melting. (This explains why crushed ice will melt faster than a block of ice of the same mass.)

Predicting

Forecasting the outcome of a specific future event based on a pattern of evidence or a hypothesis (an explanation). A prediction based on a hypothesis can be used in planning a test of that hypothesis. Note: A prediction is *not* a wild guess.

Subskills include justifying a prediction in terms of a pattern in the evidence, and making a prediction to test a hypothesis.

Example: Water flowing from a height of eight inches will wash away more sand than water flowing from a height of six inches; this prediction is based on the pattern that water flowing from six inches washed away more sand than water flowing from four inches, and water flowing from four inches washed away more sand than water flowing from two inches.

Planning and Investigating

Designing an investigation that includes procedures to collect reliable data. Planning includes devising a way to test a hypothesis. Note: Planning is not always formal.

Subskills include identifying and controlling variables, and using measuring instruments.

Example: Deciding to put a teaspoon of salt on one ice cube and a teaspoon of sugar on another identical ice cube; setting them side by side, and observing their relative melting rates in order to determine if one melts faster than the other.

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Process Skills: Definitions and Examples

Interpreting

Considering evidence, evaluating, and drawing a conclusion by assessing the data: In other words, answering the question, "What do your findings tell you?" Finding a pattern or other meaning in a collection of data.

Subskills include interpreting data statistically, identifying human mistakes and experimental errors, evaluating a hypothesis based on the data, and recommending further testing where necessary.

Example: After observing the melting rates of an ice cube sprinkled with salt and one without salt, concluding that salt reduces the freezing point of water.

Communicating

Representing observations, ideas, theoretical models, or conclusions by talking, writing, drawing, making physical models, and so forth.

Subskills include talking with a more knowledgeable person, using secondary sources, presenting reports, constructing data tables, and creating charts and graphs.

Example: Describing the relationship between the melting time for an ice cube and amount of salt sprinkled on the cube by writing about it or by constructing a graph.

Note: These definitions are adapted from the following sources:

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Student Learning: Condensation

A group of fourth-graders had glasses of cold water and ice cubes. The students noticed that the glasses were wet on the outside, apparently covered with water, and they wondered where the water came from. In searching for an explanation of where the water on the outside of the glass came from, they called on their previous experience of water leaking out of containers such as paper cups.

Based on those experiences, they reasoned that the water somehow leaked out of the glass. They told their teacher about their idea, and she asked them how they could test the idea. They said that if the water came from inside the glass, then the glass should end up with less water in it. One student said that they could mark the water level on the glass and see if the water level went down after a while. The teacher suggested that they cover the glass so water wouldn't evaporate out of it.

So the students tested their idea by covering a glass of water with plastic wrap, marking the water level, letting it sit for 30 minutes, and checking to see if the water level had gone down. They found that the water level did not change.

This test challenged their explanation, so they turned to yet another idea from their previous experience. They recalled that on cold days, sometimes their parents' car windows had dew on them. They wondered if it was the cold that caused the water on the outside of the glass and tentatively posed this as an explanation. They decided to test this idea by putting ice water in one glass and warm water in another to see if there was a difference. They reasoned that if the glass of ice water had water on the outside but the glass of warm water did not, then it must be the cold that caused it.

The students tested their idea by putting ice water in one glass, warm water in a second glass, and checking to see if there was water on the outside of either glass. They found that there was a film of water on the outside of the glass filled with ice water but no water on the outside of the glass filled with warm water.

This test supported their explanation. They concluded that it was the cold and not the water in the glass that caused the thin film of water on the outside of the glass.

Note: *This anecdote is a fictional account written for the purposes of illustrating the science process skills in action.*

The science in this anecdote: The film of water on the outside of the cold glass is caused by condensation. Condensation is the change of state from vapor to liquid. There is water vapor in the air that comes into contact with the cold surface of the glass. All air has water vapor (the gaseous state of water) in it, sometimes more and sometimes less. The degree of water in the air is called humidity. Locales with high humidity have a relatively high degree of water vapor in the air. The amount of water vapor that the air is capable of holding depends on the temperature. The colder the air, the less water vapor it can hold. If the air is cooled to a point where it can't hold the water vapor that is already in it, some of that water vapor condenses into liquid water. In our example, the cold surface of the glass cools the adjacent air enough to cause water vapor to condense from the air onto the outside surface of the glass.

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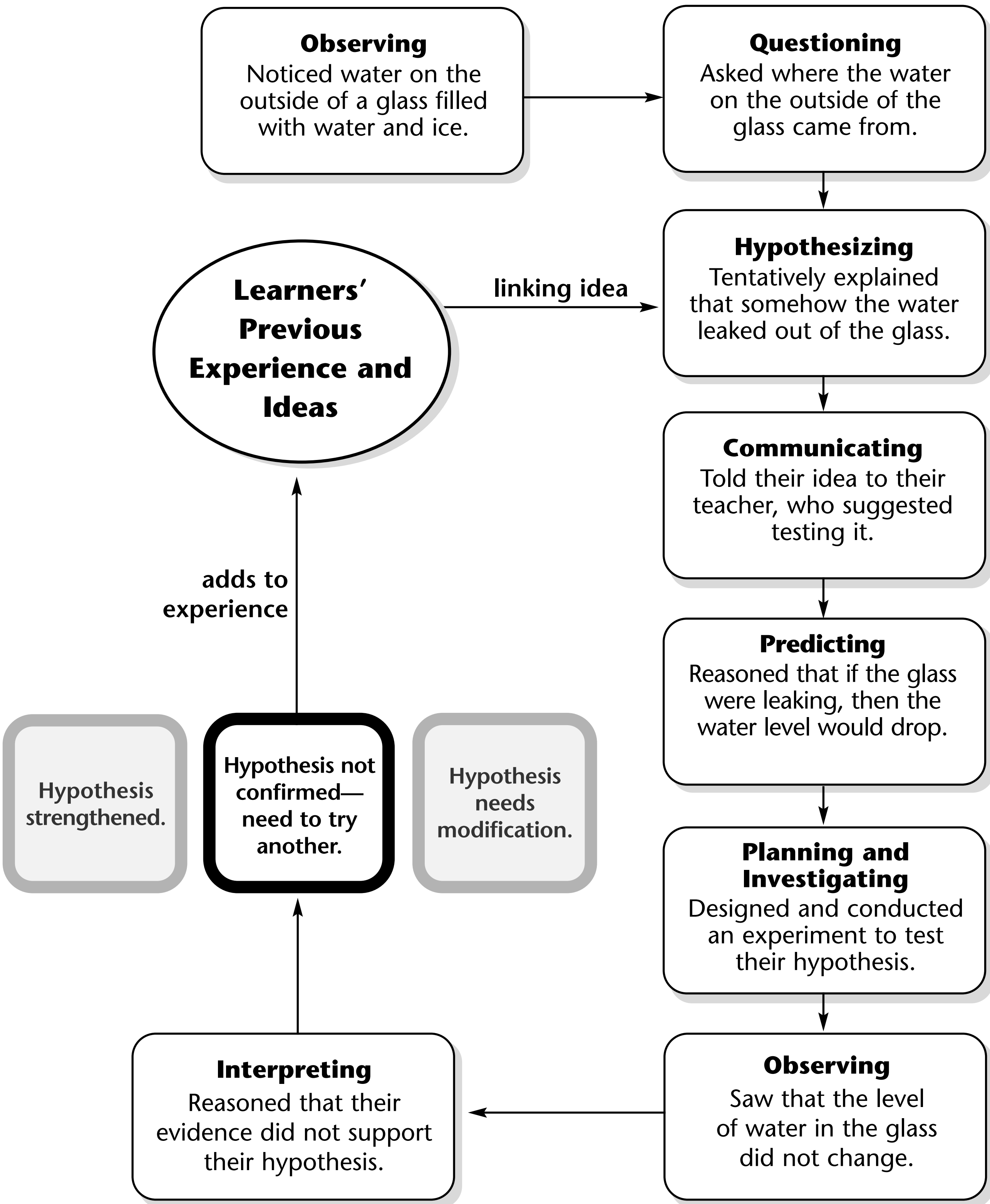
Learning about Condensation: A



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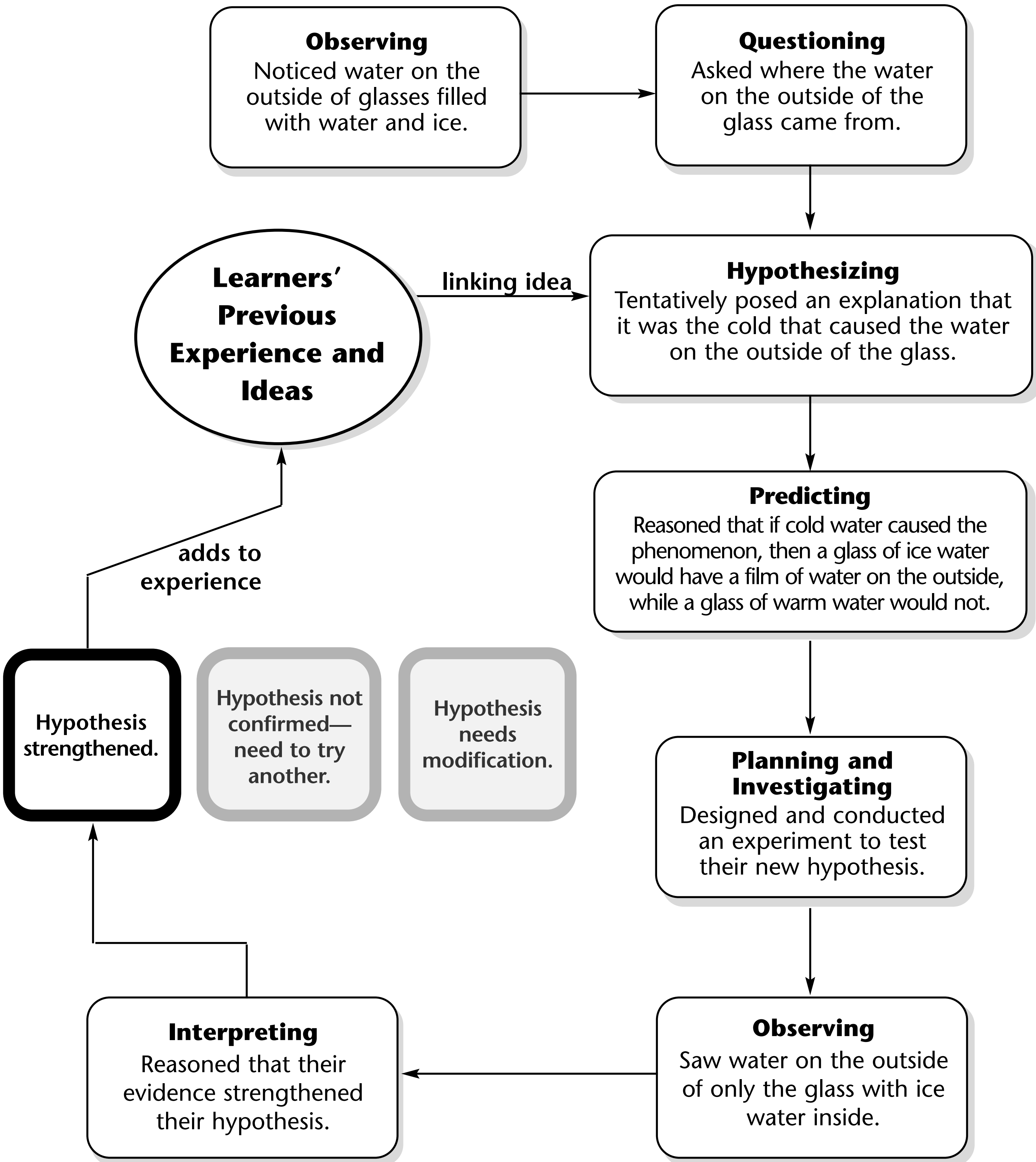
Learning about Condensation: B



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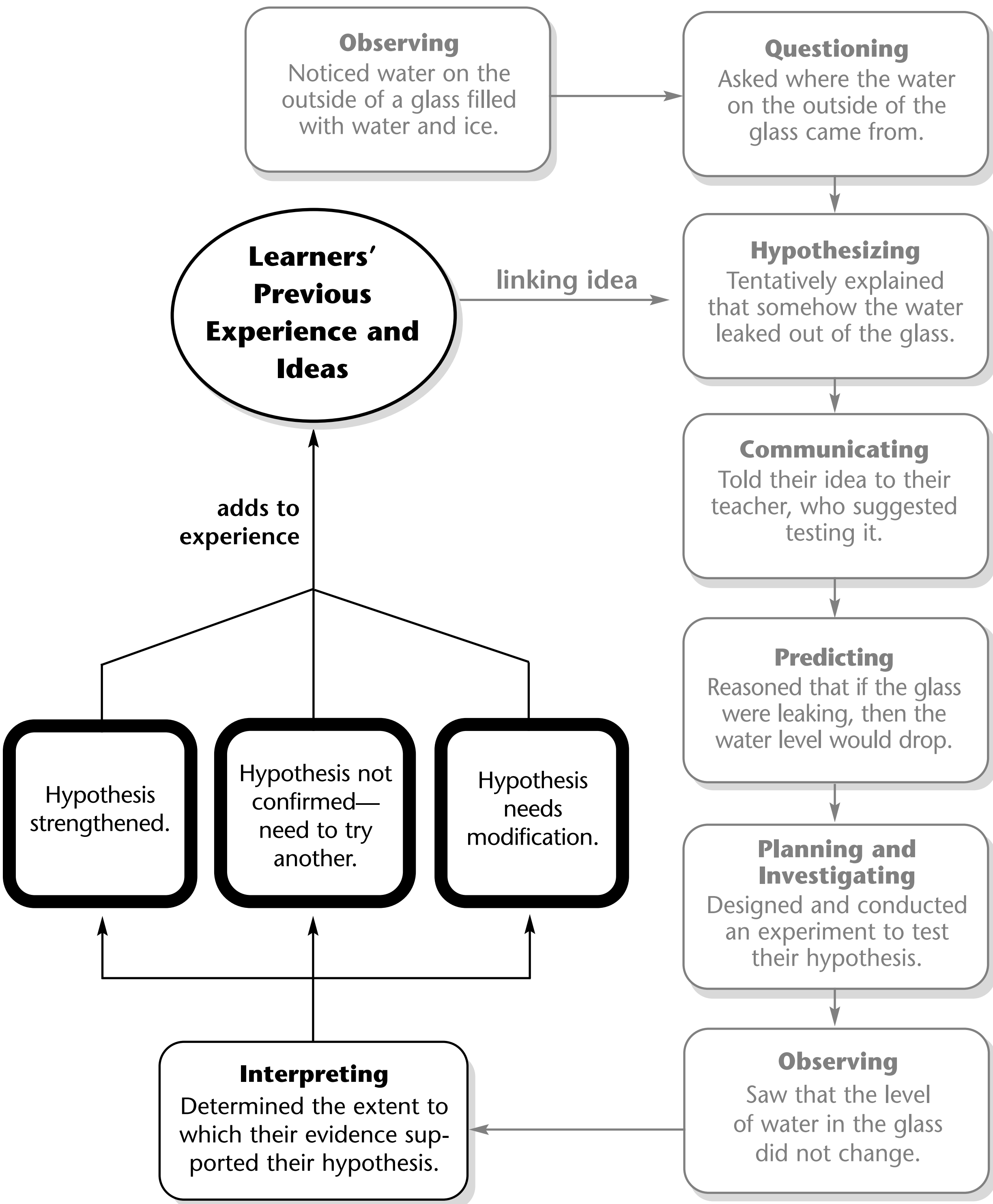
Learning about Condensation: C

Possible Outcomes of an Investigation Designed to Test a Hypothesis



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Indicators of Development of Process Skills

Using indicators of development of process skills

One way to identify process skills is by the actions that using each of the process skills involves. For example, if children are sorting leaves into groups based on how smooth or fuzzy they are, they are "identifying obvious differences between objects," an observation skill. These "operational" definitions of process skills are important for recognizing the skills in students' actions.

This list of questions for process skills helps you focus your observation on significant aspects of student behavior and to interpret your observations of these behaviors. The questions in this list can be used to interpret the full range of student behavior that can be found in their speech, artifacts, writing, and drawings. Observations from all these sources can be used to decide which of the questions in the lists below can be answered by "yes."

Finding where the positive answers to the questions turn into negative ones—or more realistically, where it becomes difficult to say yes or no—locates the students' development within the map. Furthermore, and importantly, this process indicates the next step, which is to consolidate the skills and ideas around the area where "yes" turns into "no." This pointer to where progress is to be made helps you determine what your teaching should focus on next.

Observing

Do the students:

1. Succeed in identifying obvious differences and similarities between objects and materials?
2. Make use of several senses in exploring objects or materials?
3. Identify differences of detail among objects or materials?
4. Identify points of similarity among objects where differences are more obvious than similarities?
5. Use their senses appropriately and extend the range of sight using a hand lens or microscope as necessary?
6. Distinguish from many observations those that are relevant to the problem in hand?

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Indicators of Development of Process Skills

Questioning

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 the 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 that are potentially investigable?
6. Help in turning their own questions into a form that can be tested?

Hypothesizing

Do the students:

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

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?

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Indicators of Development of Process Skills

Planning and Investigating

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?

Interpreting

Do the students:

1. Discuss what they find in relation to their initial questions?
2. Compare their findings with their earlier predictions?
3. Notice associations between changes in one variable and another?
4. Identify patterns or trends in their observations or measurements?
5. Draw conclusions that summarize and are consistent with all the evidence that has been collected?
6. Recognize that any conclusions are tentative and may have to be changed in the light of new evidence?

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, and 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 reference books to check or supplement their investigations?
6. Choose a form for recording or presenting results that is both considered and justified in relation to the type of information and the audience?

Adapted from Wynne Harlen, *Teaching, Learning, and Assessing Science, 5–12*, 3rd ed., (London: Paul Chapman Publishing Ltd, 2000), pages 147–150.

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Identifying the Levels of Process Skills

1. The Windup Toy Activity requires the following process skills:

a. The words <u>display these results</u> indicate a *communication* skill.

b. The words <u>predict how far the toy will go</u> indicate a *prediction* skill.

2. Use handout M16: "Indicators of Development of Process Skills" to determine which skill level is needed to complete each task. Write the numbers of the skill levels below.

a. ____________________ (communicating)

b. ____________________ (predicting)

WINDUP TOY ACTIVITY

On a surface covered with paper, a windup toy moves 2 inches after one turn of the winder. It moves 7 inches after two turns and 11 inches after three turns. <u>Display these results</u> in a form that will help you <u>predict how far the toy will go</u> after four turns.

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Changing the Levels of Process Skills

1. You will be assigned the process skill of *questioning* or the process skill of *predicting*.

2. Use handout M16a–c: "Indicators of Development of Process Skills" to determine the level of your process skill that's required by the Penny and Water Drops Activity.

3. Work with a partner to change the activity to increase the level of your process skill. You may modify the activity by adding new directions or materials, or you may redesign the activity completely. Take about 10 minutes.

4. If you finish revising the activity quickly, then try redesigning it for another level.

5. Be prepared to share your results.

PENNY AND WATER DROPS ACTIVITY

- **Estimate how many drops of water you can pile up on a penny.**
- **Pile water drops onto a penny.**
- **List as many questions as you can that come up for you.**

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