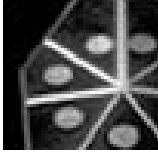


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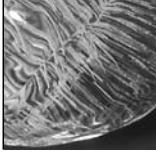
Workshop I



Workshop II



Workshop III



Workshop IV

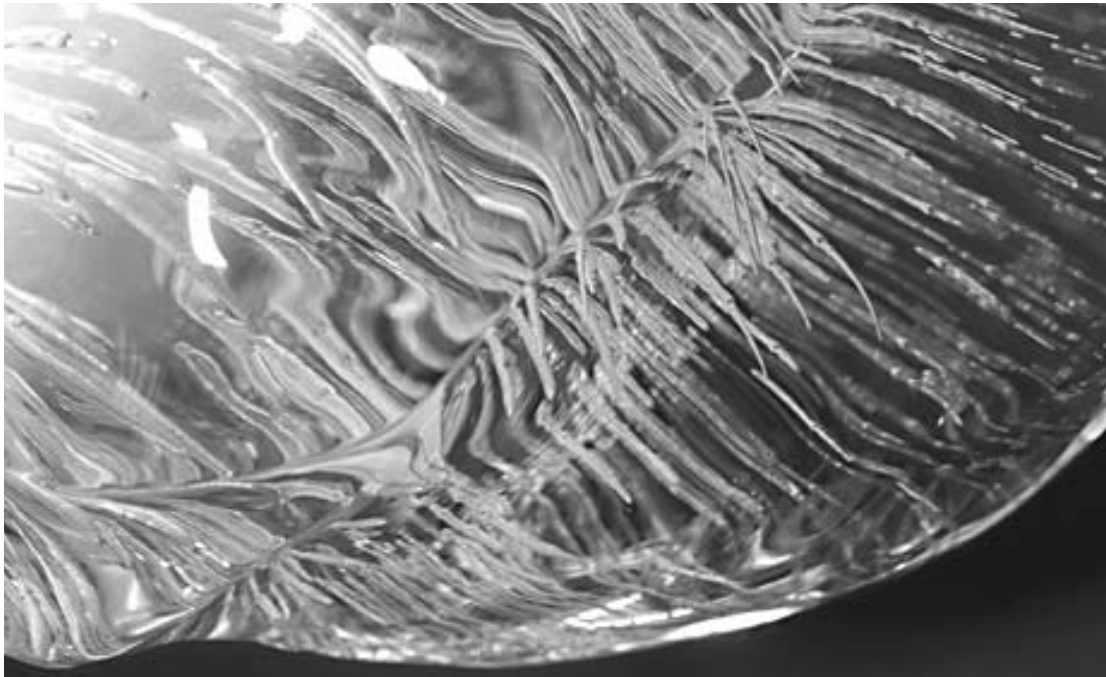


Workshop V



## Fundamentals of Inquiry Facilitator's Guide

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## WORKSHOP III: RAISING QUESTIONS

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A Professional Development Curriculum from the  
**Institute for Inquiry<sup>®</sup>**

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

## RAISING QUESTIONS

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**Caution:** The experiments in this guide were designed with safety and success in mind. But even the simplest activity or the most common materials can be harmful when mishandled or misused. Use common sense whenever you're exploring or experimenting.

You can download your own copy of this guide at [www.exploratorium.edu/ifi/questions](http://www.exploratorium.edu/ifi/questions). A wealth of background material, for this and the other guides in the series, can be found at [www.exploratorium.edu/ifi/library](http://www.exploratorium.edu/ifi/library).

In order to access these materials, you will need Macromedia Flash Player 5 or higher and Adobe Acrobat Reader 4 or higher, available for free downloading at [www.exploratorium.edu/ifi/help](http://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](http://www.exploratorium.edu/ifi/workshops/fundamentals).**



# Raising Questions

## 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 how to focus on the questions of science, rather than just the answers.

In 2000, we received a major grant from the National Science Foundation to make what we have learned available to even more educators. The result is a series of guides that provide step-by-step instructions and access to support materials online so professional developers and teacher educators can present these workshops on their own.

*Raising Questions* is designed to help teachers support students in developing the skill of questioning. We hope you find this workshop useful in establishing a vibrant setting for teachers to learn and extend their practice. And we hope that, like us, you will be inspired by seeing teachers become enthused about science, eager to bring the very best ideas and approaches to their students.

—LYNN RANKIN  
Director  
Institute for Inquiry

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# 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 Crouse, 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 third 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 teachers and other educators who are interested in developing an understanding of inquiry-based science instruction.

One of the most powerful ways for students to learn science is through questions grounded in their own curiosity. *Raising Questions* introduces teachers to ways to stimulate that curiosity, elicit student questions, and move them in productive directions that can ultimately lead to investigations. The *Raising Questions* workshop provides teachers with new pedagogical understandings and skills rather than activities they can take back to the classroom. It can be presented on its own or used as part of a series. For information about the complete curriculum, see page 8.

## **The Goals of the Workshop**

All inquiry begins with a question. Many teachers use kits and other hands-on science curricula as starting points for investigating questions in the classroom. When students use these curricula, the questions they investigate are often determined by the instructional materials.

These materials can provide excellent starting points for teachers interested in providing opportunities for their students to engage in more learner-driven investigations. While many teachers have the sense that their students would be motivated to explore topics in greater depth if they could pursue their own questions, they may be hesitant to encourage students to do this. What frequently deters them is a

### **Goals**

- To help teachers develop an understanding of the importance of giving students opportunities to ask their own questions—ones students can then investigate on their own.
- To help teachers realize they can develop their students' questioning skills so the questions students ask lead in productive directions.

concern that students won't have many questions, that it would be impossible to investigate the questions they do ask, or that their questions would not be focused on the topic at hand. *Raising Questions* responds to those concerns.

## **How the Workshop Works**

This workshop takes about three-and-a-half hours and is intended to be led by two facilitators. Typically, planning takes about six hours, not including the time necessary to prepare materials. In this guide, we list materials for 36 participants. For fewer participants, quantities can be adjusted.

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.

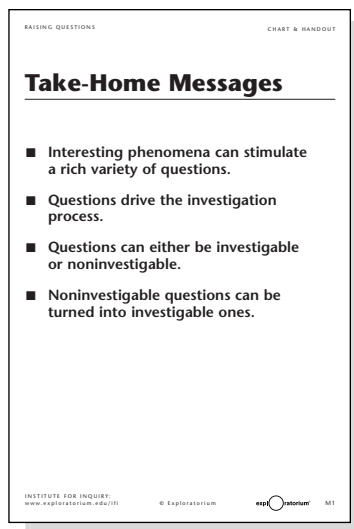
Working in small groups, participants explore “ice

balloons”—small spheres of ice made by freezing water balloons—and write down questions that occur to them. The intriguing nature of the ice lets participants experience the wonder and curiosity that flow out of engagement with real phenomena and leads to a multitude of questions.

After this exploration, each group sorts its questions into piles of “investigable” and “noninvestigable” questions and then chooses one of the investigable questions to pursue, taking note of new questions that come up as they work. They discover the dynamic nature of the questioning process: that one question leads to another, and that over time they may come up with a question that’s completely different from their initial question, which leads them in an unanticipated direction. (You can find out more about the nature of questions by reading “Different Kinds of Questions” in the box on page 34.)

Next, participants develop an understanding of an investigable question—a question that leads to taking some action with materials and phenomena. Then they learn a technique for reformulating noninvestigable questions into those that can be investigated.

Learning how to do this can be an eye-opening experience for teachers. Many realize for the first time that they can help students develop their questioning skills; they see how students’ questions can lead in productive directions that can help build an understanding of complex phenomena.



**M1**

In the last part of the workshop, teachers share ideas with each other. They talk about establishing a classroom climate in which students’ questions are encouraged and welcomed and about how they can help their students become more effective questioners.

The investigation in this workshop is purposefully brief, serving as a vehicle for learning about the relationship between questioning and investigating. While participants will learn some science concepts about ice as they work, the emphasis is on the pedagogy of questioning.

### **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

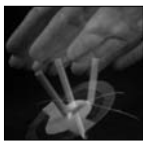
## **FUNDAMENTALS OF INQUIRY**

*Raising Questions* is the third 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**

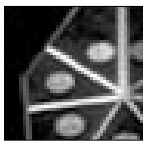
A set of workshops that serve as building blocks for an immersion into inquiry by focusing on various hands-on approaches and process skills related to inquiry learning.



#### **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](http://www.exploratorium.edu/ifi/comparing)*



#### **Workshop II: Process Skills**

Participants identify the tools needed to carry out inquiry—the process skills—and examine the role of these skills in learning (about 3.5 hours).

*Preview the workshop at [www.exploratorium.edu/ifi/skills](http://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](http://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](http://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](http://www.exploratorium.edu/ifi/subtleshifts)*



# PLANNING AND PREPARATION



- **Workshop at a Glance**
- **Essential Planning Steps**
- **Sample Room Setup**
- **Materials**
- **Charts, Overheads, and Handouts**
- **How to Make Ice Balloons**
- **Background Science for the Ice Balloon Activity**

# Workshop at a Glance

Planning and Preparation  
6 hours + materials prep

## Presenting the Workshop Part 1: Introduction and Hands-On Experience

### Introducing the Workshop

Facilitators set the context and divide participants into small working groups.  
9 groups, 4 people each. **10 minutes**

### Raising Questions

Participants explore ice balloons and generate questions about them. **30 minutes**

### Investigating Questions

Participants sort, choose, and investigate their own questions. **30 minutes**

Break — 15 minutes

## Presenting the Workshop Part 2: Identifying and Creating Investigable Questions

### Examining the Investigated Questions

Participants construct an understanding of the kinds of questions that can lead to investigations. **25 minutes**

### Developing Criteria

Participants develop criteria for identifying questions that can be investigated. **15 minutes**

### Identifying Characteristics of Questions

Participants look at the differences between investigable and noninvestigable questions. **15 minutes**

### Turning Questions

Participants learn a technique for converting noninvestigable questions into questions that can be investigated. **30 minutes**

### Connecting to the Classroom

Participants share ideas for working with questions in the classroom. **30 minutes**

### Concluding the Workshop

**10 minutes**

Reviewing the Workshop  
time as needed

**Workshop Time:** Approximately 3½ hours

**Facilitators Needed:** 2

**Participants Accommodated:** 36

### Special Materials Note

You will need to make ice balloons at least two days in advance of using them. See page 18 for details.

### Arranging Work Groups

Participants work in small groups that stay together through the entire workshop, while discussions involve the group as a whole.

# Essential Planning Steps

## Overview

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

It's important that you and your co-facilitator go over these steps together, arriving at a shared understanding of workshop goals. There is a lot to do, including reading through this entire guide, preparing to lead a discussion, trying the workshop yourselves, ordering materials, arranging for an appropriate space, and preparing over-heads and handouts.

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

## Before the Workshop

### 1. Read this guide all the way through.

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

### 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.

### 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/questions](http://www.exploratorium.edu/ifi/questions).

**3. Practice making ice balloons.** In this workshop, participants will be working with ice balloons, balls of ice made by freezing water balloons. Make a few at least two days in advance of when you will be trying out the workshop for yourself (see Step 5, below). See *How to Make Ice Balloons* on page 18.

**4. Prepare materials.** Gather and organize all materials. (See the complete list on page 16.) Materials are all common and easily available.

- Duplicate and prepare all handouts, charts, and overheads (see p. 17).

### Planning Time Needed

Planning typically takes about 6 hours, not including the time necessary to gather and prepare materials and equipment.

- To make it easy to set up on the day of the workshop, organize handouts, charts, and overheads according to when and where they will be used. Organize and store materials for each table so you can set them out quickly.

- Be sure to prepare ice balloons two days or more in advance of the workshop—one day usually isn't enough to ensure complete

freezing. Each working group will need at least two ice balloons.

**5. Do the workshop as learners.** When ice balloons are available, meet together and go through the workshop as if you were participants. Don't be tempted to skip this step. It's very important to get a personal feel for working with ice balloons in order to have insight into participants' experiences, as well as their potential questions.

This practice workshop will also help you determine the best way to make ice balloons, since variables of water quality and freezer efficiency will have to be assessed.

If possible, conduct your practice workshop in the room where the workshop will take place. Make sure that charts and overheads will be legible for all participants.

**6. Do the workshop as facilitators.** Go through the workshop again, this time as facilitators.

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

- Practice presenting scripted instructions (set in italics and marked with gray arrows) in your own words. While it's important to convey this infor-

mation in a way that is as close as possible to what is written, it will probably work best for you to say it in your own words, rather than reading the scripts.

### **7. Familiarize yourselves with each step.**

Read through the steps carefully, studying the prompts and facilitation hints and becoming familiar with the information and instructions.

- Note that facilitation for Part 1 of the workshop is relatively straightforward. Your main role will be to help participants move their explorations along, encouraging them to ask questions and take action on those questions.

- In Part 2 of the workshop, three sections require considerable facilitation: Examining the Investigated Questions (page 31), Identifying Characteristics of Questions (page 34), and Turning Questions (page 36).

The facilitator sets the context for a series of tasks that are done in small groups and then reconvenes the whole group for discussions. These discussions require active facilitation in order to lead the whole group in an examination of the ideas that have come up in the small groups. Extensive facilitation guidance is provided for these sections.

- For the Connecting to the Classroom part of the workshop (page 39), read handout M12 a&b: "Thoughts on Student Questions" to decide if you want to discuss any of the material in the article with participants. (You'll distribute this handout at the end of the workshop.)

**8. Be prepared to set the context.** Setting the context for the workshop is crucial. The facili-

### **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.

tator who introduces the workshop should study the information in Step 1 of Introducing the Workshop (page 23), and practice setting the context in his or her 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 participants have had? How is it related to district and state goals and standards? What do you want teachers to get from the experience? If you want to relate the workshop to the *National Science Education Standards*, consult page 49 of this guide.

### 9. Plan time and space carefully.

- Create a detailed schedule for facilitators to refer to during the workshop. Note the beginning and ending times for each step (e.g., Introductions, 9:00–9:05; Set context, 9:05–9:08; Refer to take-home messages, 9:08–9:10). Be sure to include time for breaks.
- Prepare a simplified version of this schedule for participants, which you can post at the beginning of the workshop. A sample schedule (based on Workshop at a Glance, page 10) is shown in the next column.
- Remember that the times given for the various parts of the workshop are approximate. The times needed for different steps may vary according to the facilitator's style.
- Decide how many participants you want in each working group. Three or four people per group works well. For simplicity, this guide assumes there are nine groups of four people. You may have to adjust for your own situation.
- Decide where the workshop will take place. You will need one large room with space for materials, a sink and refrigerator or ice chest, and work space. See the Sample Room Setup on page 15 for complete information.

#### Sample Schedule for Raising Questions Participants

9:00–9:10	Introducing the Workshop
9:10–9:40	Raising Questions
9:40–10:10	Investigating Questions
10:10–10:25	Break
10:25–10:50	Examining the Investigated Questions
10:50–11:05	Developing Criteria
11:05–11:20	Identifying Characteristics of Questions
11:20–11:50	Turning Questions
11:50–12:20	Connecting to the Classroom
12:20–12:30	Concluding the Workshop

**10. Assess the need for additional information.** Be sure to read *Raising Questions* and Inquiry Learning on page 48 and *Raising Questions* and the *National Science Education Standards* on page 49. 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 *National Science Education Standards*. You may want to copy these sections for participants.

- The additional resources on the next page may also be of interest to you or the participants. Before presenting this workshop, read through them and decide which, if any, to copy for distribution.

### On the Day of the Workshop

**1. Prepare the room.** Consult the Materials list on page 16. Set out the materials on the appropriate tables. Put the handouts, charts, and overheads near where you will be using them. (See

Sample Room Setup, page 15.)

- Set up two clamp lights at different locations in the room to provide ambient lighting when you turn off the overhead lights.

### Additional Resources

- ❑ “Cool Experiments for a Hot Day” by Ron Hipschman.

This reprint from the *Exploratorium Quarterly* magazine introduces some of the fascinating characteristics of ice and includes several easy-to-do activities. Available at [www.exploratorium.edu/ronh/cool\\_experiments](http://www.exploratorium.edu/ronh/cool_experiments).

- ❑ *Inquire Within: Implementing Inquiry-Based Science Standards*, by Douglas Llewellyn, Thousand Oaks, CA: Corwin Press, 2002, Chapters 2 and 9.

Explores different ways questions are used in the classroom, both by teachers and students.

- ❑ *Primary Science: Taking the Plunge*, 2nd ed., by Wynne Harlen, Portsmouth, NH: Heinemann, 2001, Chapters 3, 4, and 6.

Provides thoughtful information on how teachers can encourage and handle student questions.

- Keep the ice balloons in the freezer or ice chest until the last possible minute.
- Note that you’ll need to leave some extra time for filling the tubs with enough water so the ice balloons can float in them.

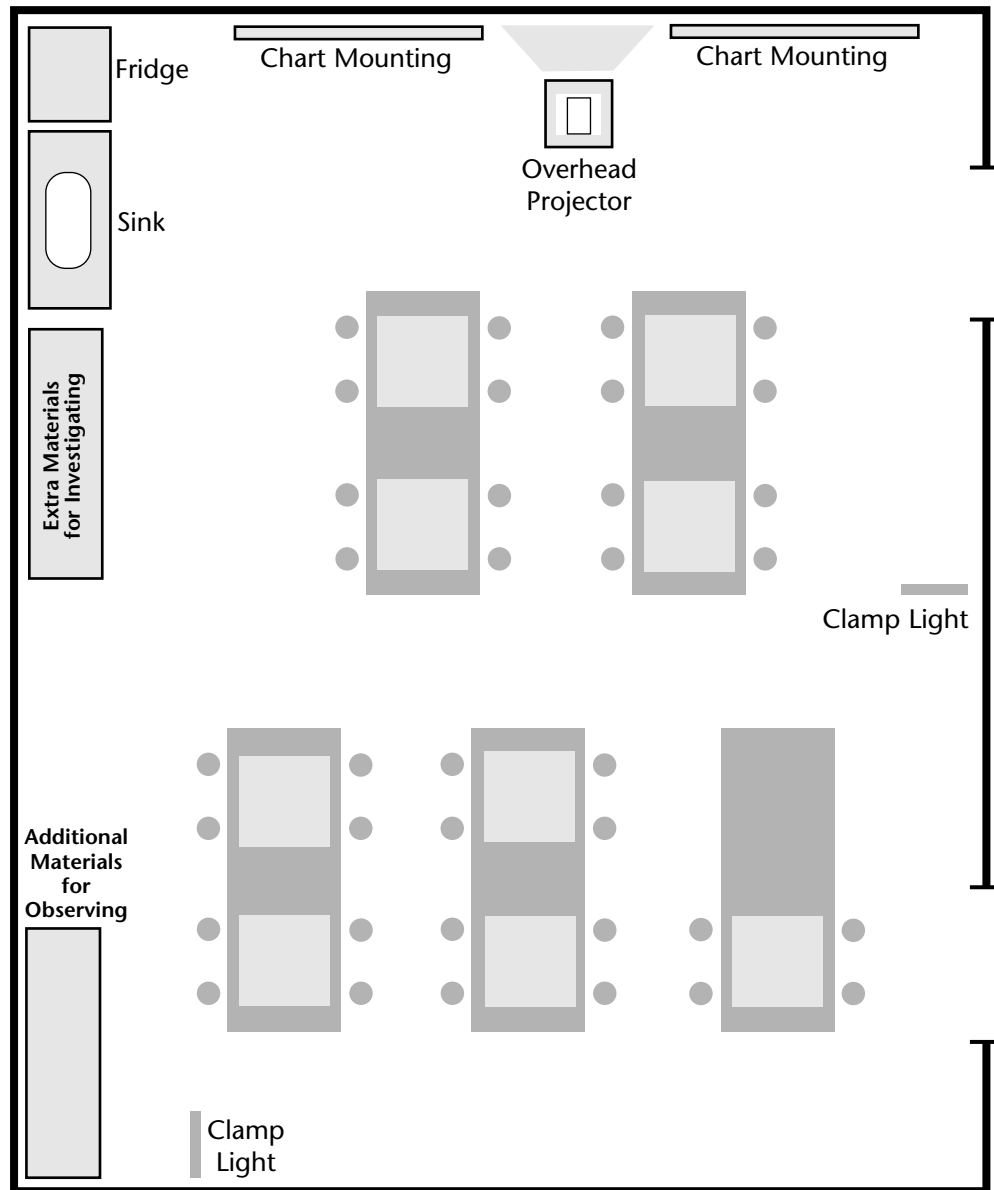
**2. Watch your schedule.** Refer to the schedule you created to keep things on track. (See Step 9 of Before the Workshop.)

### After the Workshop

When the workshop is over you and your co-facilitator should take some time to reflect on your experiences. Issues of logistics, communication, outcomes, and expectations can be addressed at this point. The Facilitation Review (page 43) will allow you to assess the results of your work and identify the successes and challenges that can help guide subsequent workshops.

# Sample Room Setup

This diagram shows a sample setup for 36 people.



## Essential features

- A refrigerator or ice chest
- A sink for hot and cold water
- Tables with space for groups of four people to work
- A place for facilitators to store additional materials that will be passed out
- A table on which to place extra materials for investigations
- A place to mount charts where all can see
- Two clamp lights

## Optional features

- An overhead projector
- Shades or curtains to darken the room

# Materials

Quantities are based on 36 people: 9 groups of 4 people each.

Item	Number for Each Group	Total	When Needed
<input type="checkbox"/> 9" round balloons for making ice balloons (Make at least two days in advance.)		18–22	Before the workshop begins; see page 18.
<input type="checkbox"/> 12-quart rectangular tubs—6" x 12" x 15"—filled with room-temperature water. Tubs must be deeper than diameter of ice balloon.	1	9	Set out on tables before the workshop begins for use in Raising Questions, page 25.
<input type="checkbox"/> clamp lights		2	
<input type="checkbox"/> cafeteria-type trays (to help organize smaller materials)	1	9	
<input type="checkbox"/> flashlights	1	9	
<input type="checkbox"/> scissors (to help peel ice balloons)	1	9	
<input type="checkbox"/> hand lens	2	18	
<input type="checkbox"/> 3" x 5" index cards	35	315	
<input type="checkbox"/> pencils	4	36	Additional materials to distribute during Raising Questions, page 25.
<input type="checkbox"/> ¾ cup sugar in container labeled "sugar"	1	9	
<input type="checkbox"/> ¾ cup salt in container labeled "salt"	1	9	
<input type="checkbox"/> 2" finishing nails	2	18	
<input type="checkbox"/> squeeze bottle of red, blue, or green food coloring	1	9	
<input type="checkbox"/> immersion thermometers	1	9	Set out in a central location before the workshop begins for use in Investigating Questions, page 28.
<input type="checkbox"/> hand drills		3	
<input type="checkbox"/> hammers		9	
<input type="checkbox"/> toothpicks		1 box	
<input type="checkbox"/> 12" bamboo skewers		1 package	
<input type="checkbox"/> straight pins		1 box	
<input type="checkbox"/> drinking straws		1 box	
<input type="checkbox"/> measuring spoons		3 sets	
<input type="checkbox"/> measuring cups		3 sets	
<input type="checkbox"/> 1 lb. box sugar		1 box	
<input type="checkbox"/> 1 box salt		1 box	
<input type="checkbox"/> 20-gauge wire (optional)		1 spool	
<input type="checkbox"/> digital or dieter's scale (optional)		1	
<input type="checkbox"/> ice picks (optional)		2	
<input type="checkbox"/> 8½" x 11" writing paper (at least one sheet for each participant)	4	36 sheets min.	Developing Criteria, page 33.
<input type="checkbox"/> sentence strips	3	27	Identifying Characteristics of Questions, page 34.
<input type="checkbox"/> masking tape (for posting sentence strips)		2 rolls	
<input type="checkbox"/> red marking pens	1	9	
<input type="checkbox"/> blue marking pens	1	9	Turning Questions, pg. 36
<input type="checkbox"/> overhead projector (optional)		1	
<input type="checkbox"/> sponges			For cleanup
<input type="checkbox"/> paper towels, rolls		2	
<input type="checkbox"/> large buckets (if no sink is available)	1	9	



# Charts, Overheads, and Handouts

Masters begin on page 50. They are identified by the letter *M* (for Master) and numbered in order of use.

## 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.

### Workshop Sections

	Page	Introducing the Workshop	Raising Questions	Examining Investigated Questions	Developing Criteria	Identifying Characteristics of Questions	Turning Questions	Connecting to the Classroom
<input type="checkbox"/> Take-Home Messages; reuse chart in Concluding the Workshop	M1	✓						
<input type="checkbox"/> Range of Questions	M2		✓					
<input type="checkbox"/> Investigated Questions	M3			✓				
<input type="checkbox"/> Criteria for Investigable Questions	M4				✓			
<input type="checkbox"/> Investigable Questions	M5					✓		
<input type="checkbox"/> Noninvestigable Questions	M6					✓		
<input type="checkbox"/> Turning Questions ("Why does salt melt ice?")	M8						✓	
<input type="checkbox"/> Turning Questions ("Why does the ice always float with the same side up?")	M9						✓	
<input type="checkbox"/> Strategies for Improving Student Questioning Skills	M10							✓

## Overheads

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

	Page
<input type="checkbox"/> Turning Questions: A Variables Scan	For Turning Questions M7a–d

## Handouts

Photocopy these handouts, making one copy for each participant.

	Page
<input type="checkbox"/> Turning Questions: A Variables Scan	For Turning Questions M7a–d
<input type="checkbox"/> Take-Home Messages	For Concluding the Workshop M1
<input type="checkbox"/> How To Make Ice Balloons (optional)	For Concluding the Workshop M11
<input type="checkbox"/> Thoughts on Students' Questions	For Concluding the Workshop M12a&b

# How to Make Ice Balloons

## About Ice Balloons

Ice balloons are water balloons that have been frozen and then peeled, revealing the beautiful ball of ice inside. Most ice balloons will freeze within two days. But because not all freezers are equally efficient, it's a good idea to practice making ice balloons at least one week in advance to determine how best to freeze them.

If you have a freezer and a faucet without an aerator on site, you can prepare the balloons there. (Most aerators can be unscrewed from the faucet. They mix air with the water to reduce flow without losing pressure.) Or you may need to prepare them in another location and bring them in an ice chest or cooler.

## Ice Balloon Assembly

**1. Stretch a balloon over a faucet or the neck of a plastic water bottle.** If you're filling balloons from a bottle, you'll need to gently squeeze the bottle to fill the balloon. Slowly fill the balloon until it's about 5 inches in diameter.

**2. Remove the balloon from the faucet or bottle and let any excess air escape.** Tie the top of the balloon.

**3. Place the balloons in a freezer for 48 hours or longer; refrigerator freezers work fine.** After 48 hours, your balloons should be frozen solid. If not, give them another day. Also, check them for clarity. The most beautiful, intriguing ice balloons are at least partially clear with needlelike structures inside.

**4. Leave ice balloons in the freezer until the last possible minute.** Then peel the balloons to reveal the balls of ice inside. (You can use scissors to cut off the knotted neck and then peel back the balloon.)

## Materials Needed

- Enough sturdy, 9" round balloons (about 18–22) so that each small group will have two ice balloons, and you'll have a few extras.
- Enough water to fill balloons 5" to 6" in diameter. (Use a faucet without an aerator, non-carbonated bottled water, or 2-liter plastic bottles filled with water that has been boiled and cooled.)
- Enough freezer room to accommodate the number of balloons you'll be making.
- Scissors to help peel away the balloon.

## Ice Balloon Troubleshooting

While the ice balloons used in this activity should be as clear as possible, a partly clear one is probably the best you'll be able to get. If your ice balloons are very cloudy, there may be several reasons why. Cloudiness comes from anything dissolved in the water, including minerals or gases. The most likely impurity will be air. The more air you have in your water, the cloudier your ice balloons will be.

If you have very hard water, which has a lot of minerals dissolved in it, you're also likely to get cloudy ice balloons. In this case, you can fill your balloons with bottled water.

To keep the level of dissolved gases low, consider boiling your water, putting the cooled water in a 2-liter plastic bottle, and then filling the balloons.

# Background Science for the Ice Balloons Activity

## Overview

Although the primary focus of the *Raising Questions* workshop is the process skill of questioning, there is plenty of science content encountered in the exploration of water and ice. Participants may raise questions about density, states of matter, temperature change, and formations found in the ice. Since this workshop is not designed to foster the development of scientific conceptual understanding, your main role will be to help participants move their explorations along, encouraging them to continually ask questions and to take action on those questions. However, if you want to familiarize yourself with some of the science content related to ice balloons, read the information in this section.

## Common Questions

### Why is the ice cloudy in the center? Why is some of the ice clear?

Most water contains dissolved air and impurities. Since water freezes from the outside in, as the ice balloon begins to freeze, air and impurities are pushed toward the center, which is still liquid. Eventually, the water freezes around small bubbles of air. These small bubbles scatter light like the foam bubbles in the head of a glass of beer. Like the beer foam, the mass of bubbles looks white. Where there are no bubbles (or fractures, which also scatter light), the ice is a transparent crystalline structure.

### Why are there spicules (long, spiky shapes) in the ice? Are they empty?

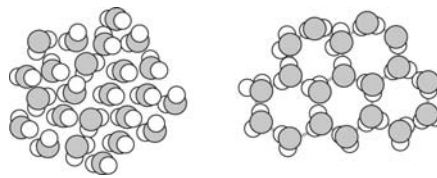
The spicules are long, skinny bubbles of air.

They're created when large bubbles form around a particle in the water, or when adjacent bubbles merge, as the freezing ice pushes the bubbles toward the center of the sphere.

### Why does the ice float?

**Density:** Most substances are denser in their solid state than they are as liquids. The atoms or molecules of a solid tend to be packed tightly together. This means that, for a particular mass (i.e., a particular number of molecules), the solid form of a substance has less volume—and therefore is denser—than its liquid form. So the solid form of a substance will normally sink in the less dense liquid form of the same substance.

Water, however, is a fascinating exception to this generalization. Ice crystals are bulky, open, six-sided structures in which the molecules are farther apart than the molecules in liquid water. This makes ice less dense than water.



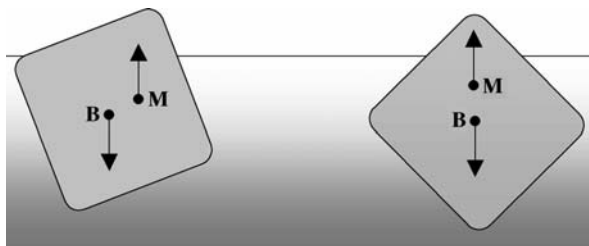
**Water molecules (left) and ice crystals**

**Buoyancy:** When you put something in water, the water pushes up on it. Archimedes, a Greek scientist of the third century B.C., discovered that this upward force, called the *buoyant force*, is equal to the weight of the water an object displaces. If the object is less dense than water, the buoyant force equals the object's weight before the entire object is underwater. The buoyant force balances the weight and the object floats.

### Why does floating ice always seem to “want” to have the same end up?

**Center of mass/center of buoyancy:** For any object that has mass, there is a point called the center of mass. For many purposes, the object can be treated as if its mass is concentrated at this point. Therefore, the downward force on an object due to gravity appears to act through its center of mass.

The center of buoyancy is the center of mass of the water displaced by an object, and the buoyant force acts upward through this point. A floating object will turn until the two points are aligned vertically and the object is in equilibrium.



The drawing on the left shows an ice cube in which the center of mass and the center of buoyancy are not in alignment. The cube will rotate until the center of mass and the center of buoyancy are vertically aligned, as shown in the drawing on the right.

### What makes ice melt?

The molecules in a solid, such as ice, are more strongly attached to each other than they are when the solid is melted. That’s what differentiates a solid from a liquid. As heat energy flows to cold ice from a warmer substance, the ice warms up until it reaches 0° C. But if more energy is added, the temperature remains at 0° C until all the ice is melted. Instead of raising the temperature, the additional energy breaks the bonds that hold the molecules together in the ice-crystal structure. Melting is actually the process of molecules breaking away from the solid. Since energy

is added to the outside surface of the solid first and takes some time to move to the inside, the outside surface melts first.

### Why does ice melt faster in water than in air?

More energy transferred to the ice means more ice melts. And the faster the energy is transferred to the ice, the faster the ice melts.

**Conduction:** Conduction involves the transfer of heat from molecule to adjacent molecule. Heat always flows from a substance (or region within a substance) at a higher temperature to a substance (or region) at a lower temperature. The greater the difference in temperature, the faster the heat flow. The rate of transfer of energy is also greater if there is more surface area in contact (i.e., more molecules in contact) between the hotter and cooler substances.

For instance, heat will flow into ice from air or water if either is above 0° C. The hotter the air or water, the faster energy will be transferred to the ice, and the faster the ice will melt. Also, if the ice has a large surface area in contact with the hotter substance (e.g., crushed ice versus ice cubes) it will absorb energy faster and melt faster.

**Heat capacity:** It takes a different quantity of heat to raise the temperature of 1 gram of one substance 1 degree than to raise the temperature of another substance 1 degree. Each substance needs a particular amount of heat, which is known as its *specific heat capacity*.

Something with a large heat capacity requires a much greater addition of energy to increase its temperature than something with a small heat capacity. Conversely, something with a large heat capacity must give up more energy to lower its temperature than something with a small heat

capacity. The specific heat capacity of water is considerably greater than that of air.

If you have similar amounts of water and air at the same temperature, the water has more energy because of its high specific heat capacity. Therefore, it can transfer more energy to the ice, and the ice melts faster than in air.

**Thermal conductivity:** The rate at which heat flows within a substance due to a temperature difference varies considerably among different materials. Water has a higher thermal conductivity than air, which means that heat generally can flow through water faster than through air. So, in addition to water having more energy available to transfer to the ice, it can also conduct energy from a region that isn't directly adjacent to the ice at greater rate than air can. This adds to the greater melting rate of ice in water.

**Mechanical factors:** Stirring the water or moving the air will bring ice into contact with water or air that has not yet cooled. This will also increase the rate of melting.

### **Why does salt melt ice?**

Ice and water coexist at 0°C, which is both the melting point of ice and the freezing point of water. Whether floating in water or sitting on a countertop with a thin film of water on its surface, ice usually exists in contact with water. If you could see this area of contact on the molecular level, you would observe some molecules moving from the ice to the water (becoming part of the water) and other molecules moving from the water to the ice (becoming part of the ice). At 0° C, the rate of molecules moving into the ice balances the rate of molecules moving into the water, so there's no net increase in either the amount of ice or the amount of water. The situation changes, however, if you dissolve salt (or

another substance) in the water.

When salt is dissolved in the water, it actually gets in the way of water molecules that were moving to join the ice—so it reduces the rate at which molecules move from the water into the ice. The rate at which molecules from the ice to the water, however, remains unchanged, so there is more melting than freezing going on. If you increase the amount of salt, there's even more interference with ice formation, which means that the ice melts even faster.

### **Why does salt melt ice faster than sugar does?**

Any substance dissolved in water will lower the water's freezing temperature. How much the freezing point is lowered is proportional to the number of dissolved particles; that is, the more interference from particles in the water, the more the freezing point is lowered.

Equal amounts of salt and sugar lower the freezing point by different amounts because they're made up of different numbers of particles. A single molecule of table sugar (sucrose), made up of 45 atoms, is a relatively large particle. The basic salt particle, on the other hand, consists of just two ions (atoms that have been electrically charged), one of sodium and one of chloride, so it's relatively small. As a result, a teaspoon of salt has many more particles in it than a teaspoon of sugar does. In addition, the ions that make up the salt separate when dissolved, creating twice as many particles to interfere with the freezing process. That's why salt is more effective than sugar in melting ice.

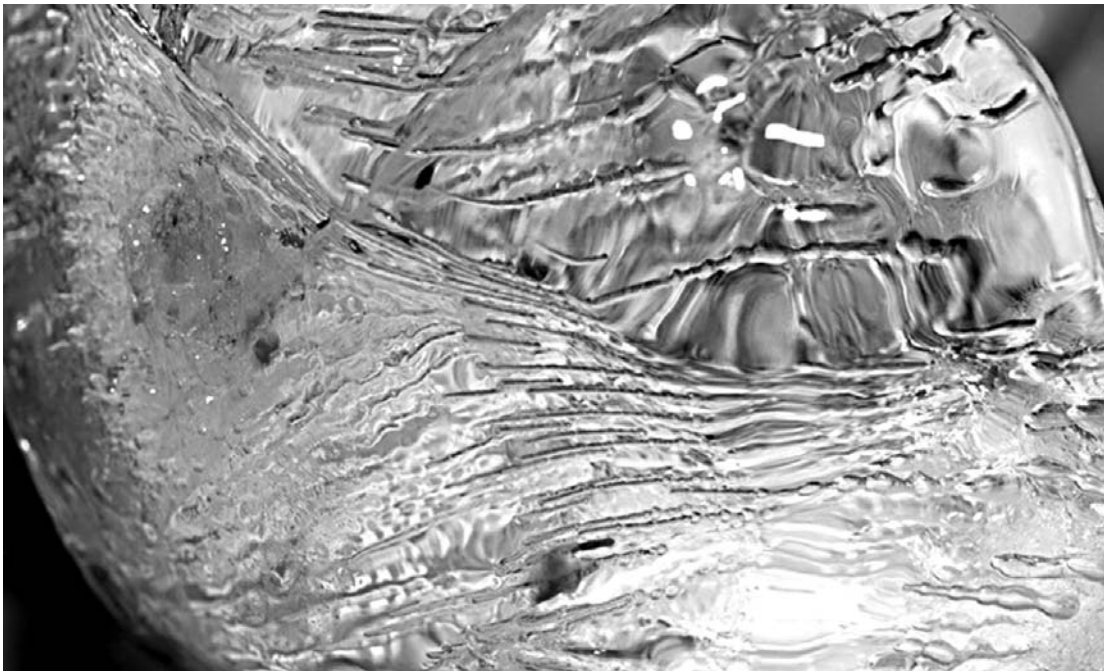
To see an animation of salt interfering with the freezing process, go to

<http://antoine.frostburg.edu/chem/senese/101/solutions/faq/why-salt-melts-ice.shtml>.

# PRESENTING THE WORKSHOP

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## Part 1: Introduction and Hands-On Experience



- **Introducing the Workshop**
- **Raising Questions**
- **Investigating Questions**

# Introducing the Workshop

## Overview

To begin, the facilitator establishes the tone for the workshop by stating its purpose and explaining how participants will work together. Letting everyone know what they will be doing and how they will be doing it is important in order to build trust and demonstrate your respect for the participants as learners. A respectful atmosphere is essential for fostering a free and open exchange of ideas.

## 7 Steps ♦ 10 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 in your own words:

► *Questions are the basis of all inquiry. Whether it's in the classroom or the research laboratory, investigations begin when we encounter materials and phenomena that we don't understand—that engage our curiosity and draw us into looking at something more carefully.*

*The purpose of this workshop is to give you an opportunity to think more deeply about the role of questioning in investigating materials and phenomena. In*

*the course of this exploration, you'll discover how to turn questions from ones that students can't investigate into ones they can.*

*As a way of raising and investigating questions, you'll be working with ice balloons—spheres of ice made by filling balloons with water, then freezing and peeling them.*

## 3. Refer to chart M1: “Take-Home Messages,” and read the messages aloud.

Tell participants:

### Materials Reminder

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

- Have the basic materials for observing ice balloons on the participants' tables—tubs of water, flashlights, sissors, hand lens, 3" × 5" index cards, and pencils (see page 16)
- Post chart M1: “Take-Home Messages”
- Put the clamp lights in place
- (Optional) Post workshop schedule for participants (see page 13)

► *Although you'll learn something about the properties of ice today, the main focus of this workshop is to examine the process of raising questions. Through direct experience and discussion, you'll be developing an understanding of the ideas expressed by the take-home messages.*

RAISING QUESTIONS CHART & HANDOUT

### Take-Home Messages

- Interesting phenomena can stimulate a rich variety of questions.
- Questions drive the investigation process.
- Questions can either be investigable or noninvestigable.
- Noninvestigable questions can be turned into investigable ones.

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**M1**

**4. Tell participants why you chose to present this workshop, describing how the workshop relates to the specific goals, standards, and other professional development activities of your district.** You may also want to talk about how the workshop relates to state and national standards. For more on how *Raising Questions* connects to the *National Science Education Standards*, see page 48.

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

- ▶ *This workshop is for the purpose of professional development. It is not intended to be replicated in the classroom. It's meant to provide you with new*

*pedagogical ideas about questioning that you can apply to your teaching.*

**6. Address the workshop schedule.** Tell participants that the entire workshop will take about three-and-a-half hours, including 15 minutes for a break. If you've posted a schedule for participants, refer to it here.

**7. Tell participants the size of the groups they'll be working in** (groups of three or four, whatever you've decided). If necessary, ask them to rearrange themselves into groups of the right size at the stations. Note that this guide assumes nine groups of four participants as an optimum workshop situation.



# Raising Questions

## Overview

In this part of the workshop, participants explore ice balloons, write down questions about them, examine the variety of questions generated, and become aware of how interacting with intriguing phenomena can stimulate questions.

There are a number of features here that encourage close observation and stimulate questions. Turning off the lights for the first 10 minutes encourages the use of flashlights, which highlights the mysterious quality and beauty of the ice and draws people into the phenomenon. Limiting the number of materials participants can use focuses attention on the ice rather than on the use of materials. Giving participants adequate time for open-ended exploration allows them to notice more and more about the ice.

During their explorations, participants begin to develop some curiosity about phenomena and make some simple discoveries. Note that the amount of time allotted here has been carefully planned to maintain a focus on the process of raising questions. People should have enough time to raise a variety of rich questions but not enough to become fully engaged in trying to answer them.

After exploring, participants take a look at the wide variety of questions they raised, all from a single, simple phenomenon.

## 7 Steps ♦ 30 Minutes

### 1. Have participants observe ice balloons and record questions (20 minutes).

It's best

not to mention anything about using the materials set out on the tables. Participants should proceed at their own pace and select materials appropriate to their own observations. They shouldn't feel that they need to begin using the various items right away. Tell participants:

- ▶ *Take the next 20 minutes to carefully observe your ice balloon. Talk with each other, and come up with as many questions as you can about what you are seeing and wondering. There are no "wrong" questions, so please don't censor or edit the ideas that occur to you.*

*Write down each question on an index card, using one side only—one question per card. One person in each group should be the recorder.*

**2. Darken the room and turn on the clamp lights for the first 10 minutes of the observation.** This will highlight the dramatic play of light on these large pieces of ice. Typically, participants will use flashlights to observe their ice balloons.

## Materials Reminder

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

- Put one ice balloon on a tray at each table
- Distribute the additional materials for observing—sugar, salt, nails, and food coloring (see Step 3, page 26)
- Post chart M2: "Range of Questions"

**3. Turn the room lights back on.** Tell participants you have some additional materials that they might like to use in exploring their ice balloons. Then distribute the sugar, salt, and nails.

After a few more minutes, give each group one color of food coloring, which can enhance interesting features of the ice balloons. (NOTE: Providing more than one color can lead participants to explore color mixing rather than using color as a tool for observing the properties of ice.) The new materials should stimulate participants to raise more questions.

Remind everyone to continue writing their questions on the cards.

**4. Keep participants apprised of the time.**

Let people know when there are 5 minutes remaining, and ask them to stop after 20 minutes of investigation.

While participants are observing the ice balloons, a facilitator should post blank chart M2: “Range of Questions.”

**5. Have participants set aside their ice balloons and examine the range of questions they generated (10 minutes).**

Explain:

- ▶ *Now we want to look at the variety of questions that came up during your explorations. Each group take about 5 minutes to look through all your cards and agree on one to read aloud.*

After 5 minutes, ask participants to report out. Write the chosen questions on the “Range of Questions” chart. (In the interest of time, you may want to record about six questions, rather than have every group report out.)

**6. After the questions have been recorded, call attention to three important points that relate to observation and raising questions.** Ask participants to note the following:

- ▶ *Notice how many different questions came up. Even though everyone observed the same phenomenon, people saw very different things.*

*Notice that the phenomenon was very simple, yet it was intriguing enough to pique everyone’s curiosity.*

*Notice that there was ample time to observe, so a rich variety of questions could be generated by each observer.*

*Notice that there was ample time to observe, so a rich variety of questions could be generated by each observer.*

**7. Bring the discussion to a close and move on to the next part of the workshop.**

RAISING QUESTIONS CHART

### Range of Questions

- Why does salt melt the ice so quickly?
- Are there substances other than salt that will melt ice?
- How long did it take the ice balloon to freeze?
- Does the range of freezing temperatures affect the formations?
- How can we determine the make-up of the “ice hairs?”
- Why does the ice balloon float?

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M2

**M2, with examples of typical responses**

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## Facilitation Hints for Raising Questions

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### ■ Support Questioning

Circulate among the groups and encourage them to write down all of their questions. Reassure them, if necessary, that no question is “wrong.”

You may worry that participants won’t ask enough questions to provide a rich workshop experience. In fact, you’ll find that the questions will flow naturally, prompted by firsthand investigations of ice balloons.

### ■ Listen Carefully

At this point, you may find it useful to get a feel for the group by carefully listening to the kinds of questions that come up. Paying attention now to how questions are being phrased can help with facilitation later in the workshop, offering opportunities to help point the group in productive directions.

### ■ Help Float Ice Balloons

If participants decide to experiment by placing their ice balloons in the tubs of water, they may need help if the water is too shallow. The water in the tub must be deeper than the diameter of the ice balloon. Ice balloons will only float if they can be totally submerged.

# Investigating Questions

## Overview

By now, participants have had a chance to raise a variety of questions about ice balloons. In this part of the workshop, they sort their questions into those they think *can* be investigated and those that *can't*. Then they'll choose one question to investigate. (For more on the difference between investigable and noninvestigable questions, see "Different Kinds of Questions" on page 34.)

This very brief investigation helps participants develop an awareness of the relationship between asking questions and investigating—how one question can lead to another, moving the investigation forward.

## 7 Steps ♦ 30 Minutes

### 1. Have participants sort their questions (5 minutes). Tell participants:

- ▶ Take about five minutes to quickly go through all your questions and sort them into two piles. One pile should be for the questions you think are "investigable," and the other pile should be for questions you think are "noninvestigable."

Just to clarify our terms here. . .

**Investigable questions** are the ones you think can be investigated by doing something concrete with tools and materials. Some people call these kinds of questions "investigatable."

**Noninvestigable questions**—sometimes called "noninvestigatable"—are the ones you think cannot be answered by investigating with tools and materials.

*The idea here is to really do a quick sort. You'll have more time later to analyze the differences between the two types of questions.*

## Materials Reminder

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

- Have extra materials for investigating (page 16) available in a central supply area
- Have a second ice balloon for each group available for distribution
- Have materials for cleanup (page 16) available in a central supply area

### 2. Have participants choose a question to investigate. Tell the group:

- ▶ Choose one question from your investigable pile that you think you can take some action on, given the time and materials available.

Point out the new materials available in the central supply area.

Tell participants to keep the cards in their investigable and noninvestigable piles because they will use them again later.

### 3. Have participants begin their investigations. Tell participants:

- ▶ Find out whatever you can in the next 25 minutes. In this limited amount of time, you probably won't be able to fully answer the question you're investigating. This experience is intended only as a sample of what it's like to investigate your own questions.

As you work, keep in mind that the questioning process hasn't stopped. Jot down new questions that come up. If you don't want to stop what

*you're doing to write down your new questions, take a couple of minutes at the end of your investigation to record them.*

**4. After 20 minutes of investigating, give people a 5-minute warning.** Let them know that the investigation is coming to an end and remind them that this is their chance to record new questions.

**5. Bring investigations to a close, acknowledging that this is an arbitrary stopping point and that people may not feel their investigation is finished.** Tell participants:

- ▶ *The main focus of our work has been on learning about questioning rather than on learning the science of ice.*

*While you may not have an answer to your initial question, you probably now have much more information about the properties of ice than you did in the beginning.*

Point out that many different areas of interest were pursued, and briefly mention a few that you noticed. (More than likely, investigations focused on these areas: different states of water—density, temperature, and melting and freezing; and different formations and structures within the ice—cracks, bubbles, and so on.)

**6. Ask people to quickly clean up and then take a 15-minute break.** (The ice balloons can be discarded now.) Then tell participants what time to reconvene after the break.

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## Facilitation Hints for Investigating Questions

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### ■ Offer Suggestions

If a group has trouble getting started, you might suggest particular materials they could use or some specific actions they could take.

### ■ Help Groups Remain Engaged

Groups having trouble staying engaged may have chosen a question that's quickly answered, such as "Does salt melt ice?" Or they may have chosen one that doesn't turn out to be very inter-

esting. If time permits, you can suggest that participants find another question from their investigable pile to pursue.

### ■ Listen and Ask Questions

Casually interact with various groups to find out what they're exploring. It's a good idea to start by listening carefully in order to get a sense of what the group is investigating. Then, you might ask group members to explain what they're doing or what they're try-

ing to find out by asking questions such as:

- ▶ *What have you been working on so far?*

*What have you found that's interesting or intriguing about ice?*

*What questions are coming up as you investigate?"*

# PRESENTING THE WORKSHOP

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## Part 2: Identifying and Creating Investigable Questions



- **Examining the Investigated Questions**
- **Developing Criteria**
- **Identifying Characteristics of Questions**
- **Turning Questions**
- **Connecting to the Classroom**
- **Concluding the Workshop**

# Examining the Investigated Questions

## Overview

In the first half of the workshop, participants examined ice balloons as a way to raise questions. In this part of the workshop, participants use the questions they raised earlier to understand what kinds of questions lead to investigations, paying particular attention to how those questions are framed.

This exercise helps participants understand that the actions they took during their investigations were driven by their questions—the ones they initially asked and those that came up as they proceeded.

## 7 Steps ♦ 25 Minutes

**1. Ask participants to return to their investigation groups (5 minutes).** Have them examine the questions they just investigated and identify the new questions that came up during their investigations. Tell participants:

- ▶ *You've just investigated ice balloons. Now we want to look at how the questions you began with led to the new questions you came up with during your investigations, and how this process drove your investigations.*

*Let's begin by looking at the questions you started with. In your groups, take five minutes to discuss the question you investigated and the actions it led you to take. Then, identify the questions that came up while you were investigating and the actions you took as a result.*

**2. Post chart M3: "Investigated Questions."** Ask for the attention of the whole group. Then ask participants to share the

initial question that they took action on.

Record at least four of these questions on the "Investigated Questions" chart. This ensures that you have enough of a pool to draw from so you can focus closely on two of the questions later.

**3. Spend a few minutes examining the recorded questions (10 minutes).** Ask one

group to read its question and briefly describe the actions taken.

To explore further, ask the same group:

- ▶ *What other questions came up while you were investigating? How did those questions come up? What new actions did they lead to?*

You don't need to record these additional questions. If participants have a difficult time identifying further questions they raised as they worked, you can ask:

## Materials Reminder

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

- **Post chart M3: "Investigated Questions"**

RAISING QUESTIONS CHART

### Investigated Questions

- Does the ice balloon melt faster in or out of the water?
- What is the difference in the melting rates in different temperatures of water?
- What makes one part of the ice balloon cloudy and the other part clear?
- Why does the ice balloon always float the same way?

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**M3, with examples of typical responses**

What action did you take—what did you actually investigate?

A group might say, “We kept turning the ice balloon to see if it always ended up floating with the same side up.”

When they explain what they did, you can ask:

- ▶ *What question do you think you were asking in taking that action?*

You might get an answer such as, “Will the ice balloon always float with the same side up?”

If time permits, ask a second group the same questions.

#### **4. Talk about the question/action cycle.**

Explain:

- ▶ *Investigating often involves cycles of questioning: raising questions, experimenting, and asking new questions based on new observations.*

By examining how questions lead to investiga-

tions that lead to new questions, people will begin to recognize the cyclical pattern of questioning.

**5. Talk about “getting stuck.”** Some participants may have gotten stuck during their investigations and not known what to do next. Ask:

- ▶ *Did anyone get stuck during the investigation?*

*Why do you think your question didn't lead in a productive direction?*

*What (if anything) did you do about it?*

It's important to acknowledge that getting stuck is a natural part of the process of doing investigations. Reassure participants that dead ends can happen to anyone during an investigation.

**6. Wrap up the discussion.** Tell participants:

- ▶ *Asking questions that lead in productive directions—where you take some action—is a skill that can be learned. A little later in this workshop, you'll learn a technique for turning noninvestigable questions into investigable ones.*

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## **Facilitation Hints for Examining the Investigated Questions**

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### **■ Listen for Good Examples**

Circulate to listen for good examples of initial questions and the actions they stimulated. You might have a few groups in mind to call upon when it's time to share questions asked and actions taken.

### **■ Be Aware of Question Formats**

It's likely that many of the partici-

pants' questions weren't expressed in an investigable form. Yet, somehow, they managed to take action anyway and had successful experiences. How can this be? Most of the time, participants just start doing something that is somewhat related to their question. This action gives them something more to notice and observe, which leads to further action.

### **■ Let Participants Follow Their Interests**

Don't worry if some groups took action on noninvestigable questions. Most likely, they followed their own interests, answering questions that were not explicitly stated.



# Developing Criteria

## Overview

In this part of the workshop, participants work in their small groups, discussing and developing a list of criteria for investigable questions.

## 3 Steps ♦ 15 Minutes

**1. Distribute blank sheets of paper to participants, then have the small groups discuss criteria for investigable questions (10 minutes).** Ask them to do the following:

- ▶ *Examine the stacks of investigable and noninvestigable questions you generated earlier, think about what makes a question investigable, and come up with some criteria for identifying investigable questions. Have one person record your criteria on the paper that's just been handed out. Take about 10 minutes.*

**2. Post chart M4: “Criteria for Investigable Questions.” Ask for the attention of the whole group and have participants share their criteria.**

As groups share, record their ideas on the “Criteria for Investigable Questions” chart.

Have each group share one criterion. Proceed

around the room until all the criteria that the groups have generated have been listed. Most groups will come up with a list like the sample shown here.

Give participants a few minutes to copy the list of criteria so they can use it as a reference when they are planning investigations in their classrooms.

**3. Bring the discussion to a close and move on.**

## Materials Reminder

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

- Post chart M4: “Criteria for Investigable Questions”
- Distribute a sheet of 8½” × 11” writing paper to each person

RAISING QUESTIONS CHART

## Criteria for Investigable Questions

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- Availability of materials
- Availability of time (can be investigated now or in the near future)
- Age appropriate
- Leads to taking action

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www.exploratorium.edu/ifi exploratorium M4

**M4, with examples of typical responses**

## Facilitation Hints for Developing Criteria

### ■ Remind Participants That Investigable = Taking Action

If it hasn't already been suggested by a participant, you might want to emphasize that an investigable question leads to taking action.

### ■ Point Out Consensus

Generally, it's easy for groups to come up with criteria for investigable questions, and all the groups will tend to have very similar lists. Assuming you find this to be so,

point out that there is a consensus about the criteria and that they can use these criteria as a guide when planning investigations for the classroom.

# Identifying Characteristics of Questions

## Overview

Now that participants have developed criteria for investigable questions, they'll begin to recognize the way language determines whether a question is investigable or noninvestigable.

### Different Kinds of Questions

Questions that lead to taking action are considered "investigable." For example, questions that begin with *what will happen if . . .* or contain the phrase *does the \_\_\_\_\_ make a difference* can be investigated. The way they are phrased invites one to experiment with materials and phenomena. "What will happen if we put salt on the ice?" or "Does the temperature of the water make a difference?" indicate a clear course of action.

Conversely, questions that do not lead to taking hands-on action are considered "noninvestigable." For example, questions that begin with *why*—such as "Why is most of the ice balloon underneath the water?" or "Why are parts of the ice balloon cloudy?" are considered noninvestigable. They're stated in a way that does not lead directly to hands-on action that would help answer the question as stated.

Instead, they're requests for information or explanations. Answering these kinds of questions will probably require obtaining information from a book, the Internet, or a person who has experience in the area. While investigations can be conducted using such resources, this workshop addresses investigations that take place through firsthand experiences with materials and phenomena.

## 6 Steps ♦ 15 Minutes

**1. Post charts M5 and M6. Distribute two sentence strips and a set of red and blue marking pens to each group.** Tell participants:

- ▶ *Select one investigable question and one noninvestigable question from your index cards. Write your investigable question in red and your noninvestigable question in blue on the sentence strips. Then post your questions on the charts with masking tape. Take about 5 minutes.*

**2. Call for everyone's attention, then begin a discussion.** Ask the group:

- ▶ *Are there any questions you think aren't in the correct category? Please tell the group why you think they don't belong there.*

If there is group consensus about a question incorrectly categorized, move the question to the appropriate chart.

**3. Continue the discussion by asking the group to notice any patterns in the ways in which noninvestigable and investigable questions are worded.** You might ask:

## Materials Reminder

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

- Post chart M5: "Investigable Questions"
- Post chart M6: "Noninvestigable Questions"
- Distribute two sentence strips to each group
- Distribute a set of red and blue marking pens to each group
- Have masking tape available for posting the sentence strips

- ▶ *What is it about the way noninvestigable questions are worded that can stop you before you get started?*

**4. Have the group talk about the investigable questions.** Ask participants:

- ▶ *What are the ways investigable questions are worded?*

**5. Be sure participants understand the difference between investigable and noninvestigable questions.** Participants will probably suggest that investigable questions lead to taking action, and noninvestigable questions don't lead to taking action. If they don't, it's important for you to bring up this idea and talk about what it is about the way questions are worded that leads to taking action or not.

For noninvestigable questions, point out the "why." Explain:

- ▶ *Questions beginning with why are requesting information rather than suggesting an action that can be taken. Generally, these*

questions can be answered by using a reference book or the Internet or by asking an experienced person.

**• For investigable questions, point out the implied action.** Tell participants:

- ▶ *Investigable questions frequently begin with "What will happen if," or include the phrase "does the \_\_\_\_ make a difference?" or "How does \_\_\_\_ affect \_\_\_\_?" The phrasing of such questions leads to taking some action that would help answer the question.*

**6. Bring the discussion to a close and move on.**

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**M5, with examples of typical responses**

INSTITUTE FOR INQUIRY: www.exploratorium.edu/ifi © Exploratorium exploratorium M6

**M6, with examples of typical responses**

**Facilitation Hints for Identifying Characteristics of Questions**

**■ Identify Alternative Phrasing**

Point out questions phrased in other ways that are also investiga-

ble. For example, "Are there substances other than salt that melt ice?" encourages the learner to try

other substances—to take some action.

# Turning Questions

## Overview

Once participants see that the way a question is framed affects how it can be answered, they are introduced to a technique called a “variables scan.” Then they can begin practicing the skill of reformulating noninvestigable questions into questions that can lead to action.

## 8 Steps ♦ 30 Minutes

**1. Tell participants they’ll be experimenting with ways to turn noninvestigable questions into investigable questions.** Say:

- ▶ *Now we’re going to experiment with a way to generate investigable questions based on noninvestigable ones.*

*As we’ve seen, investigable questions are those that lead to taking action.*

**2. Introduce the concept of a “variables scan.”** Tell participants:

- ▶ *You’ll be using a technique called a “variables scan.” The term means you’ll be scanning a noninvestigable question to identify the variables in it—that is, examining it to find elements you can change in an experiment.*

**3. Explain that the term “variables scan” was coined by British educator and curriculum developer Sheila Jelly.** Read aloud to participants what Jelly says about her experience with the “variables scan” technique.

- ▶ *“It’s not the only strategy possible, nor is it completely fail-safe, but it has helped a large number*

*of teachers deal with difficult questions. By ‘difficult questions’ I mean those that require complex information and/or explanation for a full answer . . . Essentially it is a strategy recommended*

*for handling complex questions, and in particular those of the ‘why’ kind . . .*

*“The strategy recommended is one that ‘turns’ the question to practical action with a ‘let’s see what we can do to understand more’ approach. The teaching skill involved is the ability to ‘turn’ the question.”<sup>1</sup>*

**4. Display the four-page “Turning Questions: A Variables Scan” overhead, and distribute the corresponding handout.** Go over the material, page by page, taking participants through the story it tells. Point out that each variable identified offers an opportunity to develop an investigable question. Tell participants:

- ▶ *These overheads [or handouts] show a progression from a ‘why’ question, which cannot be investigated, to a series of questions that have been turned so they can be investigated.*

## Materials Reminder

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

- **Distribute handout M7a–d: “Turning Questions: A Variables Scan” and display corresponding overhead**
- **Keep posted chart M6: “Noninvestigable Questions”**
- **Post the two “Turning Questions” charts (pages M8–M9)**
- **Distribute one sentence strip to each group**

1. Sheila Jelly. “Helping Children Raise Questions—and Answering Them.” Chap. 4 in *Primary Science: Taking the Plunge*, 2nd ed., by Wynne Harlen. (Portsmouth, NH: Heinemann, 2001), p. 44.

RAISING QUESTIONS OVERHEAD & HANDOUT PAGE 1 OF 4

**Turning Questions: A Variables Scan**

The situation . . .

- Second grade students are exploring how paper towels absorb water.
- They notice that paper towels seem to “suck up” the water.
- Someone asks, “Why does the water go into the paper towel?”

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M7a

RAISING QUESTIONS OVERHEAD & HANDOUT PAGE 2 OF 4

**Turning Questions: A Variables Scan**

The Scan . . .

- When you “scan” the situation, what variables can you find?
- The explanation must have something to do with how the *water* and the *paper towel* interact, so those are the variables we can change to help us learn more.

“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”

The Variables . . .

1. Water (or other liquid)
2. Paper towel (or other material)

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M7b

RAISING QUESTIONS OVERHEAD & HANDOUT PAGE 3 OF 4

**Turning Questions: A Variables Scan**

Turning the Question . . .

- How can the question be turned into practical action?

CONSIDER VARIABLE 1: The liquid being absorbed. What could be changed about the liquid?

- The kind of liquid (tomato juice, motor oil, etc.)
- The amount of liquid
- The temperature of the liquid

“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”

Turned Questions . . .

- Would something different happen if the water were very hot or very cold?
- Would salt water be different from fresh water?
- Would something different happen if we used tomato juice?

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M7c

RAISING QUESTIONS OVERHEAD & HANDOUT PAGE 4 OF 4

**Turning Questions: A Variables Scan**

Turning the Question . . .

- How can the question be turned into practical action?

CONSIDER VARIABLE 2: The material absorbing the liquid. What could be changed about the paper towel?

- The brand of paper towel
- The wetting procedure (pouring the water onto the paper, dipping the towel into the water, etc.)
- The kind of material (cotton, wool, cardboard, etc.)

“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”

Turned Questions . . .

- Does the brand of paper towel make a difference?
- What happens if typing paper is used?
- Does cotton cloth “suck up” water?
- What happens if you stick only the corner of a paper towel in the water?

Adapted from Sheila Jolly, “Helping Children Raise Questions—and Answering Them,” *Chapter 4 in Primary Science: Taking the Plunge*, 2nd ed., by Wynne Harlen, Portsmouth, NH: Heinemann, 2001. With permission of the publisher.

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M7d

Point out that, though the original question may not have been answered, the turned question has promoted worthwhile scientific inquiry and the students have learned quite a bit about the interactions of liquids and surfaces.

**5. Guide the group through using a “variables scan” to turn a noninvestigable question into an investigable one.** Refer to the “Noninvestigable Questions” chart from participants’ earlier ice balloon investigations. Select one of the questions on the chart (a “why” question will be easiest) and ask participants to scan it, identifying the variables they could use to turn the question.

If there are no appropriate questions, or if you would rather not refer to participants’ work, you can offer this question as an example:

- ▶ *Why does ice melt so fast when you put it in water?*

Ask participants:

- ▶ *What are the variables?*  
(1. ice; 2. water or liquid)

Next, ask:

- ▶ *How can the ice be changed?*  
(e.g., size and shape; how much it’s submerged.)

*How can the water/liquid be changed?*  
(e.g., amount; temperature; adding salt or sugar; different types of liquids)

Now ask for turned questions:

- ▶ *Can you come up with a question that involves changing something about ice?*  
(e.g., What happens when I change the shape of the ice? Do lots of little pieces melt faster than one big piece?)

*Can you come up with a question that involves changing something about the water/liquid?*  
(e.g. What happens if I put ice in salt water? Does the ice melt faster in a quart of water or a gallon of water?)

**6. Post charts M8 and M9: “Turning Questions.” Have participants “turn” noninvestigable questions.** Point out the two noninvestigable questions on the “Turning Questions” chart. Tell the small groups in one

half of the room that they will be working with the question “Why does salt melt ice?” Tell the groups in the other half of the room that they will be working with the question “Why does the ice always float with the same side up?” Tell all participants:

- ▶ Take about 10 minutes. Based on your non-investigable question, do a variables scan and then formulate questions that can be investigated. Then discuss what actions you would take to carry out the investigation.

*Remember, when you use the variables scan, first identify what you can vary and then how you might vary it before you form your turned question.*

Give each group a sentence strip and tell them:

- ▶ Record one of your turned questions on this sentence strip and post it on the appropriate chart.

**7. When all the turned questions are posted, go over them with the whole group.** Then pick out one or two and ask the small groups that wrote the questions to discuss them. Say:

- ▶ Now we want to look at how you turned the questions. Talk about your thinking as you did this. Be explicit about your method for turning the question.

After individuals explain, ask:

- ▶ What actions might these questions lead to?

In most cases, the turned questions will be investigable. In some instances, however, a question will not be worded in a way that can lead to action. In those cases, ask participants for sugges-

tions about rephrasing the question so it does lead to action. Point out that:

- ▶ There are many different ways each question can be turned. For each way of turning a question, there’s a different action that can be taken. This suggests that there are also many ways of experimenting to find information about salt melting ice or about how ice floats.

If a number of turned questions are essentially the same, but worded in slightly different ways, you could mention that this demonstrates that there can be any number of ways of phrasing a question.

## 8. Conclude by explaining:

- ▶ As we’ve seen, asking productive questions and turning noninvestigable questions into ones that can be investigated are skills that can be developed with practice.

The chart is titled "Turning Questions" and is part of a "RAISING QUESTIONS" workshop. It displays a main question and three possible turned questions. The main question is "Why does the ice always float with the same side up?". The three turned questions are: "Does the weight of the ice make a difference?", "Does the shape of the ice make a difference?", and "What would happen if I floated it in salt water?". The chart also includes the Institute for Inquiry logo and website information at the bottom.

**M9, with examples of typical responses**

# Connecting to the Classroom

## Overview

In this part of the workshop, participants reflect on some of the ideas they have about questioning, and then they share strategies for incorporating more questioning into their classroom activities, and improving their students' questioning skills.

## 3 Steps ♦ 30 Minutes

### 1. Have participants think about how ideas from this workshop might be brought into the classroom (15 minutes).

Begin by saying:

- ▶ *Now you're going to have some time to reflect on what you've experienced in this workshop and to talk about how you might use some of what you've learned to help improve your students' questioning skills.*

*In your small groups, discuss these two questions: First, based on your experiences in this workshop, what are some ideas you have about questioning? And second, what are some ways you can help your students become more effective questioners?*

Have people take 15 minutes to discuss the questions. Ask each small group to agree on one idea they want to present to the whole group, and to choose a spokesperson who can present the idea and the rationale behind it.

### 2. Post Chart M10: "Strategies for Improving Student Questioning Skills."

**Have each group share its idea (15 minutes).** Ask each spokesperson to briefly explain how his or her idea might help advance the development of students' questioning skills. Ask the whole group for comments and questions.

Record each idea on the chart. Ideas that might come up include having adequate time and opportunities to explore, having interesting materials to work with, practicing age-appropriate questioning skills in the classroom, making sure students know that not all questions have right or wrong answers, and so on.

### 3. Remind participants that this workshop is just a beginning.

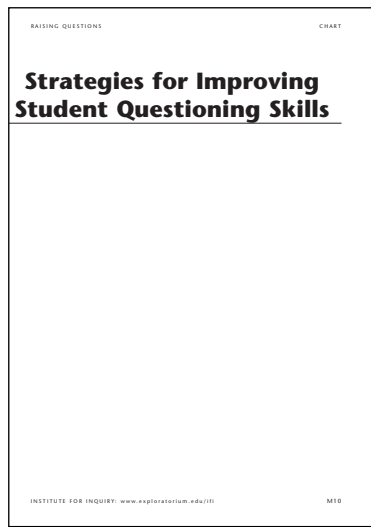
Explain:

- ▶ *Working with student questions can be complex, and this brief session is only a first step in understanding this issue.*

## Materials Reminder

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

- Post chart M10: "Strategies for Improving Student Questioning Skills"



M10

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## Facilitation Hints for Connecting to the Classroom

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### ■ Support Firsthand Interaction

Because teachers have learned in this workshop how valuable firsthand experiences can be for generating questions, they may begin to consider having students interact with materials before coming up with lists of questions. By interacting with materials first, students typically ask questions that are much more specific and much more likely to lead in productive directions—and ultimately to investigations.

### ■ Contribute Your Own Ideas

You may want to contribute by sharing some ideas you have about

working with questions in the classroom. For instance, you might mention techniques used by teachers you have worked with. Also, you might wish to contribute some ideas from the handout M12a&b: “Thoughts on Student Questions,” which you will be giving out at the end of the workshop.

### ■ Address Current Practice

As a result of their experiences in this workshop, teachers often express new thoughts about some of the current questioning approaches they’ve been using. One approach that’s often mentioned is “KWL” (What do we

know? What do we want to know? What did we learn?). This approach is frequently used in elementary classrooms at the very beginning of an activity or unit. For instance, if ice were the unit of study, typically a teacher would have the class brainstorm a list of questions about ice before they begin to work with the ice itself. Teachers frequently mention that they find the resulting questions too broad or open-ended to lead to investigations. Until students have had some experience with particular materials and phenomena, they may not have any idea what they want to know.



# Concluding the Workshop

## 4 Steps ♦ 10 Minutes

### 1. Review the workshop.

- Tell participants:
- ▶ You've just gone through a workshop in which you explored ice balloons, raised questions about what you observed, chose a question, and investigated it briefly. Then you identified the differences between investigable and noninvestigable questions, and determined what makes a question investigable.

You also learned about a technique called a “variables scan” that can help you focus on particular variables, so you can change a question that can't be investigated into one that can. And finally, you talked about some new ideas for working with students' questions in your classrooms.

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

- Say:
- ▶ The workshop you've just experienced was created specifically for professional development, to help you support your students as they develop the process skill of questioning. It was not intended as a science activity for you to take back to the classroom. However, if you want to use ice balloons with your students, you'll need to find ways of relating them to particular parts of your science curriculum.

### 3. Go over the take-home messages to summarize and reinforce the main ideas of the workshop.

### 4. Distribute handout M12a&b: “Thoughts on Student Questions.”

Encourage participants to continue the conversation with each

other about the importance of students asking and investigating their own questions. Let participants know about

any upcoming professional development workshops.

NOTE: If you are planning to do the next workshop in this curriculum, *Stream Table Inquiry*, tell participants:

- ▶ In the next workshop of this curriculum, *Stream Table Inquiry*, you'll have the opportunity to experience a complete inquiry, in which you will use questioning and the other process skills of science to learn science content.

## Materials Reminder

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

- Distribute handout M1: “Take-Home Messages”
- (Optional) Distribute handout M11: “How to Make Ice Balloons.”
- Distribute handout M12a&b: “Thoughts on Student Questions”

The image shows two overlapping handout pages. The top page is M12a, titled "Thoughts on Student Questions by the Exploratorium Institute for Inquiry". It contains text about inquiry-based learning and the role of questions. The bottom page is M1, titled "Take-Home Messages", which lists three key points: 1. Interesting phenomena can stimulate a rich variety of questions. 2. Questions drive the investigation process. 3. Questions can either be investigable or noninvestigable. Both pages include the Exploratorium logo and website information.

# 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. Think and talk about your own facilitation, and consider what adjustments you can make for subsequent workshops.

You'll also want to consider how the group's understanding of raising questions 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 understand-

ing 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**
- ***Raising Questions* and Inquiry Learning**
- ***Raising Questions* and the  
*National Science Education Standards***

## About the Exploratorium Institute for Inquiry

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

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

For more than thirty years, we have been educating teachers, administrators, and professional developers about the theory and practice of inquiry-based learning. Our workshops emphasize

both the importance of engaging learners in first-hand 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](mailto:ifi@exploratorium.edu)

Web site: [www.exploratorium.edu/ifi](http://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 six-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 the topic of formative assessment for teachers and professional developers, and is available online at [www.exploratorium.edu/ifi](http://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)

## Raising Questions and Inquiry Learning

Humans are born inquirers. You can see it from the moment of birth: babies use all of their senses to make connections with their environment, and through those connections they begin to make sense of their world. As young children discover objects and situations that are puzzling or intriguing—things that provoke their curiosity—they begin asking “why” and “how” questions and looking for ways to find answers, all in an effort to understand the world around them. Questions lie at the heart of all scientific work as well. Scientists ask questions that lead to investigations resulting in new understandings about the world. This is the essence of learning through inquiry.

Questioning should also play a major role in classroom science. This is indicated by its key place in most state curricula and as stated in the *National Science Education Standards*: “Inquiry into authentic questions generated from student experience is the central strategy for teaching science.”<sup>1</sup> According to Wynne Harlen, noted science educator and author, “Raising investigable questions is important not just for the sake of being able to formulate and recognize such questions but, as in the

case of all process skills, because such questions lead to children’s greater understanding of things around them.

This understanding

comes gradually through putting ideas and evidence together, prompted in the first instance by a desire to know, by a question.”<sup>2</sup>

Although humans are born inquirers, students don’t come into the classroom with the ability to ask questions that lead to scientific investiga-

“Science is the search for, rather than the answer to, our questions of why and how. . . . As soon as we approach a satisfying answer, we become aware of a new problem, and a fresh ‘why’ or ‘how’ shimmers above the horizon. We have not yet reached the final answer, to a single final ‘why?’ or ‘how?’, so the search continues, and it is into this search that we introduce our children.”<sup>3</sup>

tions. This is an ability that must be developed gradually, with the guidance, modeling, and coaching of a classroom teacher, and in an environment in which questioning is encouraged. The more students are able to ask and investigate their own questions, the more proficient they will become at learning scientific concepts through inquiry.

“Children and scientists share an outlook on life. ‘If I do this, what will happen?’ is both the motto of the child at play and the defining refrain of the physical scientist. . . . The unfamiliar and the strange—these are the domain of all children and scientists.”<sup>4</sup>

1. National Research Council. *National Science Education Standards*. (Washington DC: National Academy Press, 1996), p.31.

2. Wynne Harlen and Jos Elstgeest. *UNESCO Sourcebook for Science in the Primary School: A Workshop Approach to Teacher Education*. (Paris: UNESCO, 1992), p. 60.

3. Jos Elstgeest. “The Right Question at the Right Time.” Chap 3 in *Primary Science: Taking the Plunge*, 2nd ed., by Wynne Harlen. (Portsmouth, NH: Heinemann, 2001) p. 33.

4. James Gleick. *Genius: The Life and Science of Richard Feynman*. (New York: Vintage, 1992) p.19.

## *Raising Questions and the National Science Education Standards*

“Inquiry into authentic questions generated from student experiences is the central strategy for teaching science.”<sup>1</sup>

With this statement, the *National Science Education Standards* affirms that focusing on student questions is a powerful means of teaching science content. But getting students to articulate authentic questions that lead to conceptual understanding of scientific ideas does not happen automatically. The science as inquiry standards within the *Standards* consider raising questions a skill that needs to be developed over time.

In discussing the fundamental abilities necessary to do scientific inquiry, the *Standards* gives a developmental trajectory for questioning as follows:

**Grades K–4:** Students ask questions about objects, organisms, and events in the environment.

**Grades 5–8:** Students identify questions that can be answered through scientific investigations.

**Grades 9–12:** Students identify questions and concepts that guide scientific investigations.<sup>2</sup>

*Inquiry and the National Science Education Standards* states that the questions raised using these abilities are “scientifically oriented questions [that] center on objects, organisms, and events in the natural world; they connect to the science concepts described in the content standards. They are questions that lend themselves to empirical investigation, and lead to gathering and using data to develop explanations for scientific phenomena.” The authors also suggest that some student questions need to be changed into those that can “lend themselves to empirical investigation.”<sup>3</sup>

The *Raising Questions* workshop of the FUNDAMENTALS OF INQUIRY curriculum is designed to help teachers assist students in generating questions that can lead to scientific investigations. It also addresses how to transform non-investigable student questions into ones that invite investigation. In helping teachers strengthen students’ questioning skills in their teaching of science content, *Raising Questions* supports the goals of the *Standards*.

1. National Research Council. *National Science Education Standards*. (Washington, DC: National Academy Press, 1996), p.31.

2. *Ibid.*, Chap. 6.

3. National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. (Washington, DC: National Academy Press, 2000), p. 24.



# REPRODUCIBLE MASTERS

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# Take-Home Messages

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- Interesting phenomena can stimulate a rich variety of questions.
- Questions drive the investigation process.
- Questions can either be investigable or noninvestigable.
- Noninvestigable questions can be turned into investigable ones.

# Range of Questions

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# Investigated Questions

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# Criteria for Investigable Questions

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# Investigable Questions

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# Noninvestigable Questions

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# Turning Questions: A Variables Scan

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## The situation . . .

- Second grade students are exploring how paper towels absorb water.
- They notice that paper towels seem to “suck up” the water.
- Someone asks, “Why does the water go into the paper towel?”



# Turning Questions: A Variables Scan

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## The Scan . . .

- When you “scan” the situation, what variables can you find?
- The explanation must have something to do with how the *water* and the *paper towel* interact, so those are the variables we can change to help us learn more.

**“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”**

**The Variables . . .**

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1. Water (or other liquid)
2. Paper towel (or other material)

# Turning Questions: A Variables Scan

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## Turning the Question . . .

- How can the question be turned into practical action?

**CONSIDER VARIABLE 1: The liquid being absorbed.**  
What could be changed about the liquid?

- The kind of liquid (tomato juice, motor oil, etc.)
- The amount of liquid
- The temperature of the liquid

**“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”**

### Turned Questions . . .

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- Would something different happen if the water were very hot or very cold?
- Would salt water be different from fresh water?
- Would something different happen if we used tomato juice?

# Turning Questions: A Variables Scan

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## Turning the Question . . .

- How can the question be turned into practical action?

**CONSIDER VARIABLE 2:** The material absorbing the liquid. What could be changed about the paper towel?

- The brand of paper towel
- The wetting procedure (pouring the water onto the paper, dipping the towel into the water, etc.)
- The kind of material (cotton, wool, cardboard, etc.)

**“WHY DOES THE WATER GO INTO THE PAPER TOWEL?”**

### Turned Questions . . .

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- Does the brand of paper towel make a difference?
- What happens if typing paper is used?
- Does cotton cloth “suck up” water?
- What happens if you stick only the corner of a paper towel in the water?

Adapted from Sheila Jelly. “Helping Children Raise Questions—and Answering Them.” Chap. 4 in *Primary Science: Taking the Plunge*, 2nd ed., by Wynne Harlen. Portsmouth, NH: Heinemann, 2001. With permission of the publisher.

# Turning Questions

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## ■ Why does salt melt ice?

# Turning Questions

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- **Why does the ice always float with the same side up?**

# **Strategies for Improving Student Questioning Skills**

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# How to Make Ice Balloons

An ice balloon is a water balloon that has been frozen and then peeled, revealing the beautiful ball of ice inside.

Most ice balloons will freeze within two days, but since not all freezers are equally efficient, it's a good idea to try making a few before using them in the classroom.

## Materials Needed

- Enough sturdy 9-inch round balloons for your needs.
- Enough water to fill each balloon to about 5 inches in diameter. (Use a faucet without an aerator, noncarbonated water, or a 2-liter plastic bottle filled with water that has been boiled and cooled.)
- Enough freezer room to accommodate your ice balloons.
- Scissors to help strip the balloons from the balls of ice.



## Ice Balloon Assembly

1. Stretch a balloon over the faucet or the neck of a plastic water bottle. Slowly fill the balloon until it's about 5 inches in diameter. (If you're filling balloons from a bottle, you'll need to gently squeeze the bottle to fill the balloons.)
2. Remove the balloon from the faucet or bottle and let any air escape. Then tie the top.
3. Place the balloons in a freezer for 48 hours or

longer. (A refrigerator freezer should work fine.) After 48 hours, your balloons should be frozen solid. If not, give them another day.

4. Leave your ice balloons in the freezer until the last possible minute. Use scissors to snip off the knot, and then peel the balloon away to reveal the ball of ice inside.

## Ice Balloon Troubleshooting

While the best ice balloons are as clear as possible, a partly clear one is probably the best you'll be able to get.

If your balloons are very cloudy, there may be several reasons why. Cloudiness comes from anything dissolved in the water, including minerals or gases. The most likely impurity, however, will be air. The more air you have in your water, the cloudier your ice balloon will be.

If you have an aerator on your faucet, you should be able to easily unscrew and remove it before filling your ice balloons. Aerators add air to the water in order to reduce flow while maintaining adequate pressure. This extra air will make your ice balloon cloudy.

If you have very hard water, which has a lot of minerals dissolved in it, you're also likely to get cloudy ice balloons. In this case, you might want to fill your balloons with bottled water.

To keep the level of dissolved gases low, consider boiling your water, putting the cooled water in a 2-liter plastic bottle, and then filling the balloons.

The most beautiful, intriguing ice balloons are at least partially clear with needlelike structures inside.

# Thoughts on Student Questions

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## by the Exploratorium Institute for Inquiry

One of the most frequently discussed topics by teachers who are thinking about inquiry-based science is the balance between structure and freedom, or the amount of control given the learner versus the amount of teacher direction. This balance needs to be decided on an individual basis according to a teacher's particular style of teaching and the students' developmental level. However, it's important to remember that no matter how much control teachers decide to give their students, they must still play a very active role. The teacher must guide the learning experience in ways that will help students develop their skills for doing investigations and add to their understanding of science concepts.

The most structure is usually required when students are first introduced to inquiry-based learning. After they develop their skills and become effective inquirers, however, students' own questions can begin to drive their investigations. As noted in *Inquiry and the National Science Education Standards*,

the type and amount of structure can vary depending on what is needed to keep students productively engaged in pursuit of a learning outcome. . . .

As students mature and gain experience with inquiry, they will become adept at clarifying good questions, designing investigations to test ideas, interpreting data, and forming explanations based on data. With such students, the teacher still should monitor by observation, ask questions for clarification,

and make suggestions when needed. Often, teachers begin the school year providing considerable structure and then gradually provide more opportunities for student-centered investigations.\*

To help students develop their questioning skills, many teachers begin early in the year by doing very short explorations of engaging materials and phenomena and asking them to record the questions that come up. The exploration may or may not come from the science curriculum. If it does, it's usually an extension of an activity that lends itself to a little more open-ended exploration with a few more materials. It's essential that the materials are interesting and engaging to students—they need to be rich enough to generate a lot of questions.

While students are learning the skill of asking questions, the explorations needn't be followed by investigations; they can be done solely to develop the process skill of questioning. It's useful, however, to keep in mind the underlying reason for teaching this skill: Questioning leads to investigations in which students explore phenomena and materials in ways that can lead to a deeper understanding of science concepts.

It's important to make students aware of the questions they generate when they're engaged in hands-on explorations. You can record the questions they raise as they're exploring, or you can ask for questions at the end of an exploration and record them for the class to read.



It's also necessary to discuss with students how they would try to find the answers to their questions. Through discussion, they'll discover that not all of their questions will be answerable by experimentation—although it's likely that a great number will be because they've come from direct interaction with materials. But other questions may best be answered by going to a book or the Internet, or by asking someone who has experience with the topic. This can be the beginning of students' awareness that some questions can be investigated by working with materials, while others have to be answered in different ways.

Students, especially at the upper elementary level, can also learn that investigable questions can be developed from noninvestigable ones. In our experience, however, it takes some modeling and coaching to help students develop their abilities to reformulate their noninvestigable questions into investigable ones that can lead to taking action.

When students have more experience generating questions, they can begin to do very short investigations based on their questions. At first, some

teachers limit the number of questions by having all the students investigate the same question or questions. Others have the class decide on two or three questions, then have the students break into smaller groups to conduct different investigations. A specific content focus helps shape the investigations, which makes it easier for teachers to make sure key concepts will emerge. Limiting the number of questions makes materials, facilitation, and discussing conclusions more manageable.

As teachers move toward doing more inquiry in the classroom, students begin to assume new roles in which they take more responsibility for their own learning. Teachers must take on a new role as well, facilitating and supporting students as they learn to construct new scientific understandings from their experiences with materials and phenomena.

\*National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Washington, DC: National Academy Press, 2000), p.136.