

# Communicating Science

A course on teaching science  
for all science educators



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## ***Session 1: The Nature and Practices of Science***

# **Contents**

**Overview**

**Background Information for the Presenter**

**About Nature and Practices of Science**

**About Oobleck**

**Materials and Preparation**

**Preparing for the Session**

**Instructor's Guide**

**Presentation Slides** (also in separate PowerPoint document)

**Session Handouts**

## Session 1: The Nature and Practices of Science

## Overview

In this session, we address “what is science,” and “how does science work?” Participants gain insight into the nature and practices of science in the best way possible—by *doing* and *reflecting* on science.

— After an introductory brainstorm about “What is science?” participants investigate a strange substance called “Oobleck,” and then, using the evidence they’ve gathered, make generalizations about the substance, and derive “Laws of Oobleck.” This turns out to be much more complex than they may have imagined!

— The experience provides a sense of the actual practices involved in doing science and helps communicate the nature of science as an evidence-driven human endeavor to investigate, find out about, understand, and make generalizations about the natural world.

— Participants also take a critical look at what is and is not an accurate view of science. These misinterpretations, conscious and unconscious, are widespread, and examining them can help hone our own understanding of what science is and is not. Through attempting to define science, participants can gain a deeper understanding of its strengths and limitations.

— Tinker and Thornton describe science: “...not as a noun...but as a process, a set of activities, a way of proceeding and thinking.” (Tinker, R. F. & Thornton, R. K. (1992). Constructing student knowledge in science. In E. Scanlon & T. O’Shea (Eds.), *New directions in educational technology* (pp. 153–170). Berlin: Springer-Verlag.)

Not all of us learned science in this way; some of us needed to wait until graduate school to become authentically engaged with doing science. And yet, as is illustrated through the Oobleck experience in this session, science *can* be introduced to the youngest of students in ways that engage them in the firsthand collection and evaluation of evidence.

## Session 1: The Nature and Practices of Science

### Background Information for the Presenter

*Note: The science background information included here is for the presenter, and is not meant to be read aloud to participants. The background information is designed to help presenters respond to participants' questions, and be aware of inaccurate ideas that research indicates students may bring to the classroom.*

### About the Nature and Practices of Science

**Why Reflecting on the Nature and Practices of Science Is Important.** In the modern world, we are constantly presented with scientific and non-scientific information. As citizens, we vote on many issues that are informed by scientific studies. To understand the meaning and value of scientific information in these situations, it's important to understand how the scientific field gathers information, and how it comes up with explanations. (*The National Science Education Standards*, National Research Council, 1996)

The *National Science Education Standards* call on science educators to move beyond having students just *learn about* science, and be guided to *inquire about* the natural world, using the inquiry methods that scientists themselves use. Being able to critically inquire about the world will prepare students not only for future science studies, but also for life itself, as they increase their ability to make informed decisions based on evidence and to acquire new knowledge. Teaching students about the nature of science has also been shown to increase student interest in science (Lederman, 1999; Meyling, 1997; Tobias, 1990)

Understanding the nature of science is important for citizens and students, and particularly for anyone who teaches science. Science teachers who do not have a background in the nature of science tend to primarily teach vocabulary and facts, while neglecting more important aspects of science, such as how scientific knowledge is generated, and how knowledge claims are cautiously evaluated

The better understanding teachers have of the nature and practices of science, the better they can make this explicit for students. The fact is that many children and adults, including science teachers, hold a combination of accurate and inaccurate ideas about what science is. And many science teachers have not had the valuable opportunity of reflecting on the nature of science. (Gess-Newsome & Lederman, *Examining Pedagogical Content Knowledge*.)

**What is Science?** Science is an extremely valuable way of knowing. The scientific enterprise is a union of science, mathematics, and technology, as well as logic and imagination. Science assumes that the world around us is understandable, and that the basic rules that exist in one part of the Universe can be applied to others. Like many other systems of thought, science is a quest for truth, yet one of its greatest strengths is that it recognizes that it can never completely arrive at the truth. Nothing is ever completely proven in science. Science is not only open to new evidence and ideas, but actively seeks them out. Science helps us understand the world around us, and in a practical sense, it has

**Session 1: The Nature and Practices of Science**

great predictive value. Some people think science is infallible. Others see it as a static accumulation of information. Others see it as arrogant, biased, or heartless. In actuality, it is none of these things.

*Note:* See the handouts, *Science is...* and *Science is not...* for more information on “what is science?” (pages 52 and 53)

**Science, Evidence, and Explanations.** At its core, science is about *evidence*. In an attempt to understand some aspect of the natural world (as opposed to supernatural), observations are made and data collected in as objective a manner as possible. Scientific explanations are based on *all* the available evidence. Explanations that are based on selective evidence, and which ignore or exclude evidence that doesn’t support the explanation, are considered to be pseudoscience.

**Science is Self-correcting and Durable.** In science, evidence, investigations, and explanations are discussed and reviewed by peers. Investigations are repeated, and if the results are not comparable, the results are questioned. More evidence is always sought and welcomed, and if an accepted explanation doesn’t match new evidence, it is revised or replaced. Scientists also seek ways of testing explanations, and if tests show an explanation to be false, then it is revised or replaced. In this sense, science is self-correcting. Scientific knowledge and explanations are accepted within the scientific community based on consistency and strength of argument. Scientific knowledge evolves over time as the community of scientists inquires in different and deeper ways to uncover new evidence that changes and/or refines the accepted understanding of the natural world. Despite this embrace of change, and acknowledgment that science cannot attain “absolute truths,” most scientific knowledge is durable. New evidence sometimes leads to refinement of current ideas, rather than complete rejection.

**The Myth of the Scientific Method.** A common misconception about science is that there is a single scientific method—a rigid series of sequential steps scientists follow to arrive at a conclusion. This myth has been spread widely by science educators, but is a source of frustration for scientists who are aware of its limitations in describing what they do. The source of the myth is described in the following quote:

“In the 1940s a man named Keeslar wished to describe the different elements of scientists’ work. He began by generating a list of all the things he imagined scientists did: carefully making measurements, maintaining detailed written records, defining a research problem. This list was then turned into a questionnaire and given to many professional scientists for their response. Keeslar took the questionnaires as they were returned to him and put the items receiving the highest rankings into an order that seemed “logical” and published these findings in an education journal (McComas, 2000). Even though he was reporting on scientists’ uses of different thinking strategies without trying to describe a nice neat sequence, that’s unfortunately how his work has been used. A science textbook writer saw Keeslar’s list and turned it into The Scientific Method—touting it as THE way science proceeds. Indeed, there is really no such thing as a singular scientific method and this list doesn’t accurately portray the work of most scientists (which makes us wonder what teachers are trying to portray by drilling students on the scientific method).” [From Settlage, J. and Southerland, S.A. (2007). *Teaching Science to Every Child: Using Culture as a Starting Point*. New York, Routledge.]

**Session 1: The Nature and Practices of Science**

In actuality, there are many different paths scientists follow to answer questions. The methods used by an astronomer studying a distant star are quite different from those used by a biologist studying an insect. The scientific enterprise also involves human imagination and creativity.

“What appears to [the working scientist] as the essence of the situation is that he is not consciously following any prescribed course of action, but feels complete freedom to utilize any method or device whatever which in the particular situation before him seems likely to yield the correct answer...In short, science is what scientists do, and there are as many scientific methods as there are individual scientists.” (Percy W. Bridgman —“On Scientific Method”)

Scientific investigations are also peer-reviewed, reflecting the fact that the real “scientific method” is bigger than the work of an individual scientist or even the combined work of a particular group of scientists. Scientific discourse and communication are also instrumental. Scientific papers are published in journals to be reviewed by other scientists. Shared critique and discussion of methods and ideas are ongoing within the scientific community.

**Science and Human Nature.** Although a goal in science is to be objective, in reality, evidence is collected, interpreted, and influenced by current scientific perspectives and understandings and by the society, culture, and even the scientists’ sometimes-unavoidable personal subjectivity. There are patterns and habits of human thinking that present challenges in scientific endeavors, but the methods of science have been designed and re-designed to account for these.

**Scientific Facts, Laws, and Theories.** These three terms describe important aspects of the nature of science, but are often misunderstood. Each has a meaning in common usage that is different from its meaning in the scientific community, and this can cause confusion. These are the definitions as written by the National Academy of Sciences.

**Fact:** In science, an observation that has been repeatedly confirmed and for all practical purposes is accepted as “true.” Truth in science, however, is never final, and what is accepted as a fact today may be modified or even discarded tomorrow.

**Law:** A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

**Theory:** In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.

The contention that evolution should be taught as a “theory, not as a fact” confuses the common use of these words with the scientific use. In science, theories do not turn into facts through the accumulation of evidence. Rather, theories are the end points of science. They are understandings that develop from extensive observation, experimentation, and creative reflection. They incorporate a large body of scientific facts, laws, tested hypotheses, and logical inferences. In this sense, evolution is one of the strongest and most useful scientific theories we have. [Adapted from *Teaching About Evolution and the Nature of Science* (1998). National Academy of Sciences, Washington, D.C.: National Academy Press.]

## Session 1: The Nature and Practices of Science

**Science and Language.** Although “scientific proof” is an expression that’s often used by the general public, use of the words, “prove” or “proof” in science is generally inappropriate, because they imply that scientific ideas can be absolute truths. There are also many other words used in science that also are used in everyday language. Misunderstandings often arise when these words have very specific meanings in science, but more vague or sometimes quite different meanings in everyday language. For example, the word “theory” in common language is often used to describe an idea that is a guess or an explanation that has not been well tested. In science, however, as noted above, it is actually used to describe big ideas that are supported by a large body of scientific facts, laws, tested hypotheses, and logical inferences. See *Vocabulary Mix-ups*, in the *Misconceptions About Science* section of University of California Museum of Paleontology (UCMP) *Understanding Science* website: <http://undsci.berkeley.edu/teaching/misconceptions.php>

**Note:** Before presenting this session, even if the instructor is an experienced science teacher and/or scientist, it is strongly recommended that the instructor thoughtfully read the handouts and teaching notes on *Science Is...* and *Science is not...* (pages 46–47). It’s also recommended to spend some time exploring the UCMP *Understanding Science* website: <http://undsci.berkeley.edu/>

## Acknowledgments and References

We would especially like to thank Dr. Kevin Padian, of the University of California, Berkeley, Professor, Department of Integrative Biology and Curator of Paleontology at the UC Museum of Paleontology. We interviewed Dr. Padian at length and he made important contributions to this session, particularly the “Science Is” handout and related discussion.

Thanks as well to Ellen Granger, Professor in the Department of Biological Science, Florida State University, and Todd Bevis, also at Florida State, both also from the Great Explorations in Math and Science (GEMS) Center there, for conversations on the nature of science and the “Communicating Science” course.

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**Session 1: The Nature and Practices of Science**

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## Session 1: The Nature and Practices of Science

## About Oobleck

**What Kind of Mixture Is Oobleck?** Oobleck is a suspension of cornstarch in water. A suspension is a type of mixture, as are solutions, colloids, and precipitates. In a mixture, two or more substances are combined. In a solution, a solid dissolves into a liquid. The atoms, molecules or ions become evenly dispersed in the liquid. In a suspension the ingredients keep their own properties and usually can be separated fairly easily. Colloids and suspensions are both types of mixtures in which a solid is mixed into a liquid without dissolving. What distinguishes the two is that the particles in a colloid are smaller than those in a suspension. In a colloid the particles also tend to remain suspended (like milk), whereas those in a suspension tend to settle out. When Oobleck is kept moist and allowed to sit for a long time, the cornstarch will begin to separate from the water on its own. In a precipitate a solid forms in a solution due to a chemical reaction. This solid does not dissolve in the particular liquid.

**What Are Non-Newtonian Fluids?** One of the most fascinating things about Oobleck is precisely the ambiguity that students explore when they consider whether Oobleck is a liquid or a solid. Substances that flow, such as liquids and gases, are called fluids. Oobleck is a fluid, but a fluid of an uncommon sort. Its unusual nature relates to its viscosity and how its viscosity changes. Viscosity is a measure of how strongly layers of fluid resist flowing past each other when under stress, or shear forces. Words such as “thickness” or “gooiness” are often synonyms for viscosity.

Newtonian fluids, such as water, gasoline, and mineral oil, are those whose viscosity does not change as a result of a shear force exerted upon it. When you agitate a liquid by hitting it or moving your fingers through it, you are applying a shear force. Isaac Newton observed that for many fluids the flow increases in a regular way when the shear forces increase, indicating that the viscosity is a constant even when shear forces or fluid velocities change. In other words, no matter how hard you hit water or how quickly you move your fingers through it, it will have the same viscosity. Fluids that behave this way are called Newtonian fluids, and they include all gases and many liquids. Fluids that don't behave this way are called non-Newtonian fluids.

There are some non-Newtonian fluids that actually become *less* viscous when subject to shear forces. If you hit a deep pool of one of these fluids or quickly move your fingers through it, it will become less viscous. Although these are more unusual than Newtonian fluids, there are some common examples, such as blood, shampoo, fruit juice concentrates, mayonnaise, gelatin, liquid cement, paint, and ketchup. Common practical experience with this is when people shake a container to get one of these non-Newtonian fluids to flow more easily.

Even rarer are another type of non-Newtonian fluids, like Oobleck, that become *more* viscous when subject to shear forces. Your students discovered this as they noticed more resistance when they increased the shear force by hitting it hard or moving their fingers through it quickly. These fluids make transitions from liquid to a solid-like state that defy expectations of how a substance ought to

## Session 1: The Nature and Practices of Science

behave. Quicksand also becomes more viscous with agitation, which is why trying to move quickly if stuck in quicksand would make it more difficult to move. To confuse matters more, most of these fluids will also become *less* viscous if only a low shear rate is applied

There are also non-Newtonian fluids known as *plastic* fluids. These won't flow until a certain shear stress is applied. Some examples are toothpaste, hand cream, grease, and some ketchups. Toothpaste will not flow without pressure, but once the right amount of pressure is applied, it flows easily. *Time-dependent* non-Newtonian fluids either become less viscous with time (like yogurt or paint in a sealed container), or more viscous with time (like gypsum paste).

**What Makes Oobleck Behave As It Does?** Why Oobleck has such properties remains somewhat of a mystery. Some scientists have approached this question on a particle level and some at a molecular level. Here are three of their explanations:

**1. Sand in Water Model.** In this model, the starch particles in Oobleck are compared to sand and water in a plastic squeeze bottle. The grains of sand are packed closely together, with a little water in between. The surface tension of the water does not allow all of the spaces between the grains to be filled. Squeezing the bottle gently forces the grains of sand to slide against each other, increasing the spacing between some of the grains, and allowing more water to fill the spaces. The more gently you squeeze, the more time there is for the water to fill the spaces between the grains and provide lubrication so they will slide against each other, and flow. But when the bottle is squeezed quickly, there is not enough water between the spaces to start with, and friction between the grains of sand resists the flow. Although the grains of starch in Oobleck are much smaller than grains of sand, starch molecules are relatively large, as molecules go. Therefore, a mixture of water and cornstarch may act very much like a mixture of sand and water. This is one explanation for why Oobleck flows like a fluid, yet when suddenly compressed offers the resistance we associate with a solid.

**2. Long Chains Model.** This model bases Oobleck's behavior on chemical structure. Cornstarch is made of long chains called polymers. This model speculates that when a mixture of cornstarch and water is compressed, the chains are stretched in a direction at right angles to the direction of compression. The molecules become "tangled," can't slide easily against each other, and offer the resistance we associate with a solid.

**3. Electrical Charge Model.** This model suggests that the particles in Oobleck acquire an electrical charge as they rub together. The faster they're rubbed, the more electrical attraction is created between the particles, causing an increase in the mixture's viscosity.

These are among the ways scientists have attempted to explain the unusual properties of Oobleck and similar substances. An excellent discussion is provided by Jearl Walker in two articles in "The Amateur Scientist" section of *Scientific American* and there is quite a bit of scientific literature on related subjects, including an article by Albert Einstein. If you're interested in reading more, below are some references and additional notes.

**Session 1: The Nature and Practices of Science**

Billmeyer, Fred W. *Textbook of Polymer Science*, 3rd edition, John Wiley and Sons, New York, 1984.

Einstein, A. (1905) "On the Motion of Small Particles Suspended in Liquids at Rest Required by the Molecular-Kinetic Theory of Heat." *Annalen der Physik* **17**, 549–560.  
 Einstein, A. (1905) "A New Determination of Molecular Dimensions." *Annalen der Physik* **17**, 549–560. Einstein sought to explain Brownian motion, the zigzag motion of microscopic particles in suspension, as in a colloid. He suggested the cause as the random motion of molecules of the suspension medium as they bounced against the suspended particles. Using a statistical method, he could estimate the number and size of molecules in a cubic centimeter of liquid. This made an important contribution to proving that molecules *actually do exist*, not generally accepted at the time.

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Moring, Gary F. *The Complete Idiot's Guide to Understanding Einstein*, Indianapolis, Alpha Books, Macmillan USA, 2000, pages 140–161.)

Walker, Jearl. The Amateur Scientist, *Scientific American*, volume 239, number 5, pages 186–198, November, 1978, and volume 246, number 1, pages 174–180, January 1982.

**Some Additional Information on non-Newtonian Fluids.** From

<http://www.ccmr.cornell.edu/education/ask/index.html?quid=14>: The molecules that make up cornstarch are very different from the small water molecules. They consist of long chains of repeating units called sugars. Sucrose or table sugar has two such repeating units per molecule, whereas starch has many, many, more. In pure cornstarch, the sugar chains stick strongly and cannot move past one another, thus starch is a solid. However, if we add water to starch, the water gets between the starch chains, separates them and allows the chains to slide past one another; the mixture behaves as a liquid. If we apply pressure to the starch mixture, the water is squeezed out from between the chains and they are able to grab one another. Sliding is prevented and the material behaves as a solid. If we release the pressure, the water can enter between the chains to allow sliding once more. This behavior is not limited to the molecular scale. A similar phenomenon occurs when you run on wet sand at the beach. If you run fast and generate pressure quickly the sand feels hard as water is squeezed out and the sand particles cling to each other. If you step slowly to apply the pressure gradually, the sand particles have time to move past one another—your foot sinks! The sand-and-water process described here is directly comparable to the liquefaction of sediment that can take place during earthquakes. See: [www.tulane.edu/~sanelson/images/liquefaction.gif](http://www.tulane.edu/~sanelson/images/liquefaction.gif)

For a discussion of different kinds of non-Newtonian fluids, with viscosity graphs, and more on this general scientific topic of flow in matter, or rheology, see:

<http://www.sju.edu/~phabdas/physics/rheo.html>

Two articles in *The Physics Teacher* report some interesting findings about how a bowl of dried beans can act as a liquid and related issues. See "On the Difference Between Fluids and Dried Beans" by Rolf Winter (February 1990) and "Liquid beans" by Robert Prigo (volume 26, 1988). There is considerable scientific literature and fascinating findings on sand (see for example, a New York Times article of September 7, 1996—"From Grains of Sand: A World of Order").

## Session 1: The Nature and Practices of Science

**Materials and Preparation****Materials Needed for the Session**

For the whole group (if using overhead transparencies instead of PowerPoint slides):

- overheads of *Science Scenarios*
- overheads of *A Few Perspectives on Science*
- overhead *Science Is...*
- overhead *Science is not...*
- overhead *Inquiry and the National Science Education Standards*
- overhead *NSES Recommendation*
- overhead *Session Summary*
- overhead *Reflection is a powerful learning tool*
- overhead *Quick Write prompt*

**Materials Needed for the Categorizing Statements Activity**

For each group of 4–6 participants:

- 1 set of “*Scientific Statements*” (master on page 45)
- 1 copy of “*Misinterpretations of the Scientific Process*” (masters on pages 46–51)

**Materials Needed for the Oobleck Lab Investigation**

For each group of 4–6 participants:

- 1 bowl (to contain about 1.5 cups of Oobleck)
- 1 work station covered with old newspapers
- 1 large sheet of paper (a piece of flip-chart paper works well)
- 1 felt-tipped marker or crayon
- Assortment of Oobleck exploration/ test items: cork, plastic spoons, metal washers, Styrofoam, film canisters, wooden craftsticks, etc. (*A quantity of these can be placed in one location in the room for teams to pick up as they investigate.*)

For the entire group:

- cornstarch (4–5 boxes is enough for 6 groups of 4–6 participants each)
- water
- green food coloring
- measuring cup
- paper towels

**Materials Needed for the Oobleck Scientific Convention**

For each team of 4–6 participants:

- 1 bowl of Oobleck (from the Lab Investigation)

For the entire group:

- water
- paper towels
- lists of properties (from the Lab Investigation)
- chalkboard
- 1 felt-tipped marker or crayon
- 1 roll of masking tape

## Session 1: The Nature and Practices of Science

### Materials Needed for the Session Summary

For each participant:

- ❑ handout *Science Is...*
- ❑ handout *Inquiry and the National Science Education Standards*
- ❑ handout from *Why People Believe Weird Things*

### Preparing for the Session

#### For the Categorizing Statements Activity

**1. Duplicate *Science Statements*.** Use the master found on page 45 to duplicate enough sets of statements so each group of six will have a copy (e.g., if you have 36 participants, then make six copies of the entire page of statements). Cut each page into individual statements and put them into an envelope, or paperclip them together, for each group.

**2. Duplicate *Misinterpretations of the Scientific Process*.** Use the masters found on pages 46–51 to duplicate enough sets of statements so each group of six will have a copy.

#### For the Oobleck Lab Investigation

**1. Preparation and Mixing.** If possible, start mixing the Oobleck about two hours before class. It's possible to mix the Oobleck shortly before class, but you can make any necessary adjustments more easily if you allow yourself more time. In any case, allow at least 45 minutes to prepare the Oobleck, and to set up the work stations and the equipment station for the lab investigation.

**2. Prepare the Oobleck.** The proportions used here—4 boxes cornstarch, 6  $\frac{3}{4}$  cups (1600 ml) water, and about 15 drops of food coloring—will make enough for six teams of students to have about 1  $\frac{1}{2}$  cups of Oobleck each. Keep an additional box of cornstarch on the side to thicken the mixture in case it becomes too soupy.

*PLEASE NOTE: Different brands of cornstarch may require slightly different amounts of water, so you should always test the Oobleck as follows: the Oobleck should flow when you tip the bowl, but feel like a solid when you hit it or rub your finger across the surface. If it is too thick to flow, add a little water. If it is too soupy, add a little more cornstarch.*

- a. To prepare the Oobleck, add 15 drops of green food coloring to 6  $\frac{3}{4}$  cups (1 liter or 600 ml) of water in a dishtub or large mixing bowl. Slowly sprinkle in the contents of four boxes of cornstarch. Swirl and tip the bowl to level the contents.

## Session 1: The Nature and Practices of Science

**Note:** Food coloring should not be added after the cornstarch, because at that stage it is difficult to mix evenly. Also, adding more than the recommended amount of food coloring may cause Oobleck to temporarily stain hands.

- b. Mix the Oobleck with your hands (not a spoon) to ensure an even consistency. Do not try to push through the Oobleck mixture as if mixing batter, as that will prove very difficult. Instead, keep “lifting” the Oobleck from the bottom of the bowl to the top by slipping your fingers under it, until an even consistency is reached.
- c. A few minutes before you plan to start the activity, mix one more time if water has separated.
- d. Pour about 1 1/2 cups (350 ml) of Oobleck into each team’s bowl. Then put the bowls aside until after you introduce the activity.

### For the Session

**Duplicate handouts.** Make copies of the take-away handouts:  
*Science Is... Is Not...* (pages 52 and 53)  
*Inquiry and the National Science Education Standards* (pages 54–55)  
*Why People Believe Weird Things* (pages 56–57)

## Session 1: The Nature and Practices of Science

## Instructor's Guide

### Session Objectives

In this session, participants deepen their understanding of the nature and practices of science through an appreciation of the following points:

- Science strives to find the best explanations for phenomena in the natural world, based on all the available evidence.
- Scientists use a wide range of inquiry methods as they inquire about the natural world.
- Science is a socially embedded, collaborative enterprise
- Scientific “truth” evolves over time as the community of scientists inquire in different and deeper ways to uncover new evidence that changes and/or refines the accepted understanding of the natural world.

### Time Frame

Total Workshop: 2 hours

Thought Swap and Categorizing Statements

Concept Invention: *What is Science?*

Exemplar: Oobleck Lab Investigation (25 minutes)

Scientific Convention (20 minutes)

How We Acted Like Scientists (10 minutes)

Application to *What is Science?* (10 minutes)

Summary (5 minutes)

### Session Activities at a Glance

#### Thought Swap: What is Science? (10 minutes)

This session begins with a “Thought Swap,” in which participants share their ideas in rotating pairs and discuss the questions:

- **What is science?**
- **How does science work?**
- **When is something not science, but appears scientific?**
- **Why is learning about how science works important for students?**
- **Why is learning about how science works important for teachers?**
- **What is the value (or usefulness) of a scientific approach to understanding the natural world?**
- **How is a scientific view distinct from other ways of knowing?**

Partners are then encouraged to share interesting statements to begin to gain a preliminary understanding that science is based on testable evidence.

**Session 1: The Nature and Practices of Science****Categorizing Statements (30 minutes)**

The participants are seated in groups of ~ 4 and presented with statements about science that they are challenged to categorize as accurate or inaccurate.

For each statement, participants discuss the criteria they used to classify them. Participants' exact choices of which statement belongs in which group are not as important as the discussion. (Controversy, after all, is also the stuff of science.) Then in the large group, each small group shares a statement they thought was inaccurate, and why. Then they share one statement they thought was accurate. Afterward, the instructor shows the UCMP Understanding Science website the statements came from, and reveals that *all* the statements are actually considered misconceptions.

**What is Science? (10 minutes)**

The instructor now introduces (via overhead transparencies or PowerPoint slides) "*A Few Perspectives on Science*" as well as a generally accepted definition of science titled "*Science is based on...*" These criteria are used to evaluate some of the statements they previously sorted.

**Classroom Exemplar (55 minutes)**

For each Communicating Science session there is a portion of the class where we model lessons from actual classroom science activities. Depending on your audience, you may select particular activities that relate to a particular subject area that you may find more appropriate for your situation.

**The activities and potential audiences are listed here:**

Oobleck (included in this write-up): topic is properties of matter, primarily for physical science students or faculty, as well as preservice and inservice teachers.

Ice Cubes Activity (included in optional activities): The topic is Ocean Science (specifically density), primarily for ocean science students or faculty

Oobleck: Laboratory Investigation and Scientific Convention  
Participants then take part in the GEMS unit entitled, *Oobleck: What Do Scientists Do?* In these activities, participants first investigate the properties of a substance called Oobleck, said to come from a newly discovered moon in our Solar System. Then, as a community of scientists, they conduct a scientific convention at which they attempt to write their own scientific statements about Oobleck. The activities they experience demonstrate the meticulous nature of scientific exploration and debate, the challenge of making a scientific generalization that all can agree upon, and the joy of inquiry!

## Session 1: The Nature and Practices of Science

The exemplar portion concludes with participants reflecting on how they acted like scientists during the Oobleck activities. The presenter introduces the terms for inquiry skills and abilities used with students and relates them to the original list they brainstormed for “What is Science?”

### Session Summary (5 minutes)

Participants examine some of the pitfalls and stumbling blocks of science, as they read a handout from *Why People Believe Weird Things*. This handout also addresses problems in “pseudoscientific” thinking and how some of our natural human tendencies may get in the way of thinking scientifically.

## Introduce Session

**1. Introduce common conceptions about scientists.** Ask participants what immediately comes to mind when they think of a scientist. Take a few responses from the group.

**2. Connect to ideas people have about science.** Tell participants that the image of a scientist (whether positive or negative) has a certain mystique and aura, some of which may be fantasy, and some of which is accurate. Young students often enjoy wearing the trappings of science, such as goggles and lab coats and doing activities that make them feel “scientific.” Similarly, non-scientists sometimes dress up their ideas in the trappings of science to tap into its mystique. This may create misconceptions about what science is and what it is not. These inaccurate ideas may survive, in part, because the general public has not been engaged in discussion about the nature of science.

**3. Explain rationale for session.** Tell them that, since they will be teaching about science, it’s extremely worthwhile to spend some time thinking about the nature of science and how this can be communicated to others.

**4. Display three scenarios.** Revealing one at a time, introduce the three situations listed below. Ask them to think about whether each scenario could be characterized as science.

- A traditional healer uses information passed down from generations to administer herbs for healing purposes.
- A scientist argues that the complexity of current life forms could not have taken place without the involvement of a creator.
- A committee of scientists decides that Pluto should be classified as a dwarf planet rather than as a planet.

## Thought Swap: What is Science?

**1. Introduce Thought Swap.** Tell participants they will be discussing a series of questions in order to share some of their ideas about the session’s topic—the Nature and Practices of Science.

## Session 1: The Nature and Practices of Science

**2. Line up participants and establish partners.** Have participants stand shoulder to shoulder to form two parallel lines, so each person is facing a partner. Participants standing side by side should be at least six inches apart. Tell them to look across at the other line and figure out who their partner is. Tell anyone without a partner to raise their hand, and make adjustments as necessary. If you have an odd number of students, you may choose to partner with a student, or have a group of three.

**3. Explain procedure for discussing questions.** You will be raising a question for them to talk about with their partner facing them. They will have about a minute to talk. You will signal them to be quiet to prepare for the next question or statement by gently tapping on the shoulder of the first two participants at the end of the lines (the “tap of silence”). These two will then pass the tap on down the line, till the entire group is quiet.

**4. Begin the Thought Swap.** Pose the first question for participants to discuss:  
*What is science?*

**5. Share responses with group.** After about a minute, tap the first two participants at the ends of the lines and wait for the entire group to become silent. Repeat the question, “What is science?” and ask a few participants to share with the large group what their partner told them.

**6. Change partners for discussion.** Tell participants which one of the lines will shift with each question, while the other remains in place. Tell the person at one end of the line that will shift to walk down and rejoin the line at the opposite end. Have this line now shift one position to the left so everyone is facing a new person. Everyone now should have a new partner.

**7. Discuss the next four questions.** Pose the questions listed below, shifting partners in the same way after each one. Pause to briefly discuss each question with the whole group.

- **How does science work?**
- **Why is learning about how science works important for students and teachers?**
- **How is a scientific view distinct from other ways of knowing and what is the value of a scientific approach to understanding the natural world?**
- **When is something not science, but appears scientific?**

**8. Seat participants in small groups.** Ask participants to return to their seats with a group of ~ 4 people, formed from those standing next to them in the Thought Swap lines.

**9. Record large group brainstorm of “What is Science.”** Write “What is Science?” on a piece of chart paper and ask the whole group to brainstorm some statements for you to record. Don’t correct any of the statements, but encourage students to respectfully discuss, disagree, and propose changes to statements given by others.

## Session 1: The Nature and Practices of Science

## Categorizing Science Statements

- 1. Introduce sorting of science statements.** Tell participants each small group will receive a set of statements about science. Each strip of paper has a different statement about science on it. Their challenge is to discuss each statement with their group, then categorize it as to whether they think it is accurate or inaccurate.
- 2. Explain purpose of sorting activity.** Let them know that reaching “right” answers is not the point of the activity, the purpose is to create an opportunity to discuss and think about what science is and what it is not. They should discuss each statement thoroughly before placing it in a category.
- 3. Emphasize thinking about criteria for sorting.** Let participants know that some statements will be fairly easy to categorize, but others will be challenging. Tell them that even with the relatively easy ones, they should discuss why they think they should be sorted that way.
- 4. Distribute statements to categorize.** Give a set of statement strips to each small group ~ 4 participants, and have them begin.
- 5. Begin class discussion by sharing statements they classified as inaccurate.** After most groups have completed the sorting task, regain the attention of the whole group. Ask groups to share a statement they sorted into the “Inaccurate” category. Ask them to explain why they decided it was inaccurate. Do this for a several statements.
- 6. Groups share statements they thought were accurate.** Ask groups to share one statement they sorted as accurate. **This time do not ask them to explain why they sorted them as accurate.**

*Note: In a moment, the groups will learn that **all** the statements are inaccurate. To avoid embarrassment, it’s enough that they simply share the statements they thought were accurate, without investing time into explaining why they thought they were accurate.*

- 7. Use the UCMP Understanding Science website to reveal that all the statements were inaccurate.** Tell the group all the statements they just sorted came from a web page produced by the University of California Museum of Paleontology (UCMP). Use the projector to display the website home page titled *Understanding Science*:

<http://undsci.berkeley.edu/>

Select the “Resource Library” tab at the top of the page, and click on the “Misconceptions” link. This takes you to the main “Misconceptions About Science” page where you can scroll down the list of misconceptions to access more detailed information about each. Share with the group that all the statements they sorted came from this list, and therefore are considered inaccurate.

## Session 1: The Nature and Practices of Science

**8. Groups read about misconceptions from UCMP website sheet.** Click on one of the misconceptions, and show the paragraph explaining why it is an inaccurate description of science. Distribute to each group a copy of the *Misinterpretations of the Scientific Process* handout, and tell them it contains explanations for each of the misconceptions about science. Ask them to have one member of their group read aloud what the website has to say about each of the statements they classified as accurate. Encourage groups to discuss these statements once again, incorporating the additional information.

*Note: You might want to share with the group that the intention behind the sorting activity was not to trick them into thinking some of the statements were true. The purpose was to challenge them to think deeply about their own beliefs and ideas about the nature of science and scientific approaches, and to become aware of possible misconceptions on the topic. The sorting activity also provides an incentive for participants to explore the Understanding Science website.*

**9. Show the “How Science Works” page.** Also found on the “Resource Library” page of the *Understanding Science* website is a link to “How Science Works—the flow chart.” Show how each of the circles on the flow chart leads to more pages addressing what scientists really do, as opposed to the commonly taught steps of the “scientific method.” Encourage them to explore the website later and tell them that part of their homework will be to examine the *Understanding Science* website.

## What is Science?

**1. Introduce contrasting perspectives on science.** Explain that well-known scientists and educators have also pondered the question of “What is Science?” Display the overhead transparency or PowerPoint slides titled “*A Few Perspectives on Science,*” and briefly introduce each in the following order:

“Science is a limitless voyage of joyous exploration”  
Walt Whitman

“Science is a set of methods designed to describe and interpret observed or inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation.”  
Michael Shermer  
Director of Skeptics Society

“Science is a limited way of knowing, looking at just the natural world and natural causes. There are a lot of ways human beings understand the universe—through literature, theology, aesthetics, art or music.”  
Dr. Eugenie Scott  
Executive Director National Center for Science Education

“We should talk about science not as a noun...but as a process, a set of activities, a way of proceeding and thinking...”  
Tinker and Thornton, 1992, *Constructing Student Knowledge in Science*, p. 155

## Session 1: The Nature and Practices of Science

**2. Introduce a definition of science.** Display the slide “*Science is ...*” Tell participants that they will receive a copy of this as a handout. Emphasize that the following list came from various sources including an extensive literature search and conversations with scientists and educators. Explain that this summary is intended to represent the generally accepted elements of science:

**Evidence-based:** In science there are accepted methodologies, standards of evidence, and logical ways of answering questions, all of which are based on using observations, tests, and other types of data to provide evidence. The acceptance or rejection of a scientific idea depends upon the quality of relevant evidence—not upon dogma, popular opinion, or tradition.

**Making Explanations:** Scientific explanations must show an explicit cause and effect relationship based on observable evidence. They involve looking for patterns and correlations. Explanations deal specifically with explaining the natural world and are not focused on supernatural questions.

**Testable:** If an explanation offers no way to be tested, or does not have the potential to be shown to be false by evidence, it is not scientific. Repeatability of tests is often a goal in experimental types of science, but much of science does not solve problems through experimentation, relying on inferences from patterns and observations that are not necessarily repeatable.

**Consistent:** A scientific explanation needs to do more than provide a plausible account; it must fit all the observable facts better than alternative explanations do. It must be consistent with *all* available evidence, not just selected evidence.

**Scientific Community:** The scientific community is the people and organizations that generate scientific ideas, test those ideas, publish scientific journals, organize conferences, train scientists, distribute research funds, etc. The scientific community provides the cumulative knowledge base that allows science to build on itself. It is also responsible for the further testing and scrutiny of ideas and for performing checks and balances on the work of community members. Individual scientists may have lots of different agendas and can put forth a variety of opinions—these don’t necessarily represent scientific knowledge. Scientific experts in one field may not know about other fields of science. This is why we look to communities of experts to help ratify explanations and judge the evidence for scientific arguments.

**Ongoing and Self-correcting:** Answering one question inspires deeper and more detailed questions for further research—the more we know, the more we know what we don’t yet know. Scientists are very careful about what they say they know and how they know it. Science is open-minded, not empty-headed. Scientists are tentative about their findings and focus on whether evidence supports or doesn’t support their idea. This is a strength, not a weakness, because scientific ideas are revised and improved on an ongoing basis.

**Scientific ways of thinking, doing and communicating:** Science involves using multiple scientific methods, involving many different steps and procedures. The processes of science are well defined, but are used in flexible and practical ways.

**Creative:** Creativity is involved in all aspects of science whether it is developing new questions, techniques, explanations, or hypotheses. Anyone can have an idea in science, it is non-discriminating and it is not sentimental.

## Session 1: The Nature and Practices of Science

**3. Introduce what is *not* science.** Display the next slide and explain the following points:

**Science is not...**

**The absolute truth:** Scientific knowledge is only our current best approximation based on all available evidence. In science, no explanations are considered “proven.” All explanations are open to replacement or refinement, if warranted by new evidence. Yet most scientific knowledge is durable, and has withstood the test of time and critique.

**Democratic:** Science is not based on how many people vote for an idea, it’s based on the evidence. It doesn’t matter how many scientists there are with a particular opinion—the evidence is what counts. It’s also not the authority of the scientist that matters, but the quality of the evidence that provides the strength of the argument.

**The “Scientific Method”:** There is no one method for doing science. Science involves many different steps and procedures, depending on the field of science and the question being investigated.

*Note: As the handout on “What science is not...” pointed out, science is not “democratic” in the sense that “the most votes” or a “majority” determine what is accurate or which concept is correct. They do not. Scientific accuracy and conceptual correctness must be based on repeatable evidence. In another sense, however, science is democratic—it doesn’t matter who you are, your race or culture, your economic status, or what country you come from—your scientific findings are (or should be) weighted equally with anyone else’s, so long as they are evidence-based and the procedures are scientifically valid.*

**4. Explain that science is only one way of knowing.** Ask participants to briefly think about other systems of looking at the world. [art, history, philosophy] Emphasize that science is one of many systems for understanding the world around us, but not necessarily a superior system. Point out that science has great predictive value because it is a way of looking at the world with logic and evidence that helps us plan for future events. Many other disciplines also employ logic, and many also employ evidence. When science is described as studying and explaining the natural world, many people interpret this as the study of nature. However, in this context, “natural world” refers to everything in the Universe that doesn’t fall into the category of supernatural.

**5. Introduce an activity used to teach about the nature of science.** Tell participants that in the next activity, they will be attempting to write their own scientific statements. They will get an opportunity to *do* science, both to help them refine their own understanding, and to experience a classroom exemplar designed to teach children about the nature and practices of science.

## Oobleck Laboratory Investigations

**1. Set stage for Oobleck explorations.** Tell participants to imagine they are on a space ship far out in space and have sent a space probe down to a recently discovered moon within our Solar System. The moon is covered with what appear to be large green oceans, and three probes have been sent down. Contact with the first probe was lost, and what happened to it is unknown. The second probe is stuck on the surface, but the third probe managed to return with a sample of the ocean material.

## Session 1: The Nature and Practices of Science

**2. Participants as scientists.** Ask the participants to imagine they are a group of scientists in a laboratory on board a spaceship orbiting the newly discovered moon. It is their task to investigate the properties of the sample and collect evidence about the substance.

**3. Explain Oobleck is safe to handle.** Show participants the bowls of Oobleck, but don't distribute them yet. Mention that preliminary studies have shown that Oobleck is safe to handle. Add that a team of chemists is trying to find out its exact composition, and their results will be revealed when their research is completed.

**4. Introduce materials and begin investigations.** Explain that their job is to investigate the properties of Oobleck. Hold up a pencil (or another convenient observable object) and ask them, "What is a property of this pencil?" As they offer examples, make sure they understand that a property is anything you can observe directly about an object. Point out where they can collect the assorted test items, and the newspapers for covering their tables. Distribute a bowl of Oobleck to each table group and have them begin investigating.

**5. Distribute paper for recording properties.** After participants have investigated Oobleck for a few minutes and discovered some of its unexpected properties, give each group a large sheet of paper and a felt-tipped marker to start recording the properties. (If needed, help participants by circulating and asking questions such as, "How does Oobleck behave when you press on it?" "When does Oobleck behave like a solid?" "When does Oobleck behave like a liquid?")

**6. Suggest participants test their ideas.** Encourage them to resolve disagreements by performing experiments or discussing ways to describe a property so everyone on the team agrees.

**7. Indicate properties related to solid or liquid characteristics.** Ask each lab group to put a star on their list next to the property of Oobleck they think is most important in explaining under what circumstances Oobleck acts as a solid or as a liquid.

### Oobleck: Scientific Convention

**1. Introduce context for scientific conventions.** Remind participants that professional scientists in most fields and disciplines travel all over the world to attend meetings called *scientific conventions*. The topics might be "Heart Disease," or "The Planet Mars" or "Earthquake Prediction."

**2. Explain purpose of convention.** Point out that during a convention, scientists listen to each other's experimental results and research findings and critically discuss them. The goal of the convention is *not* to prove each other right or wrong, but to *arrive at the most accurate scientific understanding and to state it as clearly and completely as possible*.

## Session 1: The Nature and Practices of Science

**3. Present discussion guidelines.** Tell participants they're about to hold a scientific convention on Oobleck. The starred properties listed on the board from their lab work are the scientific results they will discuss, according to the following guidelines:

- a. Only one property of Oobleck will be discussed at a time. The instructor will select a statement to begin. The lab teams will then explain or demonstrate the observations and/or experiments that led to the property that is being discussed. This is how they will present the **evidence** for their statement of the property.
- b. Participants who wish to agree or disagree with the property being discussed are asked to raise hands to **explain why**. They can refer to their own experience for evidence to support their position. In doing so, they are *making explanations based on evidence*—an essential science inquiry ability.
- c. Encourage participants to find ways to change the wording of a property so everyone can agree on it.
- d. After fully discussing a property, vote on whether or not it is really a property of Oobleck. If three-quarters of the group votes for a property, it will be called a "Law of Oobleck." To illustrate what is meant in this case by a "law," say that most scientists would agree that "water turns from liquid to solid below 32 degrees Fahrenheit," so it could be called a "law" of water. (Note: To be completely accurate, water turns from a liquid to a solid at 32 degrees Fahrenheit—at 1 atmosphere of pressure.) (Also see the "Note" on the use of the word "Law" in science.)

*It could be pointed out here, or a participant may do so, that the "voting" in this case is a convenient way to get a quick sense of group thinking in a class or workshop, but it is NOT a model of what science is or how science advances*

NOTE: Participants may be familiar with the quite elevated use of the word "Law" in science, as in the Laws of Motion, or the 2nd Law of Thermodynamics. These are very general statements about physical forces and processes. Technically speaking a "law" in science has been defined as a **descriptive generalization about how some aspect of the natural world behaves under stated circumstances**. Taking Oobleck as an "aspect of the natural world" participants are indeed trying to come up with "descriptive generalizations" about one or more of its properties/behaviors "under stated circumstances." However, scientists themselves differ on definitions. For many, the freezing point of water would not usually be considered a "law," but a property that has been demonstrated by considerable evidence. Although the refined statements participants come up with may or may not be "laws," the use of the term adds status and motivation to their quest for scientific accuracy. There are some teachers who prefer to use terms such as "scientific fact" or "accurate statement" or "hypothesis" or "class property." The use of the term "fact" can be problematic because in everyday language it implies unchanging "truth." **Scientific fact** should be defined as in a National Academy of Sciences publication, with our emphasis on the last sentence: "If something has been observed many times by many different scientists, and no evidence has ever been found that it is not true, then it is considered to be a scientific fact. **A scientific fact is always open to being changed or eliminated if new evidence shows it to be inaccurate.**"

## Session 1: The Nature and Practices of Science

## Facilitating the Discussion

**1. Suggestions for leading the discussion.** The scientific convention is one of the most exciting parts of the Oobleck experience because participants *are* like scientists when they debate their views and refine their statements of properties in order to seek the most accurate scientific statement. Your role as facilitator of the discussion is critical to its success. Following are some suggestions for moderating a successful discussion:

- The process used to arrive at a “Law of Oobleck” can take some time. Some groups start squirming in their seats after 20 minutes. Other groups are still going strong after 45 minutes. If participants are deeply involved in the discussion, you may want to continue the discussion the following day so they can further refine their communication skills. Above all, be aware of the interest level of the group, and end the discussion when you think it is appropriate.

*While the ideal is for each group to present their starred property to the class, discussing and voting to come up with one or two “laws” may be sufficient to highlight the importance of communication and debate in science.*

- One way to maintain interest in the discussion is to break to allow one group to test a particular property of Oobleck using the bowl you saved for this purpose, demonstrating for the class, then sharing the results in a class discussion.

*If you are in the unusual situation where all groups could have quick access to Oobleck, and it would not be too disruptive, then all groups could test the disputed property.*

- Disagreements are starting points for fruitful discussions. After the first group has read their starred property and explained their choice, ask if anyone disagrees with that property or any part of it. If no one challenges it, ask if anyone can think of a case where that property would **not** be true.
- Once you’ve provoked disagreement, challenge participants to find ways of *changing the wording* so everyone can agree on a statement of the property and/or pursue one or more of the options suggested below.

**2. Resolving issues with statements.** Following are some common ways of resolving problems you might suggest to help participants refine their findings.

- Add a phrase.** For example, in one class one team listed this property: “Oobleck dries out when left on paper.” A student objected, saying that this is not true when Oobleck is put on paper for just a few seconds. The teacher asked how to resolve the disagreement. The students added the phrase, “for more than ten minutes.” Adding such qualifiers is the essence of good scientific reporting.

## Session 1: The Nature and Practices of Science

**b. Define terms.** One team listed the property: “Oobleck is sticky.” When challenged to define *sticky*, the students realized there are several different kinds of “stickiness.” After a brief debate, they changed the property to read: “Your finger will get stuck if you try to pull it out fast.” A discussion like this highlights the importance of using precise terms that are agreed on by every scientist who works in a given field.

**c. Do Another Test.** In some cases, further testing can best resolve disagreements. By keeping bowls of Oobleck on hand during the convention, you can have two or three students do the test. For example, one team proposed that contact with air made Oobleck “liquidy.” Another student suggested putting Oobleck into a plastic bag where it could not touch the air. It turned out to be just as “liquidy” in the bag as it was in the bowl. After this test, the students voted not to make that particular property a “Law of Oobleck.” Similarly, professional scientists sometimes report initial findings that later experiments show to be erroneous.

**3. Modeling scientific discourse.** Throughout the scientific convention, ask questions and probe for reasoning. It’s of tremendous importance that the presenter/teacher model respect and acceptance of all ideas while facilitating the discussion. One of the most important components of science learning is the chance to discuss and reflect upon an experiment or experience, both individually and as a group. This is a chance for you and your participants/students to engage in scientific “discourse,” to encounter different ideas, confront them, consider evidence, and, when possible, arrive at a new level of understanding that encompasses observations and findings more accurately.

### Introduce Spacecraft Design Activity

**1. Discuss the importance of applying findings.** Mention to participants that in the *Oobleck: What Do Scientists Do?* GEMS unit, there are two other activities. One of these is another very important part of what scientists (and engineers) do, and that is to *apply their findings*. In a similar way, in education one key criteria for evaluating or assessing student learning is whether or not students can apply what they’ve learned in a different context.

**2. Describe spacecraft design assignment.** In the *Oobleck* unit, students are asked to design a spacecraft that would be able to land on the ocean of Oobleck, explore the whole moon, and take off again, with all passengers aboard.

**3. Explain how some students have used what they’ve learned about Oobleck.** Tell participants that some elementary school students have come up with very creative ideas, such as flying machines with thousands of little feet that continuously press on the Oobleck so it stays solid. Others have suggested a hovercraft concept, a craft with Oobleck dryers, or a landing platform with a detachable return shuttle.

## Session 1: The Nature and Practices of Science

## Explaining about the Substance of Oobleck

- 1. Reveal composition of Oobleck.** Announce that the team of chemists mentioned earlier has reported its findings on the exact composition of Oobleck. The scientists have revealed that Oobleck is made up of cornstarch, water, and green food coloring.
- 2. Briefly discuss explanations for Oobleck's behavior.** Explain that no one really knows exactly why Oobleck behaves both like a solid and a liquid, though there are many explanations. You may want to indicate that materials like Oobleck are known as non-Newtonian fluids. Wet sand is another example of a non-Newtonian fluid— which behaves as a solid when compressed, yet flows when released.

## Reflecting on Participants Behaving as Scientists

- 1. Review Oobleck activities: laboratory, scientific convention and spacecraft design.** Ask participants to think back over the session, from their first discussions about the scientific statements, through their experiences with and reflections on Oobleck's properties. Remind them that there were three parts to the Oobleck activity: a laboratory session, the scientific convention, which they took part in, and a spacecraft design session they were told about. All of these activities involve doing many things that scientists do.
- 2. List how they behaved as scientists during the three activities.** At the top of the whiteboard (or a piece of chart paper) write four headings: Science Statements Discussion, Oobleck Lab Investigations, Scientific Convention, and Spacecraft Design. Ask: **Throughout class today, in what ways were you acting as scientists?**

Possible responses related to each part of the session are listed below.

**Science statements:** *collaborated, discussed, explained, debated, applied knowledge, reflected.*

**Laboratory investigations:** *looked, touched, smelled, recorded observations, experimented, tested ideas, talked, used instruments (plastic spoons, etc.), compared Oobleck to other known substances.*

**Scientific convention:** *talked, disagreed, argued, explained our experiments, changed words, defined words, criticized, did more experiments, voted, decided if we thought something was accurate.*

**Spacecraft Design:** *drew pictures, thought about laws of Oobleck, invented machines, imagined walking on Oobleck, changed ideas.*

- 3. Connect responses back to the list of "What is Science?"** As appropriate, connect the scientific behaviors they suggest to the first chart they generated about the characteristics of science. Explain that this is how these activities can be used to teach about the nature and practices of science with children.

## Session 1: The Nature and Practices of Science

**4. Importance of student opportunities to struggle with ideas—including inaccurate ideas.** Point out that the Oobleck activities are focused on processes of science, which are absolutely essential to understanding the nature and practices of science. In many classrooms, these processes can be neglected in favor of teaching specific and accurate science content. Scientists come up with and try out lots of ideas, including inaccurate ones, to arrive at understandings. They discuss them, and compare them with available evidence. The more chances students have to do this themselves, the more scientific their thinking can become.

### Inquiry Abilities and Understandings

**1. Introduce inquiry as defined by NSES.** Display the slide “*Inquiry and the National Science Standards.*” Explain that these are the descriptions they will find most often listed in education standards for what students should know and be able to do in science, related to science process skills and inquiry practices. Display the slide “*NSES recommendation...*” and tell them the recommendation here is that students learn about science by engaging in the practices of inquiry.

**2. Explain that students must also reflect on how science knowledge is generally developed.** Tell them the *National Science Education Standards* go a step further by recommending that students should also generalize about how science applies these skills to finding out more about the natural world—referred to as “*Understanding About Inquiry.*” Emphasize that participants should become familiar with these descriptions of inquiry practices and how inquiry is used by scientists, so that they can identify and discuss scientific behaviors and the nature of science with students.

### Session Summary

**1. Emphasize importance of teaching about the nature of science.** Tell participants that the reason this session is devoted to this topic is because it is arguably the most important—yet historically neglected—aspect of science that can be taught in a science classroom.

- We are surrounded by scientific and non-scientific information in the world.
- Increasingly, citizens must vote on issues involving science.
- Teachers often don’t understand the nature of science, and therefore tend to teach science as vocabulary and facts or as a rigid “scientific method.”

For students to gain understanding of science, every science lesson should ideally highlight some of the aspects of the nature of science.

**2. Discuss some of the drawbacks and limitations encountered in science.** Mention that, unfortunately, the scientific enterprise sometimes goes astray or

**Session 1: The Nature and Practices of Science**

“misses the mark.” Ask your students to briefly consider some possible pitfalls and stumbling blocks of science and discuss this with the people at their table. Ask if they have heard about any controversial events in the scientific community, or other occasions when science might “miss the mark.” Ask if they can think of situations where attempts at science become unscientific because they do *not* meet all of the main points on the slide. After a few minutes have a few groups quickly share a situation that they discussed.

**3. Overview of Shermer handout.** Distribute copies of the handout modified from the book *“Why People Believe Weird Things,”* by Michael Shermer. Tell them that this is a summary of some of the possible reasons for the mishaps that occur around science, as described in the book.

*Note: You may want to mention here that the book Why People Believe Weird Things by Michael Shermer is very interesting reading about science and pseudoscience. It also provides useful information about becoming an advocate for scientific thinking.*

**4. Distribute handouts.** At this time you can give participants the copies of the *Science is...* and *Inquiry and the National Science Standards* handouts. Ask if there are any questions about the session or the handouts.

**5. Display summary slide.** Display the summary slide and emphasize these main points:

- **science is based on observations and hypotheses within a testable framework of ideas**
- **scientific results must be able to be tested in order to be valid**
- **science is a collaborative enterprise and a product of the scientific community**
- **scientific knowledge evolves over time**
- **scientists use a wide range of inquiry methods**
- **students should learn science through scientific inquiry**

**6. Explain importance of reflection.** Display the slide titled *Reflection is a powerful learning tool.* Have participants read the text and explain that you will introduce a reflection prompt for a Quick Write at the end of every session.

**7. Introduce Quick Write prompt.** Display prompt. Give participants a few minutes to think and write about the session, using the following prompt:

**Reflect on how your ideas about the nature of science may have changed during this session...and if so, what do you think made your ideas shift?  
How might you apply ideas from this session to your science teaching?**

## **Presentation Slides**

Slides 1–3: Science Scenarios

Slides 4–7: A Few Perspectives on Science

Slides 8–9: Science is ... Science is Not...

Slide 10: Inquiry and the National Science Education Standards

Slide 11: *NSES* Recommendation

Slide 12: Session Summary

Slide 13: Reflection is a powerful learning tool

Slide 14: Quick Write prompt

A traditional healer uses information passed down from generations to administer herbs for healing purposes.

A scientist argues that the complexity of current life forms could not have taken place without the involvement of a creator.

A committee of scientists decides that Pluto should be classified as a dwarf planet rather than as a planet.

“Science is a set of methods designed to describe and interpret observed or inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation.”

Michael Shermer  
Director of Skeptics Society

“Science is a  
limitless voyage of  
joyous exploration”

— Walt Whitman

“Science is a limited way of knowing, looking at just the natural world and natural causes. There are a lot of ways human beings understand the universe—through literature, theology, aesthetics, art or music.”

Dr. Eugenie Scott  
Executive Director  
National Center for Science Education

“We should talk about science not as a noun...but as a process, a set of activities, a way of proceeding and thinking...”

Tinker and Thornton, 1992, *Constructing Student Knowledge in Science*, page 155

# Science is ...

- Evidence-based
- Making Explanations
- Testable
- Consistent
- Scientific Community
- Ongoing & Self-correcting
- Scientific ways of thinking, doing, and communicating
- Creative

# Science is not...

- The absolute truth
- Democratic
- The “Scientific Method”

## *Inquiry and the National Science Education Standards*

- Learners are engaged by scientifically-oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations.
- Learners formulate explanations from evidence to address scientifically-oriented questions.
- Learners connect their explanations to scientific knowledge.
- Learners communicate and justify their proposed explanations.

***From Inquiry and the National Science Education Standards, Chapter 2, pages 24–27.***

## ***National Science Education Standards*** recommendation for how to teach science...

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

***From Inquiry and the National Science Education Standards, page 105***

# Session Summary

- science is based on observations and hypotheses within a testable framework of ideas
- scientific results must be able to be tested in order to be valid
- science is a collaborative enterprise and a product of the scientific community
- scientific knowledge evolves over time
- scientists use a wide range of inquiry methods
- students should learn science through scientific inquiry

# Reflection is a powerful learning tool:

“When students summarize or paraphrase, they are doing the work of moving surface learning deeper into the schema by making the connections that constitute meaning.”

— From K. Patricia Cross (1999) *Learning is About Making Connections: The Cross Papers #3*, Laguna Hills, CA, League for Innovation in the Community College and Princeton, NJ, Educational Testing Service.

## Quick Write Prompt:

Reflect on how your ideas about the nature of science may have changed during this session...and if so, what do you think made your ideas shift?

*How might you apply ideas from this session to your science teaching?*

## Handouts

1. Science Statements (used in class only)
2. Misinterpretations of the Scientific Process  
(used in class only)
3. Science is ... Science is Not...(2 pages)
4. Inquiry and the National Science Education  
Standards (2 pages)
5. Why People Believe Weird Things (2 pages)

**Session 1: The Nature and Practices of Science**

**Scientific Statements** (*for the Categorizing Statements activity*)

Science is a collection of facts.

Science is complete.

There is a single Scientific Method that all scientists follow.

The process of science is purely analytic and does not involve creativity.

When scientists analyze a problem, they must use either inductive or deductive reasoning.

Experiments are a necessary part of the scientific process. Without an experiment, a study is not rigorous or scientific.

“Hard” sciences are more rigorous and scientific than “soft” sciences.

Scientific ideas are absolute and unchanging.

Because scientific ideas are tentative and subject to change, they can't be trusted.

Scientists' observations directly tell them how things work (i.e., knowledge is “read off” nature, not built).

Science proves ideas.

Science can only disprove ideas.

If evidence supports a hypothesis, it is upgraded to a theory. If the theory then garners even more support, it may be upgraded to a law.

Scientific ideas are judged democratically based on popularity.

The job of a scientist is to find support for his or her hypotheses.

Scientists are judged on the basis of how many correct hypotheses they propose (i.e., good scientists are the ones who are “right” most often).

Investigations that don't reach a firm conclusion are useless and unpublishable.

Scientists are completely objective in their evaluation of scientific ideas and evidence.

Science is pure. Scientists work without considering the applications of their ideas.

## Session 1: The Nature and Practices of Science

Handout #2: **From UCMP Understanding Science Website:**  
<http://undsci.berkeley.edu/teaching/misconceptions.php#b1>

### Misinterpretations of the scientific process

- **Science is a collection of facts.** Because science classes sometimes revolve around dense textbooks, it's easy to think that's all there is to science: facts in a textbook. But that's only part of the picture. Science *is* a body of knowledge that one can learn about in textbooks, but it is also a process. Science is an exciting and dynamic process for discovering how the world works and building that knowledge into powerful and coherent frameworks. To learn more about the process of science, visit our section on [How science works](#).
- **Science is complete.** Since much of what is taught in introductory science courses is knowledge that was constructed in the 19th and 20th centuries, it's easy to think that science is finished—that we've already discovered most of what there is to know about the [natural world](#). This is far from accurate. Science is an ongoing process, and there is much more yet to learn about the world. In fact, in science, making a key discovery often leads to many new questions ripe for investigation. Furthermore, scientists are constantly elaborating, refining, and revising established scientific ideas based on new evidence and perspectives.
- **There is a single Scientific Method that all scientists follow.** "The Scientific Method" is often taught in science courses as a simple way to understand the basics of scientific testing. In fact, the Scientific Method represents how scientists usually write up the results of their studies (and how a few investigations are actually done), but it is a grossly oversimplified representation of how scientists generally build knowledge. The process of science is exciting, complex, and unpredictable. It involves many different people, engaged in many different activities, in many different orders.
- **The process of science is purely analytic and does not involve creativity.** Perhaps because the Scientific Method presents a linear and rigid representation of the process of science, many people think that doing science involves closely following a series of steps, with no room for creativity and inspiration. In fact, many scientists recognize that creative thinking is one of the most important skills they have—whether that creativity is used to come up with an alternative hypothesis, to devise a new way of testing an idea, or to look at old data in a new light. Creativity is critical to science!
- **When scientists analyze a problem, they must use either inductive or deductive reasoning.** Scientists use all sorts of different reasoning modes at different times—and sometimes at the same time—when analyzing a problem. They also use their creativity to come up with new ideas, explanations, and tests. This isn't an either/or choice between induction and deduction. Scientific analysis often involves jumping back and forth among different modes of reasoning and creative brainstorming! What's important about scientific reasoning is not what all the different modes of reasoning are called, but the fact that the process relies on careful, logical consideration of how evidence supports or does not support an idea, of how different scientific ideas are related to one another, and of what sorts of things we can expect to observe if a particular idea is true.
- **Experiments are a necessary part of the scientific process. Without an experiment, a study is not rigorous or scientific.** Perhaps because the Scientific Method and popular portrayals of science emphasize [experiments](#), many people think that science can't be done *without* an experiment. In fact, there are *many* ways to test almost any scientific idea; experimentation is only one approach. Some ideas are best tested by setting up a [controlled experiment](#) in a lab, some by making detailed observations of the natural world, and some with a combination of strategies.
- **"Hard" sciences are more rigorous and scientific than "soft" sciences.** Some scientists and philosophers have tried to draw a line between "hard" sciences (e.g., chemistry and physics) and "soft" ones (e.g., psychology and sociology). The thinking was that hard science used more rigorous, quantitative methods than soft science did, and such methods were more trustworthy. In fact, the rigor of a scientific study has much more to do with the investigator's approach than with the discipline. Many psychology studies, for example, are carefully controlled, rely on large sample sizes, and are highly quantitative.

## Session 1: The Nature and Practices of Science

- **Scientific ideas are absolute and unchanging.** Because science textbooks change very little from year to year, it's easy to imagine that scientific ideas don't change at all. It's true that some scientific ideas are so well established and supported by so many lines of evidence, they are unlikely to be completely overturned. However, even these established ideas are subject to modification based on new evidence and perspectives. Furthermore, at the cutting edge of scientific research—areas of knowledge that are difficult to represent in introductory textbooks—scientific ideas may change rapidly as scientists test out many different possible explanations trying to figure out which are the most accurate.
- **Because scientific ideas are tentative and subject to change, they can't be trusted.** Especially when it comes to scientific findings about health and medicine, it can sometimes seem as though scientists are always changing their minds. One month the newspaper warns you away from chocolate's saturated fat and sugar; the next month, chocolate companies are bragging about chocolate's antioxidants and lack of trans-fats. There are several reasons for such apparent reversals. First, press coverage tends to draw particular attention to disagreements or ideas that conflict with past views. Second, ideas at the cutting edge of research (e.g., regarding new medical studies) may change rapidly as scientists test out many different possible explanations trying to figure out which are the most accurate. This is a normal and healthy part of the process of science. While it's true that all scientific ideas are subject to change if warranted by the evidence, many scientific ideas (e.g., evolutionary theory, foundational ideas in chemistry) are supported by many lines of evidence, are extremely reliable, and are unlikely to change.
- **Scientists' observations directly tell them how things work (i.e., knowledge is "read off" nature, not built).** Because science relies on observation and because the process of science is unfamiliar to many, it may seem as though scientists build knowledge directly through observation. Observation *is* critical in science, but scientists often make [inferences](#) about what those observations mean. Observations are part of a complex process that involves coming up with ideas about how the natural world works and seeing if observations back those explanations up. Learning about the inner workings of the natural world is less like reading a book and more like writing a non-fiction book—trying out different ideas, rephrasing, running drafts by other people, and modifying text in order to present the clearest and most accurate explanations for what we observe in the natural world.
- **Science proves ideas.** Journalists often write about "scientific proof" and some scientists talk about it, but in fact, the concept of proof—real, absolute proof—is not particularly scientific. Science is based on the principle that *any* idea, no matter how widely accepted today, could be overturned tomorrow if the evidence warranted it. Science accepts or rejects ideas based on the evidence; it does not prove or disprove them.
- **Science can only disprove ideas.** This misconception is based on the idea of falsification, philosopher Karl Popper's influential account of scientific justification, which suggests that all science can do is reject, or falsify, hypotheses—that science cannot find evidence that *supports* one idea over others. Falsification was a popular philosophical doctrine—especially with scientists—but it was soon recognized that falsification wasn't a very complete or accurate picture of how scientific knowledge is built. In science, ideas can never be completely proved or completely disproved. Instead, science accepts or rejects ideas based on supporting and refuting evidence, and may revise those conclusions if warranted by new evidence or perspectives.
- **If evidence supports a hypothesis, it is upgraded to a theory. If the theory then garners even more support, it may be upgraded to a law.** This misconception may be reinforced by introductory science courses that treat hypotheses as "things we're not sure about yet" and that only explore established and accepted theories. In fact, hypotheses, theories, and laws are rather like apples, oranges, and kumquats: one cannot grow into another, no matter how much fertilizer and water are offered. Hypotheses, theories, and laws are all scientific explanations that differ in breadth—not in level of support. Hypotheses are explanations that are limited in scope, applying to fairly narrow range of phenomena. The term *law* is sometimes used to refer to an idea about how observable phenomena are related—but the term is also used in other ways within science. Theories are deep explanations that apply to a broad range of phenomena and that may integrate many hypotheses and laws.

## Session 1: The Nature and Practices of Science

- **Scientific ideas are judged democratically based on popularity.** When newspapers make statements like, “most scientists agree that human activity is the culprit behind global warming,” it’s easy to imagine that scientists hold an annual caucus and vote for their favorite hypotheses. But of course, that’s not quite how it works. Scientific ideas are judged not by their popularity, but on the basis of the evidence supporting or contradicting them. A hypothesis or theory comes to be accepted by many scientists (usually over the course of several years—or decades!) once it has garnered many lines of supporting evidence and has stood up to the scrutiny of the scientific community. A hypothesis accepted by “most scientists,” may not be “liked” or have positive repercussions, but it is one that science has judged likely to be accurate based on the evidence. To learn more about [how science judges ideas](#), visit our series of pages on the topic in our section on how science works.
- **The job of a scientist is to find support for his or her hypotheses.** This misconception likely stems from introductory science labs, with their emphasis on getting the “right” answer and with congratulations handed out for having the “correct” hypothesis all along. In fact, science gains as much from figuring out which hypotheses are likely to be wrong as it does from figuring out which are supported by the evidence. Scientists may have personal favorite hypotheses, but they strive to consider multiple hypotheses and be unbiased when evaluating them against the evidence. A scientist who finds evidence contradicting a favorite hypothesis may be surprised and probably disappointed, but can rest easy knowing that he or she has made a valuable contribution to science.
- **Scientists are judged on the basis of how many correct hypotheses they propose (i.e., good scientists are the ones who are “right” most often).** The scientific community *does* value individuals who have good intuition and think up creative explanations that turn out to be correct—but it *also* values scientists who are able to think up creative ways to test a new idea (even if the test ends up contradicting the idea) and who spot the fatal flaw in a particular [argument](#) or test. In science, gathering evidence to determine the accuracy of an explanation is just as important as coming up with the explanation that winds up being supported by the evidence.
- **Investigations that don’t reach a firm conclusion are useless and unpublishable.** Perhaps because the last step of the Scientific Method is usually “draw a conclusion,” it’s easy to imagine that studies that don’t reach a clear conclusion must not be scientific or important. In fact, *most* scientific studies don’t reach “firm” conclusions. Scientific articles usually end with a discussion of the limitations of the tests performed and the alternative hypotheses that might account for the phenomenon. That’s the nature of scientific knowledge—it’s inherently tentative and could be overturned if new evidence, new interpretations, or a better explanation come along. In science, studies that carefully analyze the strengths and weaknesses of the test performed and of the different alternative explanations are particularly valuable since they encourage others to more thoroughly scrutinize the ideas and evidence and to develop new ways to test the ideas.
- **Scientists are completely objective in their evaluation of scientific ideas and evidence.** Scientists do strive to be unbiased as they consider different scientific ideas, but scientists are people too. They have different personal beliefs and goals—and may favor different hypotheses for different reasons. Individual scientists may not be completely objective, but science can overcome this hurdle through the action of the scientific community, which scrutinizes scientific work and helps balance biases.
- **Science is pure. Scientists work without considering the applications of their ideas.** It’s true that some scientific research is performed without any attention to its applications, but this is certainly not true of all science. Many scientists choose specific areas of research (e.g., malaria genetics) because of the practical ramifications new knowledge in these areas might have. And often, basic research that is performed without any aim toward potential applications later winds up being extremely useful.

## Session 1: The Nature and Practices of Science

## Misunderstandings of the limits of science

- **Science contradicts the existence of God.** Because of some vocal individuals (both inside and outside of science) stridently declaring their beliefs, it's easy to get the impression that science and religion are at war. In fact, people of many different faiths and levels of scientific expertise see no contradiction at all between science and religion. Because science deals only with [natural](#) phenomena and explanations, it cannot support or contradict the existence of [supernatural](#) entities—like God.
- **Science and technology can solve all our problems.** The feats accomplished through the application of scientific knowledge are truly astounding. Science has helped us eradicate deadly diseases, communicate with people all over the world, and build [technologies](#) that make our lives easier everyday. But for all scientific innovations, the costs must be carefully weighed against the benefits. And, of course, there's no guarantee that solutions for some problems (e.g., finding an HIV vaccine) exist—though science is likely to help us discover them if they do exist. Furthermore, some important human concerns (e.g. some spiritual and aesthetic questions) cannot be addressed by science at all. Science is a marvelous tool for helping us understand the natural world, but it is not a cure-all for whatever problems we encounter.

## Misleading stereotypes of scientists

- **Science is a solitary pursuit.** When scientists are portrayed in movies and television shows, they are often ensconced in silent laboratories, alone with their bubbling test-tubes. This can make science seem isolating. In fact, many scientists work in busy labs or field stations, surrounded by other scientists and students. Scientists often collaborate on studies with one another, mentor less experienced scientists, and just chat about their work over coffee. Even the rare scientist who works entirely alone depends on interactions with the rest of the scientific community to scrutinize his or her work and get ideas for new studies. Science is a social endeavor.
- **Science is done by “old, white men.”** While it is true that Western science used to be the domain of white males, this is no longer the case. The diversity of the scientific community is expanding rapidly. Science is open to anyone who is curious about the natural world and who wants to take a scientific approach to his or her investigations.
- **Scientists are atheists.** This is far from true. A 2005 survey of scientists at top research universities found that more than 48% had a religious affiliation and that more than 75% believed that religions convey important truths.<sup>1</sup> Some scientists are not religious, but many others subscribe to a specific faith and/or believe in higher powers. Science itself is a secular pursuit, but welcomes participants from all religious faiths.

## Vocabulary mix-ups

Some misconceptions occur simply because scientific language and everyday language use some of the same words differently.

- **Fact:** [Facts](#) are statements that we know to be true through direct [observation](#). In everyday usage, facts are a highly valued form of knowledge because we can be so confident in them. Scientific thinking, however, recognizes that, though facts are important, we can only be completely confident about relatively simple statements. For example, it may be a fact that there are three trees in your backyard. However, our knowledge of how all trees are related to one another is not a fact; it is a complex body of knowledge based on many different [lines of evidence](#) and reasoning that may change as new [evidence](#) is discovered and as old evidence is interpreted in new ways. Though our knowledge of tree relationships is not a fact, it is broadly applicable, useful in many situations, and synthesizes many individual facts into a broader framework. [Science](#) values facts but recognizes that many forms of knowledge are more powerful than simple facts.

## Session 1: The Nature and Practices of Science

- Law:** In everyday language, a [law](#) is a rule that must be abided or something that can be relied upon to occur in a particular situation. Scientific laws, on the other hand, are less rigid. They may have exceptions, and, like other scientific knowledge, may be modified or rejected based on new evidence and perspectives. In science, the term *law* usually refers to a generalization about [data](#) and is a compact way of describing what we'd expect to happen in a particular situation. Some laws are non-mechanistic statements about the relationship among observable phenomena. For example, the ideal gas law describes how the pressure, volume, and temperature of a particular amount of gas are related to one another. It does not describe how gases *must* behave; we know that gases do not precisely conform to the ideal gas law. Other laws deal with phenomena that are not directly observable. For example, the second law of thermodynamics deals with entropy, which is not directly observable in the same way that volume and pressure are. Still other laws offer more mechanistic explanations of phenomena. For example, Mendel's first law offers a [model](#) of how genes are distributed to gametes and offspring that helps us make [predictions](#) about the outcomes of genetic crosses. The term *law* may be used to describe many different forms of scientific knowledge, and whether or not a particular idea is called a law has much to do with its discipline and the time period in which it was first developed.
- Observation:** In everyday language, the word *observation* generally means something that we've seen with our own eyes. In science, the term is used more broadly. Scientific observations can be made directly with our own senses or may be made indirectly through the use of tools like thermometers, pH test kits, Geiger counters, etc. We can't actually *see* beta particles, but we can observe them using a Geiger counter.
- Hypothesis:** In everyday language, the word *hypothesis* usually refers to an educated guess—or an idea that we are quite uncertain about. Scientific hypotheses, however, are much more informed than any guess and are usually based on prior experience, scientific background knowledge, preliminary observations, and logic. In addition, hypotheses are often supported by many different lines of evidence—in which case, scientists are more confident in them than they would be in any mere “guess.” To further complicate matters, science textbooks frequently misuse the term in a slightly different way. They may ask students to make a *hypothesis* about the outcome of an experiment (e.g., table salt will dissolve in water more quickly than rock salt will). This is simply a prediction or a guess (even if a well-informed one) about the outcome of an experiment. Scientific hypotheses, on the other hand, have explanatory power—they are explanations for phenomena. The idea that table salt dissolves faster than rock salt is not very hypothesis-like because it is not very explanatory. A more scientific (i.e., more explanatory) hypothesis might be “The amount of surface area a substance has affects how quickly it can dissolve. More surface area means a faster rate of dissolution.” This hypothesis has some explanatory power—it gives us an idea of *why* a particular phenomenon occurs—and it is testable because it generates expectations about what we should observe in different situations. If the hypothesis is accurate, then we'd expect that, for example, sugar processed to a powder should dissolve more quickly than granular sugar. Students could examine rates of dissolution of many different substances in powdered, granular, and pellet form to further test the idea. The statement “Table salt will dissolve in water more quickly than rock salt” is not a hypothesis, but an expectation generated by a hypothesis. Textbooks and science labs can lead to confusions about the difference between a hypothesis and an expectation regarding the outcome of a scientific test.
- Theory:** In everyday language, the word *theory* is often used to mean a hunch with little evidential support. Scientific theories, on the other hand, are broad explanations for a wide range of phenomena. They are concise (i.e., generally don't have a long list of exceptions and special rules), coherent, systematic, and can be used to make predictions about many different sorts of situations. A theory is most acceptable to the scientific community when it is strongly supported by many different lines of evidence— but even theories may be modified or overturned if warranted by new evidence and perspectives.

## Session 1: The Nature and Practices of Science

- **Falsifiable:** The word *falsifiable* isn't used much in everyday language, but when it is, it is often applied to ideas that have been shown to be untrue. When that's the case—when an idea has been shown to be false—a scientist would say that it has been falsified. A *falsifiable* idea, on the other hand, is one for which there is a conceivable test that might produce evidence proving the idea false. Scientists and others influenced by the ideas of the philosopher Karl Popper sometimes assert that only falsifiable ideas are scientific. However, we now recognize that science cannot once-and-for-all prove any idea to be false (or true for that matter). Furthermore, it's clear that evidence can play a role in supporting particular ideas over others—not just in ruling some ideas out, as implied by the falsifiability criterion. When a scientist says *falsifiable*, he or she probably actually means something like *testable*, the term we use in this website to avoid confusion. A testable idea is one about which we could gather evidence to help determine whether or not the idea is accurate.
- **Uncertainty:** In everyday language, uncertainty suggests the state of being unsure of something. Scientists, however, usually use the word when referring to measurements. The uncertainty of a measurement (not to be confused with the inherent provisionality of all scientific ideas!) is the range of values within which the true value is likely to fall. In science, uncertainty is not a bad thing; it's simply a fact of life. Every measurement has some uncertainty. If you measure the length of a pen with a standard ruler, you won't be able to tell whether its length is 5.880 inches, 5.875 inches, or 5.870 inches. A ruler with more precision will help narrow that range, but cannot eliminate uncertainty entirely. For more on a related idea, see our discussion of *error* below.
- **Error:** In everyday language, an error is simply a mistake, but in science, error has a precise statistical meaning. An error is the difference between a measurement and the true value, often resulting from taking a sample. For example, imagine that you want to know if corn plants produce more massive ears when grown with a new fertilizer, and so you weigh ears of corn from those plants. You take the mass of your sample of 50 ears of corn and calculate an average. That average is a good estimate of what you are really interested in: the average mass of *all* ears of corn that could be grown with this fertilizer. Your estimate is not a mistake—but it does have an error (in the statistical sense of the word) since your estimate is not the true value. Sampling error of the sort described above is inherent whenever a smaller sample is taken to represent a larger entity. Another sort of error results from systematic biases in measurement (e.g., if your scale were calibrated improperly, all of your measurements would be off). Systematic error biases measurements in a particular direction and can be more difficult to quantify than sampling error.
- **Prediction:** In everyday language, *prediction* generally refers to something that a fortune teller makes about the future. In science, the term *prediction* generally means “what we would expect to happen or what we would expect to observe if this idea were accurate.” Sometimes, these scientific predictions have nothing at all to do with the future. For example, scientists have hypothesized that a huge asteroid struck the Earth 4.5 billion years ago, flinging off debris that formed the moon. If this idea were true, we would *predict* that the moon today would have a similar composition to that of the Earth's crust 4.5 billion years ago—a prediction which does seem to be accurate. This hypothesis deals with the deep history of our solar system and yet it involves predictions—in the scientific sense of the word. Ironically, scientific predictions often have to do with past events. In this website, we've tried to reduce confusion by using the words *expect* and *expectation* instead of *predict* and *prediction*.
- **Belief/believe:** When we, in everyday language, say that we believe in something, we may mean many things—that we support a cause, that we have faith in an idea, or that we think something is accurate. The word *belief* is often associated with ideas about which we have strong convictions, regardless of the evidence for or against them. This can generate confusion when a scientist claims to “believe in” a scientific hypothesis or theory. In fact, the scientist probably means that he or she “accepts” the idea—in other words, that he or she thinks the scientific idea is the most accurate available based on a critical evaluation of the evidence. Scientific ideas should always be accepted or rejected based on the evidence for or against them—not based on faith, dogma, or personal conviction.

## Session 1: The Nature and Practices of Science

*Science is...*

- **Evidence-based:** In science there are accepted methodologies, standards of evidence, and logical ways of answering questions, all of which are based on using observations, tests and other types of data to provide evidence. The acceptance or rejection of a scientific idea depends upon the quality of relevant evidence—not upon dogma, popular opinion, or tradition.
- **Making Explanations:** Scientific explanations must show an explicit cause and effect relationship based on observable evidence. They involve looking for patterns and correlations. Explanations deal specifically with explaining the natural world and are not focused on supernatural questions.
- **Testable:** If an explanation offers no way to be tested, or does not have the potential to be shown to be false by evidence, it is not scientific. Repeatability of tests is often a goal in experimental types of science, but much of science does not solve problems through experimentation, relying on inferences from patterns and observations that are not necessarily repeatable.
- **Consistent:** A scientific explanation needs to do more than provide a plausible account; it must fit all the observable facts better than alternative explanations do. It must be consistent with *all* available evidence, not just selected evidence.
- **A Product of the Scientific Community:** The scientific community is the people and organizations that generate scientific ideas, test those ideas, publish scientific journals, organize conferences, train scientists, distribute research funds, etc. This scientific community provides the cumulative knowledge base that allows science to build upon itself. It is also responsible for the further testing and scrutiny of ideas and for performing checks and balances on the work of community members. Individual scientists may have different agendas and therefore put forth a variety of subjective opinions. Also, scientific experts in one field may not know about other fields of science. Therefore, we must look to the scientific community at large to help ratify explanations and judge the evidence for scientific arguments.
- **Ongoing and Self-correcting:** Answering one question inspires deeper and more detailed questions for further research—the more we know, the more we know what we don't yet know. Scientists are very careful about what they say they know and how they know it. Science is open-minded, not empty-headed. Scientists are tentative about their findings and focus on whether evidence supports or doesn't support their idea. This is a strength, not a weakness, because scientific ideas are revised and improved on an ongoing basis.
- **Scientific ways of thinking, doing, and communicating:** Science involves using multiple scientific methods, involving many different steps and procedures. The processes of science are well defined, but are used in flexible and practical ways.
- **Creative:** Creativity is involved in all aspects of science whether it is developing new questions, techniques, explanations or hypotheses. Anyone can have an idea in science, it is non-discriminating and it is not sentimental.

Session 1: The Nature and Practices of Science

*Science is not...*

- **The absolute truth:** Scientific knowledge is only our current best approximation based on all available evidence. In science, no explanations are considered “proven.” All explanations are open to replacement or refinement, if warranted by new evidence. Yet most scientific knowledge is durable, and has withstood the test of time and critique.
- **Democratic:** Science is not based on how many people vote for an idea, it’s based on the evidence. It doesn’t matter how many scientists there are with a particular opinion—the evidence is what counts. It’s also not the authority of the scientist, but the quality of the evidence that provides the strength of the argument.
- **The “Scientific Method”:** There is no one method for doing science. Science involves many different steps and procedures, depending on the field of science and the question being investigated.

Session 1: The Nature and Practices of Science

***Inquiry and the National Science Standards***

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners connect their explanations to scientific knowledge.
- Learners communicate and justify their proposed explanations.

(From *Inquiry and the National Science Education Standards*, Chap.2, pp. 24–27)

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

(From *Inquiry and the National Science Education Standards*, p. 105)

## Session 1: The Nature and Practices of Science

**Inquiry Abilities/Process Skills and Inquiry Understandings**

<b>Inquiry Abilities</b>	<b>Science Process Skills</b>
Asking investigable questions	Questioning
Designing and conducting Investigations	Investigating Experimenting
Using appropriate tools and techniques to gather, analyze and interpret data	Using tools Organizing data Recording and interpreting results
Developing descriptions, explanations, predictions, and models using evidence	Describing Observing Explaining Predicting Hypothesizing Modeling
Recognizing and analyzing alternative explanations and predictions	Comparing Relating Analyzing Drawing conclusions
Communicating scientific arguments	Communicating Describing
Thinking critically about evidence and explanations	Inferring Synthesizing

**Understandings about Inquiry:**

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer.
- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

## Session 1: The Nature and Practices of Science

## *Modified and Adapted from Why People Believe Weird Things by Michael Shermer*

### Common Problems in Scientific Thinking

#### 1. Prior Theory Influences Observations

Our perceptions of reality are influenced by the theories framing our examination of it.

#### 2. The Observer Changes the Observed

The act of studying an event can change it.

#### 3. Equipment Constructs Results

The equipment in an experiment often affects the results.

### Common Problems in Pseudoscientific Thinking

#### 1. Anecdotes Do Not Make a Science

Without corroborative evidence from other sources, or physical proof of some sort, 10 anecdotes are no better than one, and 100 anecdotes are no better than 10.

#### 2. Scientific Language Does Not Make a Science

Dressing up a belief system in the trappings of science by using scientific language and jargon means nothing without evidence, experimental testing, and corroboration.

#### 3. Bold Statements Do Not Make Claims True

Something is probably pseudoscientific if enormous claims are made for its power and veracity, but supportive evidence is as scarce as hen's teeth.

#### 4. Heresy Does Not Equal Correctness

Just because it is controversial and new (like Galileo's ideas) doesn't mean it is true.

#### 5. Burden of Proof

The person making the extraordinary claim has the burden of proving to the experts and to the community at large that his or her idea has more validity than the currently accepted idea.

#### 6. Rumors Do Not Equal Reality

Rumors *may* be true, of course, but usually they are not.

#### 7. The Unexplained Is Not Inexplicable

There are many genuine unsolved mysteries in the Universe and it is okay to say, "We do not yet know, but perhaps someday we will." The problem is that most of us find it more comforting to have certainty, even if it is premature, than to live with unsolved or unexplained mysteries.

#### 8. Failures Are Rationalized

In science, failures are *valued* as a means of getting closer to the truth. This is not true of pseudoscience in which failures are ignored or rationalized.

#### 9. Reasoning After The Fact

The fact that two events follow each other in sequence does not mean that they are connected causally. Being able to correlate events doesn't imply causality between them.

#### 10. Coincidence

When a connection is made between two or more events, in a manner that seems impossible according to our intuition of the laws of probability (although we may have a poor understanding of the laws of probability), we have a tendency to think that something mysterious is at work. We also tend to forget the many incidences in which coincidences have not occurred.

#### 11. Representativeness

Our tendency is to remember hits and ignore misses. We must try to remember the larger context in which a seemingly unusual event occurs, and we must always strive to analyze unusual events for how well they represent their particular class of phenomena.

**Nature of Science Handout #5 Page 2**

## **Problems with Illogical Thinking**

### **1. Emotive Words and False Analogies**

Emotive words are used to provoke emotion and sometimes to obscure rationality. Analogies and metaphors do not constitute proof. They are merely tools of rhetoric.

### **2. If You Can't Disprove It, It Must Be True**

This is where someone argues that if you cannot disprove a claim it must be true. In science, acceptance should come from positive evidence in support of a claim, not lack of evidence for or against a claim.

### **3. Attacking the Messenger**

These arguments redirect the focus from thinking about the idea to thinking about the person holding the idea.

### **4. Hasty Generalization**

Conclusions are drawn before the facts warrant it. In science, we must carefully gather as much information as possible before announcing our conclusions.

### **5. Over-reliance on Authorities**

While relying on expert opinion is useful for separating the wheat from the chaff, it can be a dangerous practice if used indiscriminately. It may lead to either accepting or rejecting an idea solely because it was either supported or refuted by someone we respect.

### **6. Either-Or**

This is the tendency to dichotomize the world so that if you discredit one position, then the observer is forced to accept the other view.

### **7. Circular Reasoning**

When the conclusion or claim is merely a restatement of one of the premises, it is based on faulty logic.

### **8. *Reductio ad Absurdum* and the Slippery Slope**

The refutation of an argument by carrying the argument to its logical end and so reducing it to an absurd conclusion. The slippery slope fallacy involves constructing a scenario in which one thing leads ultimately to an end that is so extreme the first step should never be taken.

## **Problems With How People Naturally Approach New Ideas**

### **1. Need for Critical Thinking Skills and Desire for Simplicity**

Scientific and critical thinking does not come naturally. It takes training, experience, and focused effort. Most of us, most of the time, want certainty, want to control our environment, and want nice, neat, simple explanations. Now and then the solutions may be simple, but usually they are not.

### **2. Inherently Misleading Problem-Solving Tendencies**

When solving problems we tend to:

- look for patterns and notice evidence that fits a pattern while ignoring those that do not.
- look for things that confirm what we already know and ignore things that don't.
- attribute causality to random events.

### **3. Ideological Immunity**

In day-to-day life, as well as in science, we all resist a fundamental paradigm change. This is generally adaptive because we cannot constantly attend to re-evaluating every situation we encounter. Unfortunately, we tend to build up "immunity" against new ideas that do not corroborate our previously held viewpoint.

## *Session 2: Teaching and Learning*

### **Contents**

<b>Overview</b>	1
<b>Background Information for the Presenter</b>	3
<b>Materials and Preparation</b>	5
<b>Preparing for the Session</b>	8
<b>Instructor's Guide</b>	10
<b>Presentation Slides</b> (also in separate PowerPoint document)	23
<b>Session Handouts</b>	27
<b>Optional Activities</b>	37
<b>Physics Learning Stations</b>	38
<b>Ice Cube Learning Stations</b>	43
<b>Fingerprinting—Solving the Crime</b>	56
<b>Sand on Stage Model Lesson</b>	58

## **Session 2: Teaching and Learning**

### **Overview**

This session is designed to explore how people learn best and to model how to develop lessons that support a variety of learning styles.

- Participants experience a series of learning stations, each using a different teaching approach to investigate the same topic. As they visit each station, the participants are challenged to be aware of their reactions and how each activity supported—or did not support—their individual learning experience.
- The group then discusses the advantages and disadvantages of particular approaches. This shared experience makes for a dynamic discussion about teaching approaches, as well as about the diversity in individual learning styles.
- The presenter introduces a research-based, instructional model known as the “Learning Cycle,” which focuses on ordering activities to match the way people naturally learn. This useful model breaks the learning process into five different phases that may each suggest particular types of teaching approaches. Although several versions of learning cycles are currently in use, the model presented in this session is based on a five-phase cycle: invitation, exploration, concept invention, application, and reflection.
- Finally, as participants experience an exemplar lesson based on this model, they learn how the model can be used to help provoke questions and enable students to integrate and apply new concepts and information.

Participants leave the session with a useful tool for planning and conducting educational activities.

## Session 2: Teaching and Learning

## Background Information for the Presenter

There has been much research, particularly in the past 10 years, concerning the processes involved in how people learn. An awareness of some of the main findings from this research is extremely useful to anyone involved in designing or presenting educational activities. This session is designed to open the door on the topic of how people learn, and suggest ways to craft learning experiences that reflect this understanding. The Learning Cycle model introduced in this session has been developed by researchers and educators, and refined and deepened in recent years by newer findings in neuroscience and cognitive psychology. The model represents the learning process as taking place in specific phases—invitation, exploration, concept invention, application, and reflection—which eventually lead the learner to begin the cycle once again. This model for instruction also takes into account the learner's prior understandings, and recognizes their need for firsthand experiences. Lessons or activities designed according to the Learning Cycle are learner-centered, provoke questions, and enable the learner to conceptually integrate and apply new ideas and information. In fact, all the adult learning activities in this entire course have been designed with the phases of the Learning Cycle in mind. Familiarity with this instructional model can help course participants begin to understand why they should follow carefully designed activity plans, and supports their ability to make thoughtful instructional decisions while leading science activities.

While its roots go back to forerunners such as Dewey, Vygotsky, Bruner, Piaget, and others, the contemporary idea of the Learning Cycle grew out of a breakthrough in science education in the early 1960s, as scientists and educators wrestled with more effective ways to help students acquire, retain, and apply important concepts. In 1962 Robert Karplus and J. Myron Atkin described a three-phase cycle: exploration, invention, and discovery, termed the “guided discovery” approach to learning. The model was further developed in the 1970s as it was applied toward developing more effective science activities for the elementary classroom. Other learning cycle models have evolved including similar phases, although they may be named differently. Some of these instructional models maintain the three main stages of the Atkin/Karplus model, others involve four or more phases such as Rodger Bybee’s “5 E’s” model (Bybee, *Achieving Scientific Literacy*, 1997). The research on the effectiveness of the Learning Cycle has been quite extensive, (for a summary see Lawson, Abraham, and Renner, 1989; and Lawson, 1995). The Learning Cycle has been instrumental in helping curriculum developers design materials and in assisting teachers in presenting educational experiences that are consistent with what is known about how people learn.

These learning cycle-based instructional models share a common vision of how learning takes place and are grounded in a constructivist theory of teaching and learning. Constructivist ideas rely on the assumption that learners must internalize and transform information for themselves in order to create deeper understandings. As summarized in the National Research Council’s 2000 report *How People Learn: Brain, Mind, Experience, and School*, the most recent cognitive research supports the view that learners are active agents in their own construction of knowledge and delineates three key findings that relate closely to phases of the Learning Cycle.

**Key Finding #1 states:** “Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.” This finding explains why the Invitation phase of the Learning Cycle is so

## Session 2: Teaching and Learning

crucial and why teachers should take the time to uncover and try to understand students' prior knowledge of a subject before beginning an instructional sequence. The Invitation phase often provides a significant motivating factor for learning science by engendering student interest and generating a need to know and understand.

**Key Finding #2 states:** *“To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.”* This finding highlights the importance of the Exploration, Concept Invention, and Application phases of the Learning Cycle. Students should have a variety of opportunities to explore various scientific phenomena and data sets in order to acquire factual knowledge, and must also consider how this new information fits into larger conceptual frameworks. In this way, the knowledge of facts and an understanding of overarching conceptual ideas both play a significant role in helping students learn about science. Students also need multiple opportunities to apply what they've learned and “test out” their new conceptual frameworks in different situations. According to current research, the ability to easily access and transfer knowledge and understanding is key to developing expert knowledge in a discipline.

**Key Finding #3 states:** *“A metacognitive approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.”* Metacognition involves learners in considering their learning path and taking note of experiences and ideas that have led to their personal understanding. This type of internal self-monitoring exemplifies the Reflection phase of the Learning Cycle. As students acquire scientific knowledge and understandings, it's critical that they spend time discussing how they arrived at these concepts and explain their thinking. Through reflecting on their learning processes, they develop the ability to think flexibly and acquire new understanding as needed. It's important to be mindful of the fact that the Learning Cycle we present is one model that can be used to represent, organize, and categorize main phases in science learning. It's not the only way to conceptualize learning. It should not be seen as a rigid or mechanical model—people and their learning processes are gloriously complex, and there is no automatic order or sequence in which these phases must take place. That said, the Learning Cycle model of instruction can be powerful and enormously helpful in stimulating thinking about how people learn and in designing lessons that succeed in conveying concepts to students in meaningful and effective ways.

### References

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- Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills [Monograph, Number One]*. Kansas State University, Manhattan, KS, National Association for Research in Science Teaching.
- National Research Council (2000) *How People Learn: Brain, Mind, Experience, and School*, Washington D.C., National Academies Press

## Session 2: Teaching and Learning

### Materials and Preparation

**Important Note to Presenter:** You will need to decide on two important points before proceeding:

**(1) The Content of the Activity Stations.** Choose whether you want to use the four Chemistry stations (most appropriate for audiences with less background in science) or the four Physics (cup and card) stations (most appropriate for science-sophisticated audiences). While both sets of stations have been successfully used with broad audiences, we've found that the lesson is particularly effective if the activities are challenging enough to stretch the participants, but not overly challenging so they become frustrated.

*Note: The overall goals of the session apply to the teaching of any topic, however the activities are most effective if participants are authentically learning new content themselves. For this reason, we've included several choices of topics. There is a set of four chemistry stations that are challenging enough and work well for most audiences. These are described in the body of this session write up. If you are presenting this session to people with a higher-level science background (such as science teaching assistants, science professors, or researchers) who need to be challenged with a more complex problem, consider using the Physics "cup and card" learning station activities which focus on the concept of pressure (page 37). If ocean science content is more appropriate for your audience then select the Ice Cube learning stations that explore the concept of density (page 42).*

**(2) The Learning Cycle Lesson Exemplar.** Choose whether you want to present portions of the GEMS unit *Fingerprinting* described in this session or if you'd prefer to present another lesson that models the learning cycle. Here's how *Fingerprinting* follows the learning cycle:

**Invitation:** Questions to elicit interest and curiosity: "What are fingerprints?" "What do you know about fingerprints?" "Have you ever been fingerprinted?"

**Exploration:** Students make their own fingerprints, look at them, notice patterns, then group and name them in their own way. Look at 10 new prints.

**Concept Invention:** The standard classification system (arch, loop, whorl) is introduced.

**Application:** Students classify their own fingerprints using the standard system. Optional: students further apply what they've learned to a mystery scenario ("Who Robbed the Safe?")

Another excellent exemplar, from the *On Sandy Shores* GEMS unit, has been used in the Communicating Ocean Science course—we provide a concise version of this "Sand on Stage" activity (page 58). The GEMS unit *On Cabbages and Chemistry* is another excellent exemplar—but there's significant work involved preparing materials for that lesson. If you already present the unit or have access to pre-made GEMS kits, you might consider presenting "Telltale Colors" and "Presto-Change-o." Ideally, the exemplar lesson you present should be one you're very familiar with that's appropriate for the level of your participants and/or their students, as well as being specific to the science content needs of your course. The specific lesson is less important than choosing something that provides a good and relevant example of the learning cycle.

## Session 2: Teaching and Learning

### Materials Needed For the Learning Stations

***Special Note:** We recommend that for up to 20 participants, one of each of the four stations is adequate. With more than 20, you will want to provide two set-ups of each station, so participants can rotate through them in the time allowed and have a real opportunity to experience each station. Should the number of participants grow even larger, you will need to increase stations and materials accordingly.*

**For the workshop/all stations:**

- 6 cafeteria trays (or cookie sheets) to carry station materials
- 6 sets of debrief questions

**For each participant:**

- one copy of “Read and Answer” sheet (master on page 34)
- one copy of “The Learning Cycle” sheet (master on page 35)

**For each two participants:**

- one copy of “Structured Activity” sheets (master on page 32–33)

**For Station A, Open-Ended Exploration ( materials needed to set up one station):**

- 1 squeeze bottle phenol red (diluted with tap water)
- 1 squeeze bottle bromothymol blue (diluted with tap water)
- 1 squeeze bottle white vinegar (mixed 50/50 with tap water)
- 2 squeeze bottles water
- 1 labeled container of each: salt, baking soda, and baking powder
- 3 1/4 teaspoons
- 3 popsicle sticks or coffee stirrers
- 3 paint trays
- 1 dish tub for rinsing equipment
- 1 sponge
- 1 copy of the Station A instructions

**For Station B, structured activity, materials needed to set up one station:**

- 1 squeeze bottle vinegar
- 1 squeeze bottle phenol red
- 2 squeeze bottles water
- 3 labeled graduated cylinders - 25 ml size (or cough-medicine-type cups) for vinegar, phenol red, and water
- 1 labeled container of each: baking soda and salt
- 6 clear plastic cups
- 2 teaspoons
- 2 popsicle sticks or coffee stirrers
- 1 dish tub for rinsing equipment
- 1 sponge
- 1 copy of the Station B instructions

## Session 2: Teaching and Learning

### For Station C, challenge/application (materials needed to set up one station):

- 1 squeeze bottle phenol red
- 1 squeeze bottle bromothymol blue
- 1 squeeze bottle vinegar
- 2 squeeze bottles water
  
- 1 labeled container of each: salt, baking soda, and baking powder
- 3 1/4 teaspoons
- 3 25 ml graduated cylinders or plastic vials without lids
- 3 popsicle sticks or coffee stirrers
- bag of small balloons
- 3 paint trays
- 1 dish tub for rinsing equipment
- 1 sponge
- 1 copy of the Station C instructions

### For Station D, Read & Answer:

- one copy for each participant of the “Read and Answer” sheet (page 34)
- one copy of the Station D instructions (master on page 31)

## Materials Needed For the *Fingerprinting* activities:

### What You Need

#### For the group:

- 1 pair of scissors
- 1 overhead transparency “Fingerprint Patterns” (see masters following page 36)
- an overhead projector

#### For each pair of students:

- 1 envelope containing the “10 Fingerprints” cut apart (see #5 under “Getting Ready” for Fingerprinting below)
- 2 “Fingerprint Patterns” sheets (masters following page 36)
- a magnifying lens

#### For each student:

- a completed “Your Fingerprints” sheet
- a pencil

*Larger versions of the three main fingerprint patterns at the end of the set of masters that follow page 36, should you wish to use them for transparencies.*

### For the optional Solving the Mystery activity:

#### For each student:

- “Suspects” student sheet (see masters following page 36)
- “Safe with Prints” (see masters following page 36)
- 1 pencil
- 1 magnifying lens

**Session 2: Teaching and Learning**

## Session 2: Teaching and Learning

### Preparing for the Session Before the Session

Make overhead transparencies or PowerPoint slides of the following:

- Think About Your Own Learning Experiences
- The Learning Cycle
- Session Summary

### For the Chemistry Stations:

**1. Copy station signs.** Make enough signs to have one for each station you are setting up.

**2. Make copies for each participant and set aside:**

- one copy of “Read and Answer” sheet (master, page 34)
- one copy of “The Learning Cycle” sheet (master on page 35)

**3. Make copies for each two participants:**

- “Structured Activity” sheet for Station B (master on pages 32–33)

**4. Make a wall chart list of station titles.**

Write the following list of the stations in large lettering on chart paper or a chalkboard to refer to throughout the session:

- A — Open-ended Investigation
- B — Structured Activity
- C — Problem-Solving Challenge / Application
- D — Read and Answer

**5. Label squeeze bottles:**

- 3 phenol red, 2 bromothymol blue, 3 vinegar, 6 water

**6. Prepare indicator solutions.** Add a small amount of concentrated phenol red into labeled bottles—then dilute the phenol red with tap water until it is pale red in color. Do the same with the concentrated bromothymol blue solution, until it turns pale blue.

**7. Prepare the vinegar solution.** Mix white vinegar 50/50 with water in squeeze bottles.

**8. Label and fill the powder containers.** Use masking tape or self-adhesive mailing labels to label the containers, then fill them with the designated powders: 3 containers salt, 3 of baking soda, 2 of baking powder.

### For the *Fingerprinting* activities:

1. Duplicate one copy of the following two student sheets for each participant: “Your Fingerprints” and “Fingerprint Patterns” (masters after page 36)

2. Use a high quality photocopier to duplicate one “10 Fingerprints” sheet from the master following page 36, for each pair of students. If you will also present the mystery scenario, photocopy one “Suspects” sheet and one “Safe with Prints” sheet for each student from the masters following page 36.

## Session 2: Teaching and Learning

3. Make an overhead transparency of the “Fingerprint Patterns” sheet. While using a projector in this activity may seem optional, teachers have found that it significantly increases students’ understanding of how to classify fingerprints.

4. Before you begin the lesson, spend 5–10 minutes learning the technique described below by making your own set of fingerprints.

- a. Using a No. 2 pencil, rub a small black patch of graphite onto a piece of paper.
- b. Rub your finger back and forth across the graphite. (It is important that the front of the finger, not the tip, be blackened. If only the tip is blackened the print will not include the “interesting” part of the fingerprint.)
- c. After your finger is blackened, use a piece of tape to “lift” the fingerprint directly from the finger.
- d. Place the tape on a clean part of the white scratch paper: The fingerprint can now be seen and examined.

5. Cut out the ten fingerprints from the “10 Fingerprints” sheets and put them together in an envelope. Make one envelope containing all ten prints for each pair of students. Alternatively, you can have the students cut out the fingerprints. Teachers who present this activity many times to different groups of students have chosen to laminate the ten fingerprints.

6. Familiarize yourself with the standard fingerprint classification scheme by reading the descriptions of the main categories on the “Fingerprint Patterns” sheet. Practice classifying the “10 Fingerprints.” Check yourself with the key for “10 Fingerprints” included in the masters following page 36. Try classifying your own fingerprints. As you attempt to classify more and more fingerprints, you will discover that many prints seem to fit in more than one category. Your job in classifying them is to decide, for instance, whether *most* of the lines “leave” on the same side of the print that they “started” (like a loop), or whether *most* of the lines “leave” on the other side of the print (like an arch).

## On the Day of the Session

### 1. Set up the teaching approaches stations

Set up the three stations by putting the materials (described under “What You Need” above) on a tray, with the instructions for that station. You will need to set up duplicate sets of these stations if you have more than 20 participants. The three stations are: Open-Ended Investigation; Structured Activity; and Problem-Solving Challenge/Application.

### 2. Set out the materials needed for the model lesson.

Place the fingerprinting materials somewhere convenient for later distribution.

## Session 2: Teaching and Learning

### Instructor's Guide

#### Session Objectives

**In this session, participants:**

- explore the advantages and limitations of different teaching approaches.
- understand that different learners have preferences for different teaching approaches.
- see the importance of providing learners with a balance of different teaching approaches.
- learn about an effective model for instruction known as “the learning cycle,” and gain the ability to analyze how lessons can be constructed to incorporate the learning cycle.
- become aware of the power of strategic sequencing of different teaching approaches to achieve in-depth learning.

#### Time Frame

Total Workshop: 2 hours

Introduce Session & Activity stations (10 minutes)

Activity Stations (30–40 minutes)

Debrief Stations (20 minutes)

Introduce Learning Cycle (10 minutes)

Model learning cycle lesson (30 minutes)

Session Summary (10 minutes)

#### Session Activities at a Glance

##### Introducing the Session

The session begins with participants thinking back on how different teaching approaches have affected them as learners, as a way to invite participants to begin thinking about the topic, and access prior knowledge they may have about teaching and learning.

##### Rotating through Activity Stations

The participants are then briefly introduced to the logistics of rotating through and participating in four activity stations: Open-ended Investigation, Structured Activity, Problem-Solving Challenge, and Read & Answer. They then rotate through the stations while thinking about how each activity affects their experience of learning.

##### Debriefing Activity Stations

After all participants have completed each station, the presenter leads a probing discussion of their experiences and thoughts, helping the group to compare and contrast the strengths of each kind of teaching approach. The presenter draws out the fact that different learners have different abilities and preferences for teaching approaches, highlighting the importance of a teacher using a variety of approaches.

## Session 2: Teaching and Learning

### Introducing the Learning Cycle

The presenter introduces the instructional model known as the learning cycle, in the following sequence, as a helpful way to think about how people learn: **invitation–exploration–concept invention–application–reflection**.

The presenter leads participants to discuss how different teaching approaches are more or less suited for each phase of the learning cycle and to understand the logic of sequencing different types of learning activities.

### Learning Cycle Lesson Exemplar

The presenter concludes the session by conducting a lesson that exemplifies the Learning Cycle. This is an important step in which the participants apply the theory presented in this activity to an activity they may be presenting to students. Participants are invited to point out the different phases of the cycle and reflect on the power of this order in this particular learning situation.

### Session Summary

Participants reflect on how the learning cycle was used throughout the entire session and the presenter emphasizes the flexible use of the tool.

## Introduce the Topic of Teaching Approaches (10 minutes)

**INVITATION** At this point, participants access prior knowledge and experience with the topic in order to engage them and set up the learning station activity.

*Note: The phases of the learning cycle have been labeled in this write-up for the presenter's awareness, but are not meant to be announced to participants.*

**1. Initiate thinking about the topic.** Ask your participants to brainstorm different teaching approaches that they have experienced themselves. For example: lecture, textbook, simulation, debate, exploration activity, etc. Have participants discuss the following question with the person sitting next to them for about two minutes

**In your own education, what teaching approaches do you remember responding best and worst to?**

*Note to Presenters: As with all sessions in this guide, the presentation to workshop participants has been designed to “practice what we preach.” The lesson plan itself has been set up to reflect a learning cycle approach to instruction. Through the session, the participants actually experience a version of the learning cycle instructional model as they learn about it. It is important that the session and presenter provide the opportunity for participants to experience each phase of the model for themselves — resisting the temptation to dole out too much information too early. Rather, the presenter should set up the circumstances and allow the participants to bring up most issues, while strategically inserting appropriate information to help clarify and organize the experience (and learning!) of the participants.*

## Session 2: Teaching and Learning

**2. Introduce the goals of the activity stations.** Point out that in this next part of the session, they will be rotating through three stations that represent different instructional approaches. Later, they will explore a fourth approach all at the same time.

a. **Stations designed for adults.** Let them know that these stations have been specifically designed for adults, to stimulate discussion on how people learn, and how classroom learning can be structured. These activities are not meant to be presented to children. Explain that they may know a little or a lot about this particular topic, but the stations represent different approaches to teaching a topic of *any* kind.

b. **Reflect on learning experience.** Emphasize that although one of their goals is to perform the assigned tasks, and get “caught up” in the activities themselves, the most important objective is to reflect on the learning experience. Encourage them to be aware of how they personally react to each approach, and how each stimulates, stifles, or in some other way impacts their learning.

**3. Introduce the station activities.** Explain that at each station they will:

a. **Do the activity:** Work with a partner to read the signs and follow the directions. There will be a signal given when your time is almost up. You should expect to spend about eight to ten minutes at each station.

b. **Clean up the station:** When you are finished, please use the dish tubs, squirt bottles and sponges provided to rinse and clean up the materials before moving on to the next station.

### EXPLORATION

Participants experience a variety of learning stations, notice how they are affected by them, and begin to come up with questions and ideas on the topic.

### Rotating through Activity Stations (40 minutes)

**1. Pass out trays and monitor station activities.** Place an activity station tray at each table of participants. As participants work at the stations, check in with the groups to make sure they understand the directions, are making progress, and that they clean up the station before they move on.

**2. Announce time and rotate groups.** Keep an eye on the progress of groups at Station B. When most of them have finished both sides of their worksheet (after about eight to ten minutes), announce to the whole group that it is time to clean up and move on to the next station. Explain how they should rotate, with people from Station A moving on to Station B, Station B moving to Station C, and Station C moving to Station A.

**3. Hand out Station D Read & Answer worksheets.** After all groups have rotated through the first three stations, hand out the Station D worksheet to each participant to complete individually.

## Session 2: Teaching and Learning

### Debriefing Station Activities (20 minutes)

**Note to Presenter:** *In order for participants to feel comfortable sharing their own ideas in a discussion based on open-ended questions, it's important for the presenter to be accepting of all responses. The discussion may be much less effective if a hidden agenda emerges when the discussion leader responds in an accepting fashion to some comments while negatively to others. Also, in order to encourage participation from everyone—rather than just a few more assertive participants—after asking a question, allow a few seconds of “wait time” before calling on anyone.*

*The beauty of the following discussion is that participants bring up all the points, and the leader merely serves as facilitator of the discussion. Although the “script” for leading this discussion is provided as a guideline and framework, it should not simply be read off to participants. Instead, the discussion leader should ask open-ended questions—many of which are suggested in the script—and “flow” with the participants’ responses and comments, while keeping the discussion generally on track and within schedule. This kind of dynamic interchange cannot be fully scripted, and depends on the facilitation skills of the presenter.*

**1. Participants discuss responses to Station A.** Ask participants to reflect on their responses to the activities. Draw attention to Station A, the Open-ended Investigation, and ask them to reflect on their reactions to the station. How did it make them feel? Did they learn from it? Be accepting of all responses. Be prepared for (and welcome) some disagreement. If only positive reactions to the station are brought up, ask if anyone had a negative reaction, and vice versa.

*You may want to point out that the Open-Ended Investigation station was intentionally unstructured in an exaggerated fashion, in order to provoke reaction and discussion. In the classroom, an open-ended activity need not be completely unstructured. You may want to point out that providing specific procedural directions, suggesting charts for recording data and conducting debrief discussions can often make an investigation a more rewarding educational experience for all learners.*

**2. Discuss reactions to rest of the stations.** Follow the same process in discussing stations B, C and D. Give ample time for discussion of each station and make sure participants point out both strengths and weaknesses of each approach.

**3. Conduct a quick vote for favorite stations, and discuss participant preferences.** Ask participants to raise their hand for the station at which they felt most comfortable. Read the station titles and letters from the wall chart one at a time, and take a quick visual survey of the group’s votes. Point out and discuss any interesting trends that may emerge in your group.

Explain that different individuals often have different teaching approach preferences, and each group of participants may (or may not) have a shared collective preference. Note that these preferences may have to do with individual

## Session 2: Teaching and Learning

learning styles or with what teaching approaches they've had most exposure to in the past.

**4. Ask participants to suggest some possible goals related to different teaching approaches.** Point out that teachers' choices for different approaches can often depend on the goals of the lesson. Ask what goals each type of approach might serve. Use the following summary, not to read off item by item, but to supplement the discussion, if necessary.

### Open-Ended Investigation

- Introduce a new subject area
- Generate questions
- Generate student interest and foster positive attitudes about science.
- Encourage students to work together without direct teacher instruction
- Develop and identify concepts, processes and skills, raise questions and problems.
- Provide a common base of experiences.
- Practice observation skills.

### Structured Activity

- Introduce concepts, vocabulary, processes, skills, and investigation methods.
- Guide students toward specific discoveries.
- Provide a common base of experiences.
- Provide successful activities with predictable outcomes.

### Problem-Solving Challenge/Application

- Model what scientists do.
- Provide a sense of accomplishment.
- Challenge students' conceptual understanding and skills by applying them to new situations.
- Develop deeper and broader understanding through real world applications.

### Read and Answer

- Provide specific content information and vocabulary on a topic.
- Extend the information from an activity into descriptions of related experiences that are impractical in a classroom setting.
- Provide alternative explanations and make connections into other subject areas.

**5. Note other factors that may impact teachers' choices.** Point out that choices of teaching approaches also depend on available time, home and school culture, and the previous experiences of the audience and the teacher. One of the most significant factors influencing an educators' choice of teaching approach is their own comfort level with learning via a given approach. For example, if an educator prefers to learn from an Open-Ended Investigation approach, they are more likely to teach using that approach. Remind participants to keep in mind that not all learners function best with one particular approach. Some groups (and individuals) may need more guidance, and others may need more time to explore. Because of different learners' readiness, as well as their preferences—it's best to use a balanced diet of teaching approaches.

## Session 2: Teaching and Learning

**6. Discuss the sequence of stations.** If it hasn't been mentioned, point out that each group rotated through the groups in a different sequence. Ask if they thought there were any advantages to the order they did the activities, or if there is a different order they think would suit them better or be more effective.

### CONCEPT INVENTION

Participants' experiences and ideas are integrated into research and ideas of educational experts, as the learning cycle is introduced.

### Explaining the Learning Cycle (10 minutes)

**1. Introduce questions about how people learn.** When faced with a new experience or learning situation, how do people tend to approach and successfully integrate lessons into useful knowledge? Many scientists and educators have openly wondered about the same thing: How do people learn? Is there a specific sequence that encourages optimal learning?

**2. Provide background about the model.** The Learning Cycle is a model that was developed to provide a method for organizing and delivering educational experiences that are consistent with what is known about how people learn. This instructional model was actually foreshadowed by leading educators in the early 1900s, and has now gained wide acceptance as a useful way to look at the phases encountered when people learn. In the early 1960s scientists and education researchers who were dedicated to designing science and mathematics lessons that were educationally effective and better aligned with the learning process, began using the learning cycle model to help guide their curriculum development. It has been transformed and deepened through educational research on common components of good instructional models, as well as the work of cognitive scientists and classroom-based researchers who study teaching and learning.

#### Some Other Variations of the Learning Cycle

"The Five E's": Engagement, Exploration, Explanation, Elaboration, and Evaluation from the chapter entitled "Improving Instruction" in *Achieving Scientific Literacy: From Purposes to Practices* by Roger Bybee (1997). David Kolb's (1984) Experiential Learning Model: Concrete experience, Reflective observation, Abstract conceptualization, and Active experimentation. (Referred to in *Learning is About Making Connections* by K. Patricia Cross.) Also "Common Components Shared by Instructional Models from Inquiry and the *National Science Education Standards*," page 35. In addition, the "Ignatian Pedagogical Paradigm" of the Jesuits: Context, Experience, Reflection, Action, and Evaluation.

**3. Display the *Learning Cycle* slide, and describe each phase.**

**Invitation:** An invitation is a question, problem, observation or demonstration that initiates the learning task. It should make connections between past and present learning experiences, anticipate activities and organize students' thinking toward the learning outcomes of current activities. If learners are not engaged, they may not retain what they learn and are probably only involved in rote learning.

## Session 2: Teaching and Learning

**Exploration:** Learner is engaged in open-ended investigation of real phenomena, and can also involve some discussion about discoveries, results, ideas, and questions that arise. This can be through hands-on activity or through discourse and thought processes. It can be more or less structured, but the idea is that exploration should be driven mainly by the *learner's* interest and questions.

**Concept Invention:** The concept invention phase involves the active processing of the experience by the learner. Learners now review evidence and data gathered through exploration and try to make sense of it. With interest and attention focused, new ideas can be discovered and the learner can solve problems and begin to construct new meanings. When possible, students should be free to invent and discuss their own understandings directly from their hands-on experiences.

**Application:** Armed with new ideas and concepts, the learner applies knowledge and abilities to different situations from those they have already encountered. Researchers agree that in-depth learning requires being able to transfer knowledge from familiar circumstances to novel ones.

**Reflection:** After trying out new ideas in different settings, students reflect on how their original notions have been or need to be modified. They may also generate new questions that can initiate a new learning cycle.

### APPLICATION

Participants apply the phases of the learning cycle to the activities they just experienced.

**4. Connect the structure of this session with the learning cycle model.** Draw participants' attention to the elements of the session that fit with the learning cycle model.

**Invitation:** The initial questions posed at the beginning of the lesson.

**Exploration:** The station activities and discussion.

**Concept Invention:** The introduction to the learning cycle model.

**Application:** Discussing how the learning cycle applies to the structure of the session. Further application and reflection will occur later in the session.

**5. Emphasize the learning cycle as a *model*.** Explain that every successful lesson need not include all stages of the Learning Cycle. There may be cycles within cycles in one lesson, or just one stage of a cycle in a lesson. Sometimes students may have explored a subject extensively before coming to class and be ready to enter the cycle at the concept invention phase right away. Emphasize that the learning cycle is a **model**—meant to represent, organize, and categorize main phases in learning—but not to suggest that this is the only way to conceptualize learning! Nor should it be seen as a rigid or mechanical model—people and their learning processes are gloriously complex. Depending on the person and the content being learned there is no requirement that these phases *must* take place during a single lesson.

**6. Describe drawbacks of focusing on only one phase.** Point out that many educational activities suffer as a result of the instructor focusing on the particular phase of the cycle with which *they* feel most comfortable. For example, many teachers spend most of their time with concept invention, most likely because

## Session 2: Teaching and Learning

this is the way they were taught. It can also be just as detrimental to focus solely on exploration, neglecting or rushing other important phases in the process.

### Model a Learning Cycle-Based Lesson (30 minutes)

*Note: Following are instructions for presenting a portion of the GEMS unit Fingerprinting, as an exemplar of a learning cycle-based lesson. Be sure to give enough time for your course participants to experience at least a sense of what students would experience in classroom presentation, and to get a feel for the overall flow of the lesson, but keep in mind the 30-minute time frame for the activity. It's okay to abbreviate and shortcut certain portions, once the participants understand what's intended to happen with students. (If you have more time, you may also want to go through the optional mystery scenario, on page 56.)*

### Introducing Fingerprinting

**1. Introduce the model lesson.** Tell the participants that you'll now be presenting a lesson that embodies the learning cycle. At the conclusion of the lesson, you'd like them to share their ideas of how the different phases of the learning cycle relate to the activities.

**2. Introduce Fingerprints.** Lead participants in a short discussion of fingerprints by asking:

- "What are fingerprints?"
- "Raise your hand if you've heard that all people's fingerprints are different."
- "Have you had your fingerprints taken?"
- "What are some of the reasons fingerprints are taken?"
- "Why are prints taken from fingers—couldn't we take elbow or ankle prints instead?" [One logical response is that fingers are used to pick things up.]

**3. Explain Criminalist's role.** Tell participants that they will become *criminalists* in this activity. Explain that criminalists are people who study crimes and analyze clues in a systematic and scientific way and fingerprints are an important part of what criminalists study. *A criminalist is a person who uses science to analyze physical evidence in legal proceedings. Another name for a criminalist is a forensic scientist.*

**4. Demonstrate technique for recording fingerprints.** Model the following steps for making fingerprints:

- a. Using a No. 2 pencil, rub a small black patch of graphite onto a piece of paper.

## Session 2: Teaching and Learning

b. Rub your finger back and forth across the graphite. It's important that the front of the finger, not the tip, be blackened. If only the tip is blackened the print will not include the "interesting" part of the fingerprint. The "interesting" part of the print can be seen by looking at the front of your finger. The area between the tip and the bend at the first knuckle has lines that swirl, loop, arch, or in some other way have a pattern.

c. After your finger is blackened, use a piece of tape to "lift" the fingerprint directly from the finger. Place the bottom edge of the tape on the line of the first joint. (Make a simple drawing on the board that shows the tape going across the front of the finger.)

d. Finally, place the tape on a clean part of the white scratch paper: The fingerprint can now be seen and examined.

**5. Warn about not making fingerprints too dark.** If the fingerprints are too dark, this makes them very difficult to read. One way to avoid this is to point out that the graphite mark on the scratch paper need not be too dark. Using the same graphite patch to print all fingers will help keep the prints from becoming too dark. Also, encourage participants to use paper towels to keep their fingers clean, which will keep the tape from getting smudged.

**6. Make practice prints.** Ask the participants to start by making a few practice prints. The goal is to let them practice until they can make clear prints.

**7. Distribute materials.** Distribute a pencil and a piece of scratch paper to each student and a tape dispenser to each group of students, and let them begin practicing.

**8. Circulate between working groups.** Go around the room and help, making sure that:

- the prints are coming from the front of the finger, not the tip,
- the tape is not wrinkled, and
- the fingerprints are not too dark.

Always examine the prints after the tape has been placed on the paper, as it is much easier to see them this way. When everyone can make clear prints, go to the next step.

### Making a Clean Set of Fingerprints

**1. Introduce student sheet.** Hold up a "Your Fingerprints" sheet and tell the participants to each make a set of very clean prints and stick them to their sheets. Show them how they can use either their right hand (palm down) or their left hand (palm up). Ask them to record on their sheet which hand they use.

## Session 2: Teaching and Learning

**2. Begin making prints and recording.** Distribute a “Your Fingerprints” sheet to each participant and have them get started. Encourage them to make the best set of prints possible. If someone “messes up,” it’s easy to start over. Just remove the print by peeling the tape off the paper. Circulate around the room as they work, and help them make clear prints.

**3. Participants examine their prints.** Give magnifying lenses to people who finish early, and have them examine their prints carefully. When everyone is done, collect the fingerprint sheets.

**4. Describe sessions.** Explain to participants that ordinarily this would end one class session, and students would be told that in the next session they would have a chance to examine their fingerprints much more closely. For this course, you’ll just go ahead into the next activity, which is called “Classifying Fingerprints.”

### Students Create Their Own Fingerprint Classifications

**1. Introduce ten fingerprints.** Show the participants an envelope containing the ten fingerprints. Explain that each team will get a set of these ten prints. Tell them that they may use magnifying lenses to examine the prints more carefully.

**2. Explore and describe prints.** Have participants look at the ten fingerprint patterns and think of words to describe what they see. Distribute the packets of ten fingerprints and the magnifying lenses. Let participants have several minutes to examine the prints. Emphasize that it is important that students be given enough time to develop their own descriptive categories for fingerprints.

**3. Share discoveries.** Ask participants to share words that describe the patterns of lines in the fingerprints. Record “descriptions” on the board. Accept and record *all* responses. Typical descriptions include: rainbow, bulls-eye, square, maze, coiled, dark, circular, swirling, wave, and tornado. The goal is to involve everyone in examining and describing the lines that make up a fingerprint.

**4. Introduce grouping fingerprints.** Explain that criminalists must be able to pick out one particular fingerprint out of thousands. To do this they have to find ways to group them. Ask participants to now sort the ten fingerprints into groups. They may choose to make as many or as few groups as they’d like.

**5. Assist groups as needed.** Walk around and encourage the participants. If a team has difficulty getting started, give them an example: If we wanted to sort all of the shoes in this room, we could do it in several ways. We could put all of the tie shoes in one pile, the buckle shoes in a different pile, and the slip-on shoes in a third pile. How else could we sort the shoes? [By color, by size, etc.]

Ask pairs why they grouped as they did. Typical responses include: “These are hills” “These are waves.” “These have waves over triangles,” “These are circles” and “This has little humps.” Encourage them to be imaginative.

## Session 2: Teaching and Learning

**6. Discuss fingerprint groups.** After everyone has sorted their prints, reconvene the group and ask, “Which prints did you group with print #1?” Write several groups’ responses on the board. Ask them to explain why they grouped a particular print with print #1. You can do this with all ten prints, depending on the level of interest and the time available.

### Introducing Standard Fingerprint Classification System

**1. Introduce standard classification.** Tell participants that criminalists have also devised a way to sort or classify fingerprints. Use the overhead and the transparency to show the three patterns to the whole class.

#### 2. Define the three basic fingerprint types:

- *arches* have lines that start on one side, rise, and exit on the other side of the print
- *loops* have lines that enter and exit on the same side of the print
- *whorls* have circles that do not exit on either side of the print.

If possible, relate the “standard” categories to categories that the groups generated. (For instance: The “arch” group seems to be just a different name for what Steve and Lisa called their “rainbow” group.)

**3. Explain that some prints might seem to fit in either of two groups.** For example, a print might have some lines that start on one side and exit on the other side of the print (like an arch) and other lines that enter and exit on the same side of the print (like a loop). Tell them that they will need to decide whether most of the lines are like the lines in an arch or whether most of them are like the lines in a loop. Ask the participants if they have any questions.

### Applying the Standard Classification

**1. Participants classify prints.** Ask the groups to now use the arch/loop/whorl system to classify the ten prints that they had previously classified on their own. Walk around the room and help, as needed.

**2. Debrief classifications.** After everyone has classified the fingerprints, go to the board and write the three headings, “arch,” “loop,” and “whorl.” Under these headings list the numbered prints by asking, “Which prints did you think were arches?” Write the responses on the board.

**3. Discuss differences.** After all of the responses are listed on the board, identify a number that’s listed under more than one heading. Lead a short discussion to decide in which category that print fits best. If there’s a lot of contention and the class can’t decide, ask if they think a new category needs to be invented. (It’s not only okay to struggle with the task of classifying hard-to-classify prints, but such discussions are important in developing their understanding of both the standard fingerprint classifications and the process of classifying. The goal is not to force everyone to agree on a particular categorization, but to clarify and **refine the definitions of each category** so it will be easier to classify individual prints.)

## Session 2: Teaching and Learning

**IMPORTANT NOTE:** Some of the fingerprints that do not fit easily into the three categories are sometimes put into a fourth category called “mixed.” An unusual fingerprint is included in the set of ten. Encourage them to grapple with this print using their own classifications and the standard system. If your participants find shortcomings in the system encourage them to suggest solutions. Go ahead and present the fourth category of “mixed” only after the group has considered all other options. Introducing this new category too early often results in students placing all hard-to-classify prints in it. If this becomes a problem, come up with a rule for when it’s okay to call a print “mixed.”

### Finding Their Own Fingerprint Formulas

- 1. Participants classify their own prints.** Now have individuals classify their own prints, using the standard classification system. Have them refer to the “Your Fingerprints” sheet they made in the first activity. Participants who finish quickly can double-check their classifications or help another person who is unsure.
- 2. Introduce fingerprint formulas.** When everyone has finished, tell them that you’d like them to figure out their “fingerprint formulas.” A fingerprint formula is the list of print classifications for one hand, from thumb to pinkie. For example, a hand that has fingers of loop, arch, arch, whorl, loop, has a formula of l-a-a-w-l. Ask each person to write his or her fingerprint formula at the bottom of the “Your Fingerprints” sheet.
- 3. Explain how students share results.** Tell participants that students would now trade data sheets with their teammates and check each other’s classifications. If the teammates disagree, they are encouraged to discuss their opinions with one another.

#### **APPLICATION**

Participants apply the phases of the learning cycle to the model lesson they have just experienced.

### Debriefing the Learning Cycle-Based Lesson (10 minutes)

- 1. Reflect on learning cycle structure in model lesson.** Ask participants to note the stages of the learning cycle in the lesson you just presented. For example, the following is a suggested outline of the learning cycle stages of *Fingerprinting*.

**Invitation:** Questions to elicit interest and curiosity: “What are fingerprints?” “What do you know about fingerprints?” “Have you ever been fingerprinted?”

**Exploration:** Students make their own fingerprints, look at them, notice patterns, then group and name them in their own way. Look at 10 new prints and categorize them.

**Concept Invention:** The standard classification system (arch, loop, whorl) is introduced.

**Problem-Solving Challenge/Application:** Students classify their own fingerprints using standard system.

Optional: students further apply what they’ve learned to a mystery scenario (“Who Robbed the Safe?”)

## Session 2: Teaching and Learning

**2. Reiterate importance of encouraging invitation and exploration before concept invention.** Explain that putting concept invention at the beginning of an activity tends to introduce information that children have not necessarily thought about and may not be interested in, and can steal the fun of discovering ideas for themselves. By opening an activity with an invitation and free exploration, youth can develop their own ideas, and it creates a much more learner-centered experience.

**3. Contrast with typical science presentation.** Point out that it is very common for science to be presented in a non-learning cycle-based way in the classroom. Often instructors choose to introduce science topics and content vocabulary before students have a chance to explore for themselves. There may not be adequate time allotted for students to discover science ideas on their own, or a teacher may instruct students to follow a procedure through which chosen concepts are merely demonstrated or verified. Explain that it can be easy to reformat “traditional” science activities to follow a more student-centered, learning cycle approach.

**4. Reflect on their experience in today’s session.** Point out that you *could* have started the lesson today by skipping the exploration and invitation phases and moving immediately to concept invention about the learning cycle. Ask them how their experience would have been different had the lesson begun with the introduction of the learning cycle without the station activities and discussion.

**5. Explain how Learning Cycle can be used.** Point out that the learning cycle approach can be an extremely valuable tool for designing educational activities and classroom lessons. When a lesson is ineffective, it’s often because concepts and vocabulary have been introduced *before* exploration. The learners aren’t interested yet, and have little context for the concepts. In some cases, students are given the opportunity to explore but not to engage in concept invention, which is a missed opportunity for them to try to make sense of their experience. Some otherwise great activities lack the opportunity for application, which can result in lessening the impact of the experience.

*An internalized learning cycle model is an excellent lesson-planning tool—and it can also help guide the many on-the-spot decisions educators must make during instruction.*

**6. Emphasize that flexible use of the learning cycle model is the most effective.** Close by emphasizing that the learning cycle model is not meant to be viewed in a mechanical or lockstep fashion. Remind participants that they will see as they present different science activities, that there is not always a complete learning sequence that applies in every situation. It is important to be flexible in applying the learning cycle, depending on the specific topic, the children’s experience level, and many other factors. Rather than a closed circle, it is more fitting to see the learning cycle as an ongoing, ever-spiraling process. Even as one question is investigated, many new questions arise.

**7. Summarize goals for effective teaching.** Display summary slide. Explain that effective teachers are aware of the advantages and limitations of different teaching approaches and use them accordingly. They are also aware that learners have different needs and preferences so they are careful to use a variety of approaches in the classroom. They also know that sequencing lessons using the Learning Cycle can help students to achieve deeper understanding of content.

**Session 2: Teaching and Learning**

**Presentation Slides**

Slide 1: Think About Your Own Learning Experiences

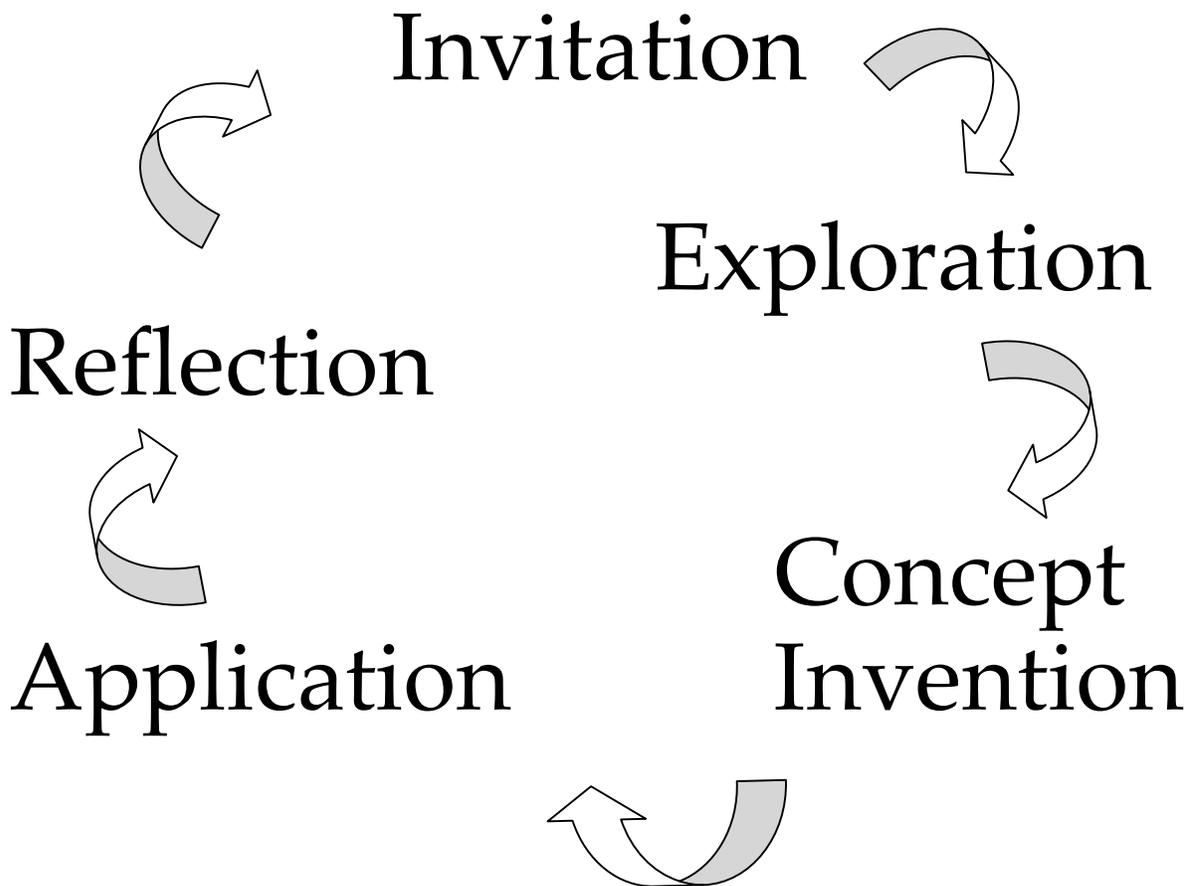
Slide 2: Learning Cycle

Slide 3: Session Summary

*Think about your own learning experiences...*

- **What are some teaching approaches or strategies that you are familiar with?**
- **What teaching approaches do you respond best and worst to?**

# The Learning Cycle



# Session Summary

- **Be aware of the advantages and limitations of different teaching approaches and use them accordingly.**
- **Since learners can have different preferences, use a balance of teaching approaches.**
- **Sequencing lessons based on the Learning Cycle can achieve deeper learning for students.**

**Session 2: Teaching and Learning**

**Session Handouts**

1. Chemistry Station signs
2. Chemistry Structured Activity handout
3. Chemistry Read and Answer handout
4. Learning Cycle Explained Handout

# Station A

## Open-ended Investigation

Find out  
whatever you  
can about these  
chemicals.

# Station B

## Structured Activity

Do the experiments  
and answer the  
questions on the  
back.

# Station C

## Problem-Solving Challenge

Using the chemicals provided, can you figure out a way to make bubbles?

To make a color change?

To inflate a balloon?

# Station D

## Read and Answer

Read the  
information sheet  
and answer the  
questions.

Session 2: Teaching and Learning

## Station B - Structured Activity

Do the experiments and then answer the questions on the back of the page.

### Experiment in Cup # 1

- use the graduated cylinder labeled “water” to measure 15 ml. water, and pour it into a cup.
- measure 1 teaspoon of salt and add it to the water.
- add 5 ml. phenol red using the graduated cylinder labeled “phenol red.”

Record your observations below.

- now use the graduated cylinder labeled “vinegar” to measure and add 15 ml. of vinegar to the same cup.

Record your observations below.

### Experiment in Cup # 2

- use the graduated cylinder labeled “water” to measure 15 ml. water, and pour it into another cup.
- measure 1 teaspoon of baking soda and add it to the water.
- add 5 ml. phenol red using the graduated cylinder labeled “phenol red.”

Record your observations below.

- now use the graduated cylinder labeled “vinegar” to measure and add 15 ml. of vinegar to the second cup.

Record your observations below.

**Session 2: Teaching and Learning**

## Questions

Phenol red turns yellow when it comes in contact with an acid. Did you observe any evidence of an acid in your tests?

Which of these chemicals (if any) do you think might be acids?

When an acid is added to a carbonate, carbon dioxide gas bubbles are released. Did you observe any evidence of a carbonate in your tests?

Which of these chemicals (if any) do you think might be carbonates?

**Session 2: Teaching and Learning***(Read and Answer sheet)***Chemical Reactions**

In a chemical reaction, the original substances, reactants, are transformed into other substances, the products. This chemical change is frequently accompanied by changes in physical properties such as color or physical state and changes in energy such as evolution of heat. Many types of chemical reactions exist and there are several ways to classify them. One useful classification distinguishes chemical reactions by the physical state of one or more products. Reactions forming a gas are an important and commonly encountered class.

The reaction of hydrochloric acid with sodium bicarbonate is an interesting example of a gas-forming reaction. In this reaction, hydrochloric acid (HCl) reacts with sodium bicarbonate ( $\text{NaHCO}_3$ ) to produce sodium chloride (NaCl), carbon dioxide ( $\text{CO}_2$ ), and water ( $\text{H}_2\text{O}$ ). Of the three products, only carbon dioxide is a gas and we can observe its formation by effervescence or bubbling of the resulting aqueous solution.

The common name for sodium bicarbonate is baking soda. In addition to bicarbonate ( $\text{HCO}_3^-$ ) salts, the related carbonate ( $\text{CO}_3^{2-}$ ) salts are also commonly found in everyday life. Sea shells, cement, limestone, marble, and chalk each contain bicarbonate or carbonate. The reaction between hydrochloric acid and sodium bicarbonate can be generalized. In fact, all bicarbonate and carbonate salts react with acids to produce carbon dioxide.

There are many examples of this reaction occurring in everyday life, some useful and others harmful. In one useful application in cooking, we add baking powder to cake batter so that during baking bubbles of carbon dioxide are formed which make the cake rise. The reaction in that case is between tartaric **acid** and sodium **bicarbonate** and takes place when they are mixed with water. In the environment, a harmful effect of acid rain involves this gas-forming reaction. Acid rain, produced by fossil fuel combustion, often contains sulfuric acid. When acid rain contacts buildings made of limestone or cement and marble statues, the sulfuric acid damages them by dissolving away the carbonate materials.

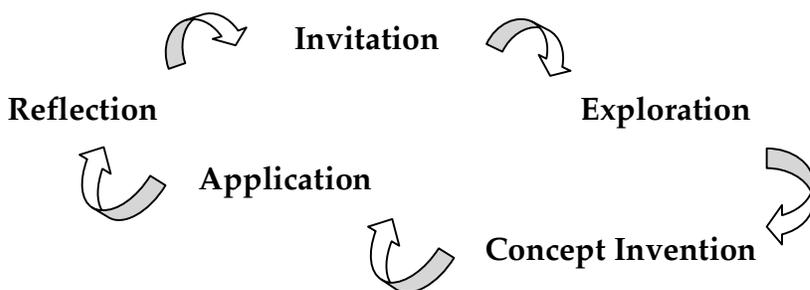
**Questions:**

- (1) What happens when an acid reacts with a carbonate salt?
  
  
  
  
  
  
  
  
  
  
- (2) What elements are in all carbonates and bicarbonates?
  
  
  
  
  
  
  
  
  
  
- (3) Name two products formed when sulfuric acid reacts with a marble statue.

## Session 2: Teaching and Learning

## Teaching and Learning Session Handout

## Learning Cycle Explained



**Invitation**—Initiates the learning task and sets the context. Makes connections between past and present learning experiences, generates anticipation of topic to be explored, and begins to focus learner’s thinking on the topic of the upcoming activities.

**Teacher’s Role:**

Create interest and generate curiosity. Raise questions and problems to be explored. Elicit responses that uncover students’ current knowledge about the concept or topic.

**Exploration**—Involves open-ended exploration of real phenomena, followed by discussion about learner discoveries, results, ideas, and questions. Provides a common base of experiences for learner to develop new concepts, skills and processes.

**Teacher’s Role:**

Encourage students to work together without direct instruction from the teacher. Observe and listen to students as they interact. Ask probing questions to redirect students’ investigations when necessary. Provide time for students to puzzle through problems. Act as a consultant and facilitator for learners.

**Concept Invention**—After interest and attention is focused, learner can invent concepts and /or methods to solve problems, which enables them to construct new meanings and make sense of experiences. Learner may be encouraged to develop conceptual statements by reflecting on what they’ve learned through explorations.

**Teacher’s Role:**

Encourage students to explain concepts and definitions in their own words. Ask for evidence, results and clarification from students, to help guide them to making sense of their experience. Provide formal definitions, explanations, and new vocabulary, as necessary. Use students’ direct experiences as the basis for explaining concepts.

**Application**—Armed with new ideas, learner applies new knowledge and skills to solving a problem or meeting a challenge. They may also apply their new knowledge to unfamiliar contexts in the world, through activity, or through discussion. Learner gains deeper and broader understanding, gathers more information and develops transferable skills.

**Teacher’s Role:**

Provide opportunities for students to use vocabulary, definitions, and explanations in a new context. Encourage students to apply the concepts and skills in new situations or problems. Evaluate student progress.

**Reflection**—Learner reflects on their learning and compares new ideas to alternative explanations. They make connections and construct new conceptual frameworks. They use metacognitive skills to analyze how they arrived at their current understanding.

**Teacher’s Role:**

Encourage students to confront their former ideas and evolve new ones, to solidify conceptual framework connections, and to help build metacognitive skills.

## **Masters Needed for the Fingerprints Activities**

**“Your Fingerprints”**

**“Fingerprint Patterns”**

**“10 Fingerprints”**

**“10 Fingerprints Key”**

**“Suspects”**

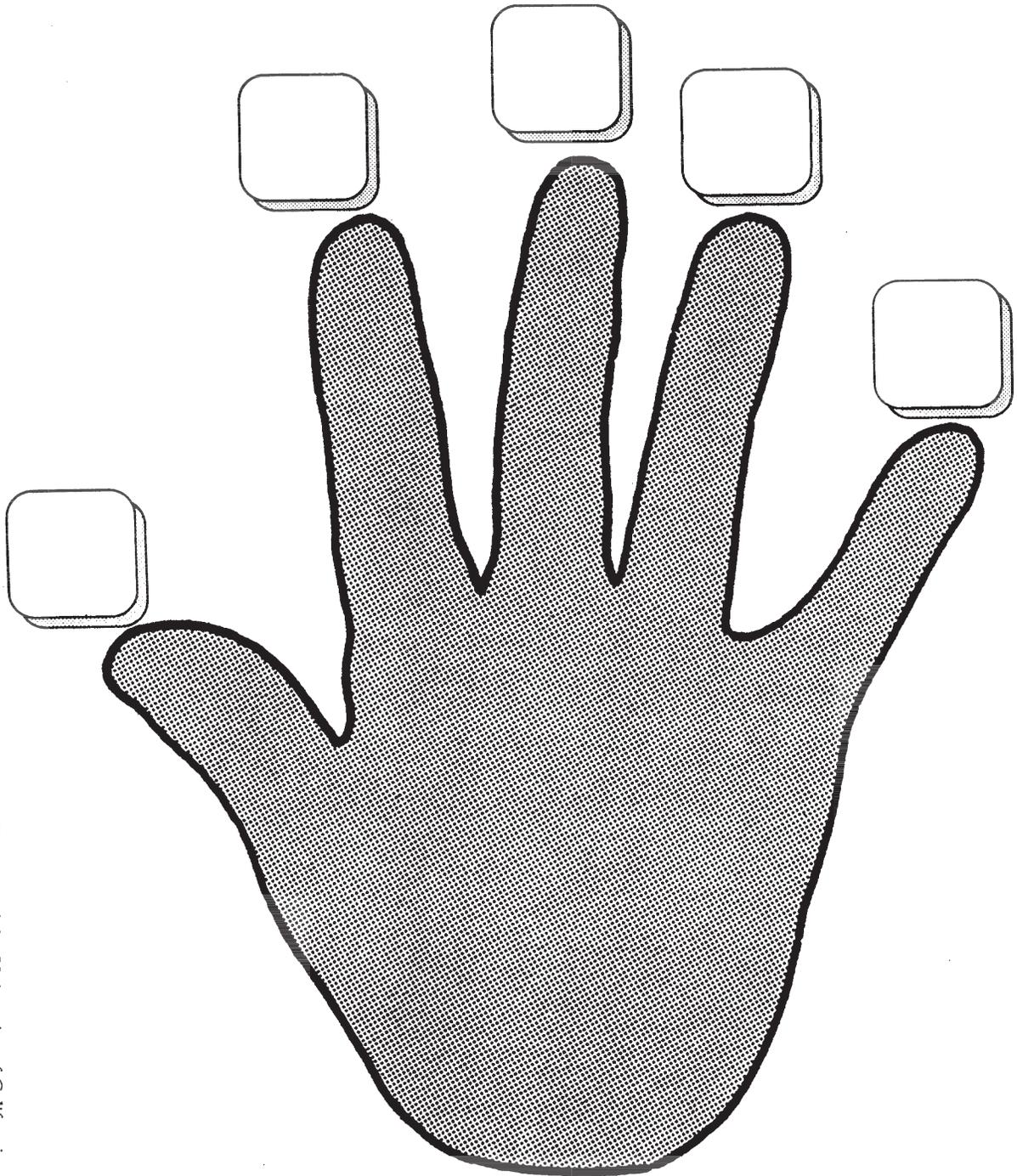
**“Safe with Prints”**

**“Large Versions Fingerprints”**

# Your Fingerprints

Name \_\_\_\_\_

Use this sheet with your right hand (palm down) or your left hand (palm up).



© 1987 by the Regents of the University of California  
LHS—Great Explorations in Math and Science: *Fingerprinting*  
May be duplicated for classroom or workshop use.

Which hand did you use? \_\_\_\_\_

What is your fingerprint formula? \_\_\_\_\_

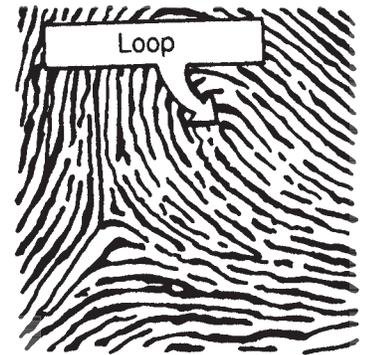
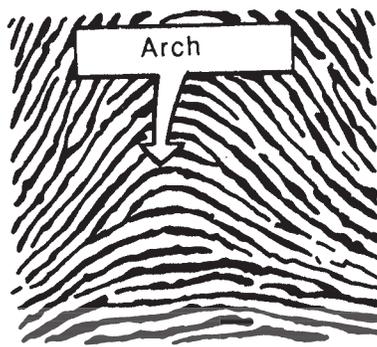
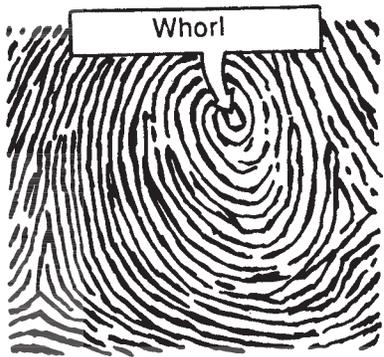
# Fingerprint Patterns

Every person in the world has a unique set of fingerprints, unlike those of any other person who ever lived.



Even though everyone's fingerprints are unique, there are basic patterns that are always found. These patterns help criminalists classify fingerprints.

The three basic patterns are:



**Whorl** patterns have lots of circles that **do not leave** either side of the print.

**Arch** patterns have lines that start on one side of the print, rise toward the center, and leave on the **other** side of the print.

**Loop** patterns have lines that start on one side of the print, rise toward the center, turn back and leave on the **same** side from which they started.



# 10 Fingerprints



1



2



3



4



5



6



7



8



9



10

# 10 Fingerprints Key

*arch*

1

*whorl*

2

*loop*

3

*whorl*

4

*mixed*

5

*arch*

6

*loop*

7

*arch*

8

*whorl*

9

*loop*

10

This is the key to the student sheet for Session 2, "Classifying Fingerprints." (Remember that these categories are not absolute.)

# Suspects

Name \_\_\_\_\_

An Example →



Arch



Loop



Whorl

Thumb

Forefinger

Middle finger

Ring finger

Little finger

President



Secretary



Vice-President



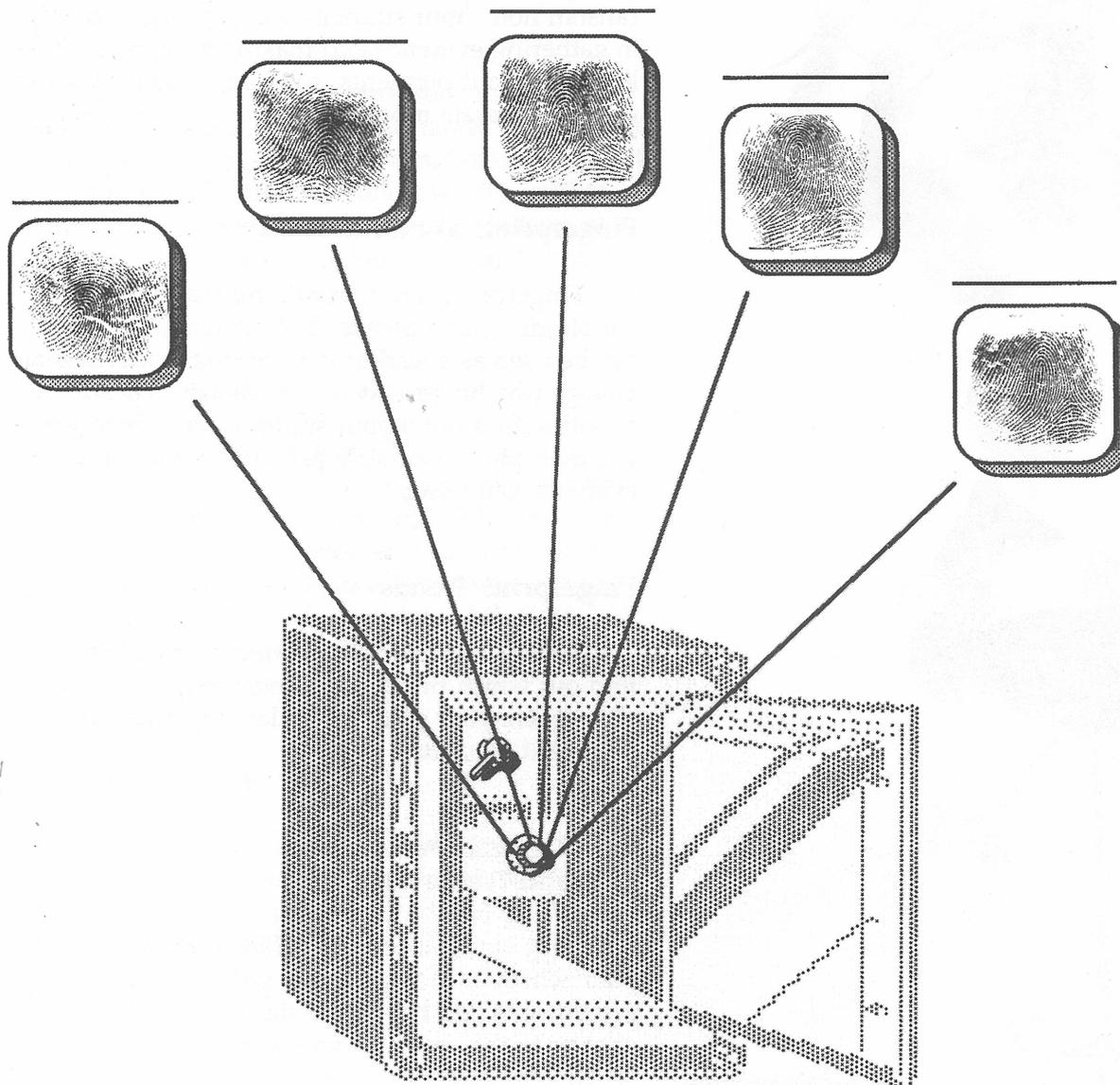
Accountant



Janitor



# Safe with prints





Whorl



Arch



Loop

**Session 2: Teaching and Learning**

**Optional Activities**

**Physics Learning Stations**

**Ice Cube Learning Stations**

**Fingerprinting—Solving the Crime**

**Sand on Stage Model Lesson**

## Session 2: Teaching and Learning

# Physics Learning Stations

## Materials Needed For the Cup & Card Stations

### For the workshop/all stations:

cafeteria trays for materials

### For each participant:

- one copy of “Read and Answer” sheets (on pressure and volume)
- one copy of “The Learning Cycle” sheet (page XX)

### Station A: Open-Ended Exploration (materials for one station)

2 Erlenmeyer flasks, 250 and 500 ml

2 rigid plastic glasses

4-6 flexible plastic cups (squat Solo type)

~25 pennies

1 dish tub filled with water

4-6 plastic coated 3 x 5 cards

1 copy of Station A Instructions

### Station B: Structured Activity (materials for one station)

50 ml graduated cylinders

4-6 flexible plastic cups (squat Solo type)

~25 pennies

1 dish tub filled with water

4 plastic coated 3 x 5 cards

4-6 graduated cylinders (50 ml)

3 rulers

1 copy of Station B Instructions

### Station C: Problem-Solving Challenge/Application (for one station)

4-6 flexible plastic cups (squat Solo type)

~25 pennies

1 dish tub filled with water

4 plastic coated cards

50 ml dropper bottle of liquid soap (diluted)

4 graduated cylinders (50 ml)

1 copy of Station C Instructions

### Station D: Read & Answer Station (materials for one station)

Reading excerpted from textbook on Pressure/Volume relationship

## Session 2: Teaching and Learning

### Preparation for the Physics Stations:

**1. Copy station signs.** Make enough signs to have one for each station you are setting up.

**2. Make copies for each participant and set aside:**

- one copy of “Read and Answer” sheets
- one copy of “The Learning Cycle” sheet

**3. Make copies for each two participants:**

- “Structured Activity” sheet for Station B

**4. Make a wall chart list of station titles.**

Write the following list of the stations in large lettering on chart paper or a chalkboard to refer to throughout the session:

- A - Open-ended Investigation
- B - Structured Activity
- C - Problem-Solving Challenge
- D - Read and Answer

Before participants go to the stations, demonstrate the Cup & Card phenomenon.

Fill a solo cup halfway with water. Place a piece of plastic coated cardstock on top of the cup. While holding the card tightly against the cup, turn the cup upside down. Ask the participants what they think will happen when you remove your hand from the card.

Do it—it will remain suspended. Tell them that they will be exploring this same phenomenon in different ways, at each of the stations you’ve prepared for them.

Session 2: Teaching and Learning

## **Physics—Station Instructions**

### **Open-Ended Investigation**

Find out everything you can about the inverted cup with water and card shown below.

### **Structured Activity**

Follow the instructions on the “Exploring Pressure” activity sheet and answer the questions.

### **Problem-Solving Challenge**

Design an experiment that explains why the card remains suspended upon inverting the cup with water.

### **Read & Answer**

Read the text provided and answer the questions that follow.

## Session 2: Teaching and Learning

## Physics - Structured Activity Handout

### Exploring Pressure

**Procedure:**

1. Measure 200 ml of water and add into a cup.
2. Add 5 pennies to the cup with water.
3. Place a card on top of the cup and invert the cup while holding the card in place. Release the card.

**Task:** Add more pennies to the cup to try to find the maximum number of pennies that the card will support (along with 200 ml of water). Make sure to count the number of pennies that can be added until the card no longer stays up.

Total number of pennies added to cup = \_\_\_\_\_

4. Using the data from the previous task, along with following information, determine the maximum pressure supported by the card for 200ml of water and the total number of pennies added.

$P_T$  (total pressure) =  $\square$  (pressure from pennies + pressure from water)

Pressure is determined by the amount of force per unit area :

$P$  (pressure) =  $F/A$  so,

$P_T$  = force from pennies / area of cup opening  
+ force from water / area of cup opening

The downward force of an object is determined by its mass and the acceleration due to gravity:

$$F = mg.$$

( $g = 9.8 \text{ m/sec}$ , the mass of one penny is 2.5 g, the mass of 1 ml water is 1g)

The area of a circle is  $A = \square r^2$

Total pressure supported by the card = \_\_\_\_\_

5. What is the difference between the downward pressure exerted by the pennies & water and the external air pressure?

## Session 2: Teaching and Learning

**Physics - Read and Answer handout****Gas Behavior: Pressure and Volume**

A gas is a collection of particles that move independently and fill a volume containing mostly empty space. Of the three physical states of matter, gases are the only state that has indefinite shape and volume. A gas can fill a container of any shape and expand or compress to different volumes.

Under ideal conditions, the behavior of gases can be predicted since a small set of physical properties describe a gas. These four properties or variables of a gas are: pressure, temperature, volume, and amount (or number of moles). In fact, these four variables can be combined into one law describing a gas, the Ideal Gas Law. If two of these variables are held constant, the relationship between the other two is easily discerned.

With a constant amount of gas and temperature, the pressure (P) and volume (V) have a well-defined relationship. If a fixed amount of gas is held at constant temperature, the volume is inversely proportional to the pressure. This is *Boyle's Law*. Stated mathematically:

$$PV = \text{constant}$$

or

at constant amount and temperature

$$V = \text{constant}/P$$

In other words, if the pressure of a gas is doubled, the volume is halved.

Robert Boyle derived this law from pressure and volume measurements on gases. Boyle first performed these quantitative experiments in 1661. Using a J-shaped tube sealed at one end, he added liquid mercury to the open end until the mercury level was the same on both sides of the J. The enclosed gas was then at atmospheric pressure (1 atm or 760 mm Hg). Addition of 760 mm of Hg to the open end doubled the pressure, and the volume of the enclosed gas decreased by half. Another addition of 760 mm Hg, tripling the pressure from the original pressure, decreased the gas volume to one-third of the original volume. From his results, Boyle concluded that in general the volume of a gas was inversely proportional to the pressure—Boyle's Law.

**Questions:**

- (1) Two properties of a gas are indefinite shape and volume. Give an example that demonstrates each.
  
- (2) State Boyle's Law. Be specific about the variables held constant.
  
- (3) In Boyle's experiments with the J-shaped tube, determine the pressure of the enclosed gas when the volume was one-third of the original volume.

## Session 2: Teaching and Learning

# Ice Cube Learning Stations

## Materials Needed

### For the Ice Cube Activity Stations

(The materials here are for approximately 20 participants with one set-up of each of the four stations with up to 5 participants per station.)

#### For the session/all stations:

- ❑ 4 cafeteria trays (or cookie sheets) to carry station materials

#### For each participant:

- ❑ one copy of "Read and Answer" sheets for Station B
- ❑ one copy of "Structured Activity" sheet for Station D
- ❑ one copy of "The Learning Cycle" sheet
- ❑ one copy of "Mystery Water – What Happened and Why" sheet

#### For the entire group:

- ❑ ice cubes
- ❑ 3 pitchers of tap water
- ❑ 3 pitcher of salt water
- ❑ paper towels
- ❑ kosher salt
- ❑ stir stick or spoon

#### For Station A, Open-Ended Investigation (materials needed to set up one station):

- ❑ 2 identical approx. 12 ounce clear containers (plastic cups or beakers)
- ❑ 1 large sheet of paper (a piece of flip chart paper works well)
- ❑ food coloring (any dark color – red, blue, dark green, not yellow)
- ❑ small plastic bag or bowl to contain ice cubes
- ❑ 1 sponge
- ❑ small tub to dispose of used water
- ❑ small plastic bag containing kosher salt
- ❑ spoon (to use with the salt)
- ❑ pitcher of fresh water (labeled "fresh water")
- ❑ pitcher of salt water (labeled "salt water" and prepared the day before)
- ❑ 1 copy of the Station A sign
- ❑ 1 copy of Station A directions
- ❑ 2 thermometers
- ❑ miscellaneous "sink and float" objects including marbles, blocks, crayons, paperclips

## Session 2: Teaching and Learning

### **For Station B, Structured Activity (materials needed to set up one station):**

- ❑ 2 identical approx. 12 ounce clear containers (plastic cups or beakers); one labeled “salt water,” the other labeled “fresh water.”
- ❑ 1 large sheet of paper (a piece of flip chart paper works well)
- ❑ food coloring (any dark color – red, blue, dark green, not yellow)
- ❑ small plastic bag or bowl to contain ice cubes
- ❑ 1 sponge
- ❑ small tub to dispose of used water
- ❑ pitcher of fresh water (labeled “fresh water”)
- ❑ pitcher of salt water (labeled “salt water” and prepared the day before)
- ❑ 1 copy for each participant of the Station B instructions
- ❑ 1 copy of the Station B sign

### **For Station C, challenge/application (materials needed to set up one station):**

- ❑ 2 identical approx. 12 ounce clear containers (plastic cups or beakers)
- ❑ 1 large sheet of paper (a piece of flip chart paper works well)
- ❑ food coloring (any dark color – red, blue, dark green, not yellow)
- ❑ small plastic bag or bowl to contain ice cubes
- ❑ 1 sponge
- ❑ small tub to dispose of used water
- ❑ 1 pitcher fresh water (labeled A; otherwise unlabeled)
- ❑ 1 pitcher salt water (labeled B; otherwise unlabeled)
- ❑ 2 thermometers
- ❑ miscellaneous “sink and float” objects including marbles, blocks, crayons, paperclips
- ❑ 1 copy of Station C directions
- ❑ 1 copy of the Station C sign

### **For Station D, Read & Answer:**

- ❑ 1 copy for each participant of the “Read and Answer” sheets
- ❑ 1 copy of the Station D sign

## Session 2: Teaching and Learning

### Preparation Before the Session

#### Ice Cube Activity Stations:

- 1. Copy station signs.** Make enough signs to have one for each station you are setting up. You might want to laminate the station signs because they are likely to get wet.
- 2. Make copies for each participant and set aside:**
  - one copy of “Structured Activity” sheet
  - one copy of “Read and Answer” sheets
  - one copy of The Learning Cycle and the Sand Activity
  - one copy of “The Learning Cycle” sheet
  - one copy of “Mystery Water – What Happened and Why” sheet

- 3. Make a wall chart list of station titles.**

Write the following list of the stations in large lettering on chart paper or a chalkboard to refer to throughout the session:

- A — Open-ended Exploration
- B — Structured Activity
- C — Problem-Solving Challenge/ Application
- D — Read and Answer

- 4. Prepare salt water solution:**

Add 11 tablespoons of kosher salt to 1 gallon of fresh water. Allow the solution to sit until water is no longer turbid. Use this solution for all stations of the activity. This makes a solution of about 40 ppm (a salinity that ensures that food coloring density isn't a factor in the saltwater part of the experiment and makes the visual impact more dramatic.)

### Preparation on the Day of the Session

#### Set up the stations

Set up the four stations by putting the materials (described under “What You Need” above) on a tray, with the instructions for that station. You will need to set up duplicate sets of these stations if you have more than 20 participants. The four stations are: Open-Ended Investigation; Structured Activity; Problem-Solving Challenge/ Application; and Read and Answer.

# Station A

## Open-ended Investigation

**Examine the materials on the tray. Using only those materials, devise investigations you can perform to learn as much as you can about:**

- **the characteristics of warmer vs. cooler water.**
- **the characteristics of salty vs. fresh water.**
- **the relative densities of different temperatures and salinities of water.**
- **density-driven currents in the ocean.**

**And remember, this is a science classroom—no tasting!**

# Station B

# Structured Activity

**Follow the procedures described on the worksheet provided. You may work as a group to conduct the activity and to arrive at your answers.**

## Instructions and Worksheet for Station B – Structured Activity

1. Find two cups of water on the table. One is labeled “salt water,” the other is labeled “fresh water.”
2. If you place the same number of ice cubes in each cup at the same time, which do you predict will melt the fastest?

Why?

3. Now place two ice cubes in each cup of water. Observe both cups for 90 seconds. Do not stir or disturb the ice cubes or take them out of the water. Allow them to continue to melt in the cup as you complete this station.

4. Observe the ice cubes in the cup. Which ice cubes melted the fastest? (Look from the side and from the top of the cup.)

5. Do you have any further explanation to match your evidence?

6. Gently add 2 drops of food coloring to each cup right on top of the ice cube without stirring or otherwise disturbing the water. Describe your observations.

7. Explain what you think is happening.

# Station C

## Problem-Solving Challenge

**There are two beakers of water on the table. One contains salt water, the other fresh water.**

**Using only the materials at the table, devise an investigation that you can perform right now to find out which is the salt water.**

**Record your experiment (design, procedures) and the results. Describe the evidence that you collect and how it supports your determination of which is the salt water.**

**Oh, and by the way, no tasting allowed!**

# Station D

# Read and Answer

**Read the information sheet  
and answer the questions.**

## Reading for Station D

### Water Density, Ocean Stratification and Density-Driven Circulation

Density is a property of all substances and is the ratio of the mass of a substance to its volume: **density = mass / volume**. In aquatic systems water density plays an important role in structuring the environment and in determining how water moves.

#### Pure Water

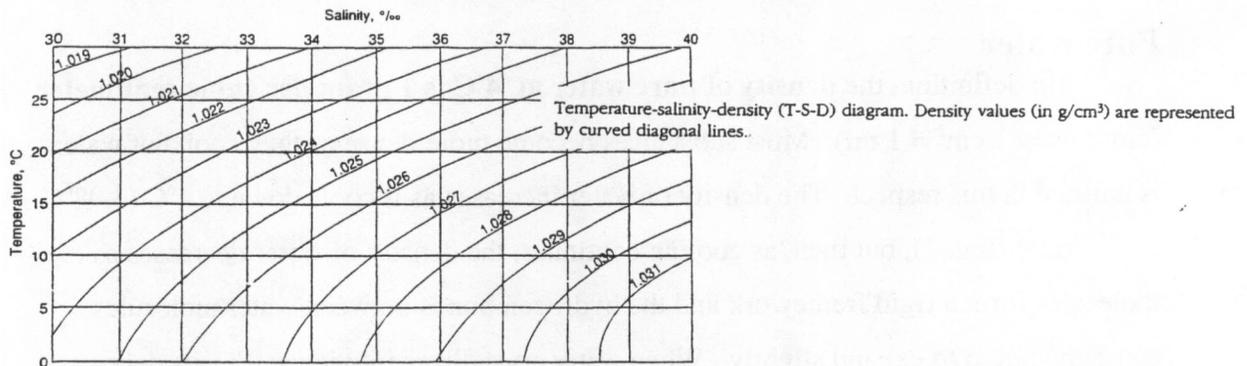
By definition, the **density of pure water at 4°C is 1 gram per cubic centimeter** ( $\text{cm}^3$ ; note:  $1 \text{ cm}^3 = 1 \text{ ml}$ ). Most substances become more dense as they cool, but water is unusual in this respect. The density of water increases as it cools down to 4°C (3.98°C, to be exact), but then, as cooling continues, the density of water decreases as the molecules form a rigid framework and the hydrogen bonds between water molecules cause the liquid to expand slightly. When water crystallizes into ice at 0°C, its density decreases abruptly. Ice is less dense than an equal volume of water. As ice cools below 0°C its density increases, but no matter how cold ice becomes its density never reaches the density of liquid water. Since ice is less dense than water, ice “freezes over” as a floating layer instead of “freezing under” or freezing from the bottom like almost all other liquids.

#### Seawater

Seawater is a solution of pure water and dissolved materials. A liter of seawater weighs between 2% and 3% more than a liter of pure water. Most of materials dissolved in seawater are ions (positively or negatively charged atoms and molecules) that combine into salts when the water is evaporated. **Salinity** is the total grams of salts in 1,000 grams of seawater, and salinity is commonly expressed in terms of **parts** (of salts) **per thousand** (parts of seawater). For example, ocean water which has 35 g of salts dissolved in 1000 g of seawater has a salinity 35 parts per thousand or 35‰. (Note: Scientists now express salinity as a conductivity ratio using the Practical Salinity Scale, but this change does not need to be considered in this discussion of salinity and water density.)

## Session 2: Teaching and Learning

**The density of seawater is determined by salinity and temperature.** Seawater density increases as salinity increases and/or temperature decreases (Fig 2).



## Ocean Stratification and Density-driven Circulation

Ocean water tends to form into stable layers with the least dense water at the surface and the most dense water on the bottom. This phenomenon is called **density stratification**. In the open ocean, salinity does not vary to a great extent, and density stratification is determined primarily by temperature. In coastal areas and bays, in contrast, salinity can vary significantly due to inputs of freshwater from rivers and land run-off, and density stratification may be determined primarily by salinity. The greater the difference in density between the surface and bottom waters the more stable the water column is and the harder it is to mix surface water down to depth or deep water up to the surface.

Density differences between water masses drive deep-ocean currents. In some regions of the ocean dense water masses form at the surface (e.g. polar regions like the Norwegian Sea and Weddell Sea, or enclosed regions like the Mediterranean Sea). These dense water masses sink and displace less dense water underneath. This density-driven circulation is called **thermohaline circulation** (“therme” = heat; “halos” = salt). Virtually the entire world ocean is involved in thermohaline circulation, a slow process that is responsible for most of the vertical movement of water in the ocean and for the circulation of the world ocean as a whole.



**Session 2: Teaching and Learning**

**Use Fig. 2 (in the reading) to solve these problems:**

**6. DATA** (these measurements were made in the vicinity of the Straits of Gibraltar)

	<u>Temperature</u> (°C)	<u>Salinity</u> (‰)	<u>Density</u> (g/cm <sup>3</sup> )
Mediterranean Sea	18	39	_____
Atlantic Ocean	20	36	_____

- Determine the densities of Mediterranean Sea water and Atlantic Ocean water.
- How will water from the Mediterranean Sea behave when it flows into the Atlantic Ocean at the Straits of Gibraltar?

**7. DATA**

	<u>Temperature</u> (°C)	<u>Salinity</u> (‰)	<u>Density</u> (g/cm <sup>3</sup> )
Yukon River (AK)	4	_____	_____
Bering Sea	9	33	_____

- Determine the densities of Yukon River water and Bering Sea water. What assumptions (if any) do you have to make?
- How will water from the Yukon River behave when it flows into the Bering Sea?

**8. Can you think of any factors in addition to temperature and salinity that might affect the density of seawater?**

## “Mystery Water” – What Happened and Why?

Ice melts faster in fresh water than in salt water.

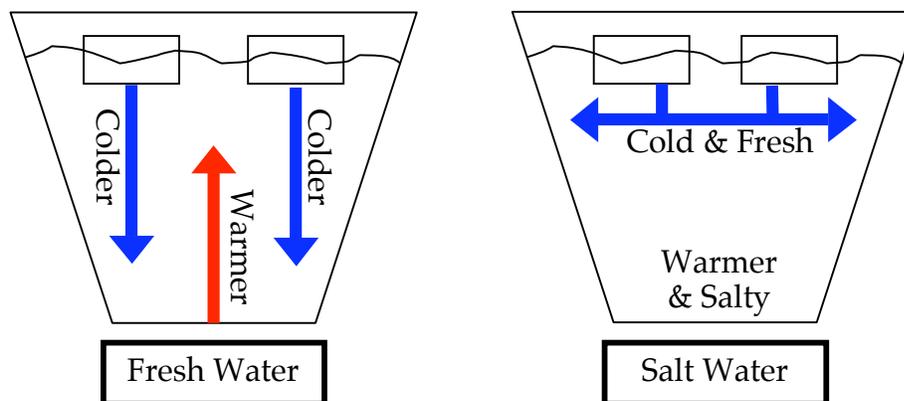
It’s all about density!

### 1. What happens when ice melts in fresh water at room temperature?

- Water from melting ice is cold and fresh. It is more dense than fresh water at room temperature (REMEMBER: Water density decreases as *temperature* increases.)
- The denser cold water from the melting ice sinks to the bottom of the cup. That’s why you saw the food coloring sink to the bottom of the cup.
- When the dense cold water sinks to the bottom of the cup, it displaces water at the bottom of the cup. The room-temperature water at the bottom of the cup has to go somewhere when it is pushed out of the way by the sinking cold water. The displaced room-temperature water from the bottom of the cup moves up toward the surface. You saw that the food coloring was eventually mixed throughout the cup just by the movement of dense cold water sinking and room-temperature water being displaced.
- The result of this mixing process is that the ice is always being surrounded by new room-temperature water as the dense cold water sinks and less dense room-temperature water is pushed upward. Therefore, ice melts faster in fresh water.

### 2. What happens when ice melts in salt water at room temperature?

- Water from melting ice is cold and fresh. Fresh water is always less dense than salt water no matter what the water temperature is. (REMEMBER: Water density decreases as *salinity* decreases.)
- Since the cold water from the melting ice is less dense than the salt water, it floats on the top of the salt water. That’s why you saw the food coloring form a layer at the top of the cup.
- The layer of cold water from the melting ice “insulates” the ice. In other words, the cold, fresh water from the melting ice helps keep the ice cold. Therefore, the ice melts more slowly in salt water.



## Session 2: Teaching and Learning

## Fingerprinting— Solving the Crime

The students solve a mystery by using the standard classification system they've just learned. They are given the suspect's fingerprints, the formula of the fingerprints found at the scene of the crime, and copies of the actual prints.

### What You Need

#### For each student:

"Suspects" student sheet (master included following page 36)

"Safe with Prints" (master included following page 36)

1 pencil

1 magnifying lens

### Who Robbed the Safe?

1. Tell the students to imagine that a crime has been committed. It's time to use what they have learned about fingerprints to try to solve the crime. Explain that a safe has been robbed. The safe is in the office of the president of a big company, and was found early this morning open and empty. The theft was discovered by the night security guard. The guard called the police immediately. There are five suspects:

- *Barbie Brilliant*, the president of the company, is in debt, owing money to many people.
- *Stewart Starr*, the vice-president, has been trying to take over control of the company.
- *Peter Page*, the secretary, was recently fired unfairly. He left without returning the keys to the building.
- *Ned Numbers*, the accountant, has three cars, a big house, and lives very luxuriously.
- *Carla Clean*, the janitor, was recently injured on the job and wasn't given any days off to recuperate. She is very angry about this.

2. Hold up a copy of the "Suspects" sheet. Tell students that these are the fingerprints of the suspects' right hands. The fingerprints found on the safe were from a right hand. Explain that when the police first investigate evidence, they narrow down the number of suspects by comparing the suspects' fingerprint formulas to the formula of prints found as evidence.

3. Tell your students that their first task will be to find the fingerprint formulas of the five suspects. You will give them the formula of the prints found on the safe after they have figured out the fingerprint formula of each suspect. This serves as a review and practice of the standard classification system. There are examples of the categories at the top of the data sheet, for those students who have forgotten what they look like. [Two of the formulas match the fingerprint formula on the safe.]

## Session 2: Teaching and Learning

4. Distribute a “Suspects” sheet to each student and have them begin. Answer questions about the classifications and help students determine the fingerprint formulas.
5. After all the students have figured out the suspects’ fingerprint formulas, reveal the fingerprint formula of the prints found on the safe: l-a-l-w-l (thumb to pinkie), or loop, arch, loop, whorl, loop.
6. Let students speculate on “who done it.” Ask which suspects they can now eliminate, based on this evidence.
7. Now distribute the “Safe with Prints” sheet.
8. Ask the students to decide whose prints are on the safe. (They will be making a one-to-one comparison of the prints and will probably be able to do this very quickly.) Ask students who finish early to determine whether they have the same fingerprint formula as the one that appeared on the safe.

### Discussing the Evidence

1. Ask students to tell you which of the suspects has prints that match those on the safe. Also ask them to give you reasons why they think that the others do not match. Encourage very specific answers. Some teachers have had their students write a description of the evidence and what led them to think it was a certain suspect’s prints on the safe.
2. After the students have decided whose prints are on the safe, ask whether or not these prints might normally be on the safe, or if finding the prints proves that the suspect they identified robbed the safe. One of the goals of this series of activities is to let students gather evidence and draw conclusions from the evidence. Who actually robbed the safe is less important than the *process* your students use to arrive at their conclusions. (By the way, it was the accountant’s prints that were found on the safe, but we still don’t know who robbed the safe. While the accountant may have needed the money, there are lots of legitimate reasons why his fingerprints might be on the safe!)
3. Ask the students if there are any other techniques they can think of that they, as detectives, could use to help solve this crime.

## Session 2: Teaching and Learning

# Sand On Stage Model Lesson

## Modeling a Learning Cycle-Based Lesson

*Note:* Following are instructions for presenting a portion of the MARE/GEMS activity *Sand on Stage* (from the GEMS teacher's guide *On Sandy Shores*). Be sure to give enough time for your students to experience at least a sense of what elementary students would experience in classroom presentation, and to get a feel for the overall flow of the lesson, but keep in mind the 40-minute time frame for the activity. It's okay to abbreviate and shortcut certain portions, once the participants understand what's intended to happen with students.

### Start the Model Lesson

Tell participants you'll be presenting a lesson that embodies the learning cycle. At the conclusion of the lesson, you'd like them to share their ideas of how the different phases of the learning cycle relate to this lesson.

### Introducing the Activity

1. Lead participants in a short discussion of **sand** by asking:

- "Where are some of the places you can find sand?"
- "What are some ways we can use sand?"
- "How might sand be made?"
- "How does sand get onto the beach?"

2. Tell your students that they will become *sand scientists* (arenologists) in this unit to see if they can learn something about sand by making some close observations. To do this, they will first need to select a sand to learn more about and make a sand sample.

1. Show the students how to make a sand sample:

- a. Choose a small ziplock bag of sand.
- b. Select an index card and place a quarter-sized smear of white glue in the center of the card. If the chosen sand is dark in color, choose a white card. If the sand is light in color, choose a colored card.
- c. Carefully open the ziplock bag of sand and sprinkle a pinch or two of sand onto the glue. Completely close the ziplock bag when finished.
- d. Finally, write the location of your sand below your sand sample on the card. Be careful not to smear your still-wet sand sample.

## Session 2: Teaching and Learning

2. Pass out Sand on Stage datasheets to each student (see master following page 63)
3. Inform students that they will each be exploring and learning more about the sand of which they just made a sample.

### Making Observations

1. Give each student a *Sand on Stage* data sheet. Have them take a close look at their own sand sample with a hand lens, and write down or show with colored crayons or markers all the different individual colors that they see.

*Note:* Your college students will be able to go through the activities on their own with simple directions from the teacher. With younger students, going through the student sheet together with the teacher asking guiding questions will help students to work together and complete each observation task successfully.

2. Have students pass their own card to the person on their right and look at the sample the person on their left passes to them. Encourage students to especially notice the colors of the different sands. Have them keep passing the cards around the circle, looking at each, until they have their own card back. What are some reasons for sand being different colors? (dark sands are often volcanic in origin, light sands can be made of shells, corals or of quartz from granite mountains.)
3. Have each team categorize their sands into color groups of their own choosing. Are there some samples which are difficult to categorize? Why?
4. Now, have each group sequence the samples in a line on their table from darkest to lightest and record their results on their worksheets.
5. The next few tasks take some extra concentration, so tell students to help their fellow team mates. Have students look again at their slide through a hand lens (or a microscope). This time look specifically at the shape of individual grains. Have students draw several large examples of the exact shape of their grains on their worksheet. Why are some grains smooth and others bumpy? (Very round grains have been worn smooth for hundreds or thousands of years, while angular grains may have broken off a rock or shell quite recently.) Have students compare their grains to those shown on their worksheet. Is their sand smooth (very old) or angular (very young?)
6. Have each group sequence their sand cards again, this time from the smallest grains to the largest grains. Have them record their results on the worksheet. Students can now measure the size of their grains by comparing them to the size chart. Have them record their findings.

## Session 2: Teaching and Learning

7. Ask the students to imagine they are a very tiny sand grain, about the size of the smallest grain in their group's samples. What might happen to them if they were hit by a large wave or were in a fast rushing river? Do they think they would be able to stay in one place? What about if they were one of the larger grains? [They might stay put because they are heavier.] What could the size of the sand grain tell you about the kind of place your sand sample was from? [If their grains are very small, they were probably from an area with slow moving water such as a protected bay beach or a pool in a slow moving stream. Tiny particles can stay put only where the water is moving slowly and gently. Large waves or fast water pick up small grains and carry them away down the river or off the beach and out to the ocean. If their sand has mainly large grains, it was probably from a wave-tossed beach where the rough water carried all the smaller grains away. Only the larger grains were not picked up by the waves.]

8. Have students drag a magnet along the outside of their sand sample bag. Are any grains moving inside the bag? If so, this is evidence that the sand contains some magnetic minerals, such as iron or magnetite. What color is the magnetic sand? Students record their results.

9. What are the sand grains made of? small rocks? shells? wood? glass? plant material? How do they get broken up into tiny sand grains?

10. Give each group a rock and/or mineral kit. Have students compare their sand grains to the kit. Can they make any guesses about what types of rocks or minerals could have been broken down to become their sand?

11. Explain that sand is almost always in constant motion, and that the sand grains on a beach one day, might be entirely replaced by others in a few weeks. One way that sand moves is by the wind. Place a little sand in a tray, box lid, or shoe box and give each student a chance to gently blow on it for five seconds or so. The wind blows almost all the time at the beach. What effect does this have on beach and dune sand? [The "wind" separates or sorts the small grains from the larger ones.]

12. Have students look at their own sand sample now. If all the grains are roughly the same size, they may have come from a windy beach. If the sample is "mixed" in size, then it may have been from a beach with very little wind. Can they make a guess about whether or not their sand came from a windy place?

### The Experts Meet

1. Now have students with the same type of sand meet together in "expert groups." They can compare their answers on their student sheets and discuss any discrepancies.

2. As they finish, ask them to imagine the beach their sand came from. What does it look like? Is it a sunny warm place with tropical animals or a cold one? Where did the sand come from? A coral reef? A mountain? A lava flow? Clam and mussel shells? Is the sand very old or very young? What **evidence** do they have for each inference?

## Session 2: Teaching and Learning

3. If appropriate, have each student in the new teams complete the Expert Team student sheet (masters following page 63).
4. Have students each draw a picture of what their beach looks like. Have them label their drawings with the name of where the sand came from. Post the student art around the room next to the sand sample it illustrates. Students can present to the class their drawings and evidence.
5. Discuss with students why sand is important to people. It creates fun and beautiful places for us to walk and play. It is an important home to many, many plants and animals. Many things that we use are made from sand. What are some items made from sand? (It is important for oil and cement production. Glass is made from melted and reformed sand. Sand is used for sandblasting, sandpaper, and of course, in playgrounds and sandboxes.) If it wasn't for sand, we might not have paved streets, tall buildings, concrete sidewalks or glass windows.
6. Hold up the Key Concepts for one or more students to read aloud. Post it near your sand table or sand display for students to refer to later.
  - Sand grains can be made of animals, plants, rocks, or minerals.
  - Sand grains come in many different shapes, sizes, and colors.
  - Differences between sand grains can be clues about where the sand came from and how it got to the beach.

## Debriefing the Learning Cycle-Based Lesson

1. Ask participants to note the stages of the learning cycle in the lesson just presented. Following is a suggested outline of the learning cycle stages of *Sand on Stage*.

**Invitation:** Questions to elicit interest and curiosity: "What is sand?" "Where can sand be found?" "How might sand be made?"

**Exploration:** Students make their own sand samples, look at them, notice similarities and differences, then group and answer specific questions based on observations and evidence.

**Concept Introduction:** The process of erosion and transport is introduced.

**Problem-Solving Challenge/Application:** Students meet as "experts" to explore their sand further. Students make inferences based on evidence to depict their sand's origin.

**Session 2: Teaching and Learning**

**Masters Needed for Sand on Stage Activity**

**Sand on Stage! student sheet (2 pages)**

**Expert Group student sheet (2 pages)**

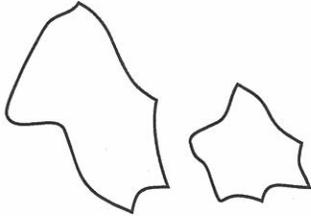
# SAND ON STAGE!

**1.** Look closely at your sand with a magnifier. List or use crayons to show all the different colors you see.

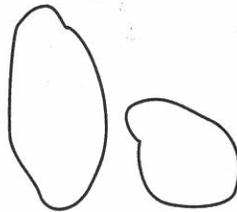
**2.** Draw a picture of some of your sand grains. Draw them BIG!

**3.** Circle the pictures that have shapes like your sand.

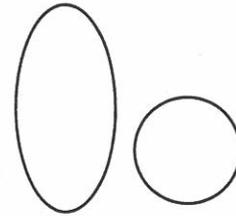
not  
rounded



a little  
rounded



very  
rounded



**4.** Gently rub a magnet on the outside of your bag of sand. Are any of the grains in your sand attracted to the magnet?

If so, what color are the magnetic sand grains?

**5.** Which of the following things can you find in your sand?

- small rocks
- pieces of glass
- pieces of plants
- other things. They are:
- pieces of shells
- pieces of wood
- pieces of plastic

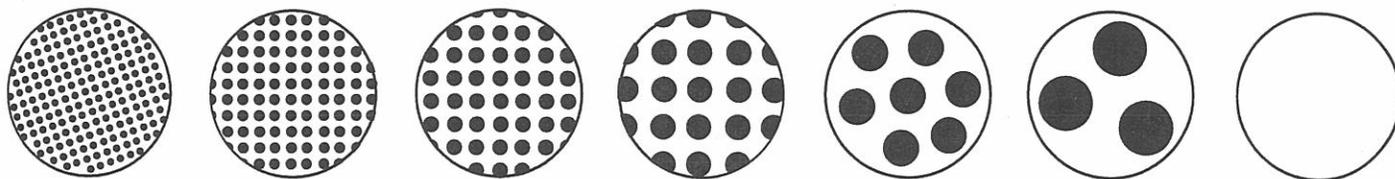
6. Look at the rock kit. Does your sand have pieces of rock that match some in the kit? List the kinds of rocks that may be in your sand.

7. Which sand in your cooperative group is the lightest in color?

Which is the darkest?

Put them in order from lightest to darkest.

8. Compare your sand slide to the size chart below. Imagine that the black dots are grains of sand. Color the group of dots that are about the size of your sand grains. If your sand is not like any of these use the empty circle to draw how yours looks.



Are your grains all about the same size or many different sizes?

9. Which sand in your cooperative group has the biggest grains?

Which has the smallest grains?

Put them in order from smallest to biggest.



• **Part 1:** Draw a picture of where your sand came from (a clam, a mountain, a coral reef, or ?...) before it arrived on the beach.

• **Part 2:** Here's what happened next.

• **Part 3:** Look what happened next!

• My grain of sand now looks like this.

**Session 3: Constructing Understanding**

***Session 3: Constructing Understanding***

**Contents**

<b>Session Overview</b>	2
<b>Background Information for the Presenter</b>	3
<b>Constructivism and Alternate Conceptions</b>	3
<b>Science Content: Moon Phases and Eclipses</b>	7
<b>Materials and Preparation</b>	11
<b>Instructor's Guide</b>	13
<b>Session Handouts</b>	26
<b>Presentation Slides</b> (also in separate PowerPoint)	30
<b>Alternative Activities</b>	41

### **Session 3: Constructing Understanding**

## **Session Overview**

There are different ways to consider learners: as “blank slates” open to learning information as it is transmitted to them; or as having clever minds already full of well-reasoned ideas and private explanations that affect how the learner understands new information.

In this session, participants are presented with evidence to support the latter view—that learners enter the classroom with prior knowledge, beliefs, capabilities, and skills, and that understanding and engaging learners’ mental frameworks is critical to helping them accommodate and generalize their ideas. This session provides information about the persistence of privately held views about particular science concepts and what teachers can do to help learners adjust those frameworks in light of new experiences and information in order to deepen their understanding.

As a light-hearted invitation into the topic, the session begins with an exploration of children’s, often humorous, conceptions about love. This also initiates participants’ exploration of children’s ideas about the world, and how these ideas might evolve. Participants then read research cards about teaching and learning and discuss how instruction can be designed in order to apply each piece of research. Participants then experience an exemplar activity modeling a variety of strategies for dealing with students’ alternate conceptions related to Moon phases. After discussing effective teaching strategies from the exemplar, they view a video that illustrates how students can sometimes incorporate elements of new understandings, but still retain their original conceptions in quite ingenious ways.

Throughout this session, participants learn some basic ideas of constructivism, and begin to envision effective constructivist teaching strategies as applied to the classroom.

### Session 3: Constructing Understanding

## Background Information for Presenter

### Constructivism

Constructivist learning theories have led educators to develop teaching strategies that can help make explicit the connections between new learning and previously learned knowledge, strategies that have been shown to be most effective, over time, in helping learners develop new ideas, deeper understandings, and construct more complete mental frameworks. These strategies engage and motivate the learner with interesting, culturally/socially-relevant activities and experiences that allow them to discover, infer, reflect upon and apply concepts. They also provide opportunities for learners, peers, and educators to engage in meaningful conversations about the experiences and content. In the same spirit, a constructivist approach to learning engenders a view of the educator as a facilitator of learning, rather than simply a transmitter of information. In the words of the Brazilian educator Paulo Freire, “To teach is not *to transfer knowledge* but to create the possibilities for the production or construction of knowledge” and “Liberating education consists in acts of cognition, not transferrals of information.”

Constructivism groups together a number of related learning theories and educational ideas based on the research and practices of educational psychologists, cognitive scientists, and a wide range of educators. It is by no means monolithic, and is no stranger to controversy and debate! With roots in the work of John Dewey, Maria Montessori, Jean Piaget, Lev Vygotsky, Jerome Bruner, and many others, it has branched out in a multitude of directions. Constructivism is now a widely used term in science education circles. The central claims of constructivism are that human knowledge is acquired through a process of active construction; concepts are invented rather than discovered; and learners’ prior knowledge and experiences are important (Duit, 1995). Each of us generates our own “rules” and “mental models,” which we use to make sense of our experiences. Learning, therefore, is perceived as an active process of engaging and manipulating objects (Piaget, 1983), experiences (Dewey, 1938), and conversations (Vygotsky, 1986) in order to construct mental pictures of the world; and is cumulative, iterative, and social. To understand and make sense of their world, individuals transform, organize and relate new information and experiences with those in the past. In this way, learning is a contextualized process of making sense of experiences in terms of prior knowledge within social and physical contexts over time (Rennie & Johnston, 2004).

A learner’s attitude is also important for learning, and thus, engagement and motivation are necessary. The more a learner is interested in a topic, the more they are motivated to remain engaged and learn about it. For example, research and theory in psychology show that people are more able to attend to and grasp the importance of an intrinsic goal for their learning when they feel free to decide for themselves to learn rather than feeling forced to do so (Deci & Ryan, 2000; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004). Learners’ cultural backgrounds are also potentially influential. In short, in supporting learning, it is important that educators understand how learners’ motivations shape their experiences.

### Session 3: Constructing Understanding

Learning is a social activity, and occurs through discourse within social interactions (Vygotsky, 1978). This perspective requires a shift from thinking of learning as something that happens on an individual level, to thinking of learning as a social activity involving people, the things they use, the words they speak, and the actions they take (Rogoff, 1998). From this perspective, knowledge is co-constructed between members in the activity, and knowledgeable adults and peers play important roles in helping less experienced learners make meaning of new experiences. They promote learners' curiosity and persistence, direct learners' attention, structure experiences, support learning attempts, and regulate the complexity and difficulty of levels of information (Bransford, Brown, & Cocking, 2000). It is important to remember that constructing knowledge requires intellectual support. Without guidance, a learner, and children in particular, may not be able to make sense of concepts and potentially leave an interaction with an incomplete or incorrect understanding of an idea (Grandy, 1997; Klahr & Nigam, 2004). A learner's potential—with such guidance—has been called the "zone of proximal development" or zpd (Vygotsky, 1978). The zpd concept addresses how experienced individuals can help less experienced learners extend their learning beyond where they are able to go on their own based on their physical or developmental level. "The zpd is the area between what a person can accomplish on their own, to that which they could achieve with the help of someone more experienced" (Hohenstein & King, 2007).

### Alternate Conceptions

Research shows that the ideas and frameworks students bring into the classroom—even in the earliest grades—are already quite well developed. Humans go through a tremendous amount of learning as infants and young children. On their own, children make generalizations from their direct experience and through social interaction with other young people and adults. They enter school with boundless curiosity and a great thirst to learn more—but they also have devised quite elaborated mental frameworks to try to explain and make sense of what they have already experienced of the world around them.

These frameworks of understanding need to be taken into account as new learning takes place. The *construction* of new understanding results from a combination of prior experience and learning, new experience and information, and readiness to learn. There is a large body of research describing the science concepts that students of different ages bring with them into the classroom. These often mistaken or incomplete ideas are usually called "misconceptions" when they are not accurate. They have also been called "alternate conceptions" to reduce the negative connotations and indicate that they precede more evolved concepts. The term "alternate conceptions" is also used to give more weight and value to the ideas that students have worked out for themselves, which, although they may not be fully accurate, are often complex, and part of an extensive mental framework developed over time.

### **Session 3: Constructing Understanding**

Importantly, research has shown conclusively that such alternate conceptions can be held on to quite stubbornly and creatively! People do not part easily from their established frameworks and previous understandings. When confronted with new experiences and/or data that don't make sense to them, people sometimes still force the new information to conform to their existing framework. To fully achieve new understanding, successive experiences over time are often required, of greater complexity from grade to grade. In science, it is especially helpful to work with substances, phenomena, or models that behave in unexpected (or discrepant) ways that cause students to directly confront their previous interpretations. Reflection upon these discrepant experiences and discussions in which alternate points of view are raised can be instrumental in student development of more accurate conceptions in science.

Studies show the "tenacious nature" of student alternate conceptions, but rather than leading to pessimism about learning, this has led to strong advocacy by educators for more effective teaching strategies that take into account some of the prevalent alternate conceptions identified by researchers and provide students with experiences to help them build more accurate ideas. These methods include active, experiential, "hands-on, minds-on" learning in which students engage in meaningful, relevant activities that allow them to discover, infer, reflect upon, and apply the scientific concepts involved. It is these kinds of experiences that have been shown to be most effective, over time, in helping students acquire new ideas, deeper understandings, and construct more complete mental frameworks. In the same spirit, constructivism views the role of the teacher as a facilitator of learning, rather than simply a transmitter of accurate information. Again, research has shown that it is when students (of all ages!) grapple with alternate ideas raised by their own experiences that concepts are retained and meaningful learning takes place.

Unfortunately, teachers and other educators are often unaware of or give little attention to student ideas. As a result, they do not probe for underlying reasoning or provide sufficient opportunities for active learning. Students may then hold onto their conceptions, even repeating back information given by the teacher in order to pass a test, but not really believing, understanding, or retaining it.

Having an awareness of common alternate conceptions is helpful in many ways. It is not only important in helping a teacher decide where to start with her students, it also can be very useful when assessing student understanding. As a teacher develops questioning strategies to gauge the depth of student comprehension and encourage students to explain their reasoning, it is likely that some of these mistaken ideas may crop up. Having students draw or diagram what they think is going on can also help reveal underlying ideas. Curricula that take such alternate conceptions into account, and provide the teacher with concise research-based information on obstacles their students may encounter, are of course extremely helpful for teachers and students.

### Session 3: Constructing Understanding

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### Session 3: Constructing Understanding

## Science Content: Moon Phases and Eclipses

*The science background information included here is for the presenter, and is not meant to be read aloud to participants. The background information is designed to help presenters respond to participant questions, and be aware of inaccurate ideas that research indicates students may bring to the classroom.*

### Moon Phases and Eclipses

You will likely find that the most useful science background on Moon phases is looking at the actual Moon periodically, and exploring the Moon/ball, Sun/light bulb, Earth/head model yourself. In fact, if participants ask content questions about Moon phases or eclipses, the best response from the presenter is often to tell the participants to “ask the objects,” and attempt to use the model to figure out the answer themselves.

### What are common alternate conceptions about shadows and Moon phases?

It can be difficult for a learner to understand what causes Moon phases if they harbor alternate conceptions about shadows. The following are some common alternate conceptions that students (and many adults) have regarding shadows.

#### Common Alternate conceptions About Shadows

- A shadow is only the dark shape cast by one object on another object.
- It does not include the dark side of the object that is blocking the light. *This is particularly important in understanding Moon phases.*
- It does not include the three-dimensional area behind the dark side of the object.
- Shadows are independent of the objects causing them.
- Shadows are the reflections of objects.
- Shadows are dark light.

#### Common Alternate conceptions About Moon Phases

- The phases of the Moon are caused by the shadow of the Earth on the Moon. *This is the most common alternate conception.*
- The shape of the Moon always appears the same.
- The Moon can be seen only at night.
- The phases of the Moon are caused by clouds.
- The phases of the Moon are caused by the Moon moving into the Sun’s shadow.

### What causes the phases of the Moon?

The Moon *appears* to go through phases. In other words, the amount of the Moon that we can see changes over time in a cyclic period that repeats itself about once a month. (The actual period of this cycle is approximately 29.5 Earth days.) The cause of these phases is the positions of the Sun, Earth, and Moon relative to one another. No matter what phase the Moon is in, HALF of it is ALWAYS lit by the Sun. (Which half is always lit? The half that is facing the Sun.) The reason that the Moon does not always appear half lit to us is because of Earth’s position relative to the Moon and the Sun. As the Moon moves in its orbit, different portions of it appear (to us) to be lit up as we look at it from Earth. This is why we see lunar phases. When the Moon is between the Earth and the Sun, the lit side is facing away from us, and the shaded side is toward the Earth. That’s a new Moon, when we can’t see the Moon. When the Moon has orbited one quarter of the way around the Earth, we see half of it lit by the Sun, and half shaded.

### Session 3: Constructing Understanding

**The important point is that the Moon doesn't change, nor does the amount of the Moon that is lit by the Sun change. The only thing that changes is the position of the Moon relative to the Earth and the Sun. This change in position causes the apparent phases of the Moon.**

#### **What is a Shadow?**

When talking about Moon phases, it's helpful to have a discussion about shadows—what causes them and what is and is not considered a shadow. It is important for learners to understand that a shadow is more than the dark shape cast by one object on another object. A shadow also includes the dark side of the object that is blocking the light. For example, it is the Moon itself that is blocking the sunlight from reaching the portion of the Moon that appears dark. The part of the Moon that appears dark to us from Earth, is said to be in shadow, and that shadow is caused by this part of the Moon's shadow. (One of the most common alternate conceptions about the phases of the Moon is that they are caused by the shadow of the *Earth* on the Moon.) A shadow also includes a third part: the three-dimensional area behind the dark side of the object. This part of a shadow can only be seen if an object, like a finger, is inserted into it. In space, this part of the shadow can be seen when an object like a spaceship is inserted into it.

#### **Does the Moon make its own light?**

The Moon does not make any light of its own light. The Sun lights up one side of the Moon; the other side is dark. When we see the Moon from Earth, we see different amounts of Earth's light side and the dark side, depending on where the Moon is in its orbit around Earth.

#### **Does the Moon rotate? If so, how is it possible that we always see the same side of the Moon from Earth?**

The Moon keeps the same face toward Earth as it orbits the Earth, because over millions of years, it has become "gravitationally locked" with Earth. The pull of gravity between the Earth and Moon has slowed down the Moon's spin to exactly once each time it makes one orbit around Earth. From Earth, it can seem like the Moon is not rotating at all, but if you were on the Moon, you would see the stars go around in the sky once a month, complete with a sunrise and a sunset. The far side of the Moon was not seen until it was photographed by spacecraft.

#### **Is there a dark side of the Moon?**

This term may have arisen in reference to the *far* side of the Moon, which is always the same side, and which is always facing away from the Earth. But actually, the far side of the Moon gets just as much sunshine as the side that faces Earth. There *is* always a dark side of the Moon, just as there's always a dark side of the Earth—that's where it's night time. But, as with Earth, the side that's dark is constantly changing. During a new moon, the far side of the Moon is fully lit by the Sun. Sometimes the part of the Moon that's not directly lit by the Sun is visible. This happens most often just after a new moon, when you can see the full circular shape of the Moon with the crescent shape lit up on one edge by the Sun. The light that makes the darker part of the Moon visible is also from the Sun, but it's Earthshine—sunlight that is reflected off Earth.

### **Session 3: Constructing Understanding**

#### **Why does the Moon appear to change size?**

Since the Moon does not orbit Earth in a perfect circle, its distance from Earth changes slightly. This makes the Moon look slightly different sizes at different times. The difference between the apparent diameter of the Moon at its largest and smallest is about 10 percent. When the Moon is near the horizon, it can seem larger, but this is an illusion. No one is sure why, but the height of the Moon above the horizon, and the other objects that can be seen with the Moon, such as distant trees and hills, affect the way our brains interpret the Moon's size. Even when the Moon looks huge, if you stretch out your arm, the tip of your pinky finger can still easily cover up the Moon.

#### **What causes Eclipses?**

The processes that cause eclipses often are confused with the processes that cause Moon phases. Sometimes the processes that cause eclipses are even confused with the processes that cause day and night. The orbit of the Moon is tilted a little bit from the orbit of Earth around the Sun. This means that during each full moon and each new moon, it is very unlikely that the Sun, Earth, and Moon will be exactly lined up. In the rare cases when they do line up, there is an eclipse.

**What causes Lunar Eclipses?** Lunar eclipses can happen only during a full moon. They occur when the Moon passes through the shadow of Earth. During a total lunar eclipse, the Earth gets in the way of sunlight headed toward the Moon. The full, bright disk of the Moon becomes darkened as Earth blocks its light. It lasts for a few minutes to a few hours, depending on the path of the Moon through Earth's shadow. Lunar eclipses are much easier to see than solar eclipses. If you can see the Moon, you can see the eclipse, so people in that half the world can see lunar eclipses, while people in much smaller parts of the world can see solar eclipses (see below). There are no special safety precautions needed for observing a lunar eclipse (there are for solar eclipses).

**Why does the Moon look orangish or brownish during a Lunar eclipse?** In a total eclipse of the Moon, sunlight passes through the Earth's atmosphere, which filters out most of the blue colored light and also bends or refracts some of this light so that a small fraction of it can reach and illuminate the Moon. The remaining light is a deep red or orange color, and is much dimmer than pure white sunlight. The total eclipse stage of a lunar eclipse is so interesting and beautiful precisely because of the filtering and refracting effect of the Earth's atmosphere. If the Earth had no atmosphere, then the Moon would be completely black during a total eclipse. Instead, the Moon can take on a range of colors from dark brown and red to bright orange and yellow. The exact appearance depends on how much dust and clouds are present in the Earth's atmosphere.

**What causes Solar eclipses?** Solar eclipses can happen during a new Moon when the Moon blocks our view of the Sun. The Moon actually casts a "Moon shadow" on Earth. Only people in the shadow see the eclipse. The sky darkens, bright stars and planets are visible, and the glowing gases around the Sun (the solar corona) become visible (because they are not drowned out by the brightness of the Sun). Birds accustomed to singing at sundown may start to sing during a solar eclipse.

### **Session 3: Constructing Understanding**

Unlike total lunar eclipses, which can be seen from half the Earth (the night side) at a given time, total eclipses of the Sun can be seen only along a narrow “path of totality,” which is, at most, 270 kilometers wide. The path of totality is the shadow of the Moon projected on the Earth’s surface, and it moves from west to east at about 1,700 kilometers per hour. The shadow of the Moon covers only a small portion of Earth, so only people in the right locations can see a totally eclipsed Sun. People in a larger part of Earth can see the Sun partly covered by the Moon. This is a partial eclipse. On most of Earth, the eclipse cannot be seen at all for most people, and it takes, on average, four centuries for a path of totality to touch a given place on the Earth. So avid eclipse watchers typically need to travel to far reaches of the globe.

The next total solar eclipse viewable from the United States will be on August 21, 2017, with the center of the path of totality running through 10 states (Oregon, Idaho, Wyoming, Nebraska, Missouri, Illinois, Kentucky, Tennessee, North Carolina, and South Carolina). The Sun is so bright that it can damage a person’s eyes. This is why one must use the right filters or projection techniques to watch a solar eclipse. Eclipse or not, it is never a good idea to look directly at the Sun for a long period of time.

#### **What is waxing and waning?**

When the lighted part of the Moon—as we see it from Earth—increases each night, the Moon is said to be waxing. When it decreases each night, the Moon is said to be waning. You can also tell if the Moon is waxing or waning without watching it night after night. If the left side of the Moon is dark, the Moon is waxing. If the right side is dark, then it’s waning. (This is the case in the Northern Hemisphere; in the Southern Hemisphere, it’s just the opposite.) Astronomers distinguish among the repeated phases of the Moon by referring to the waxing or waning crescent, half, and gibbous phases.

## Session 3: Constructing Understanding

# Materials and Preparation

## Materials Needed

### For the class:

- "Private Universe" video, can be ordered from Annenberg Media, Learner.org (<http://www.learner.org/catalog/series28.html>) or can be viewed online at: [http://www.learner.org/vod/vod\\_window.html?pid=9](http://www.learner.org/vod/vod_window.html?pid=9)
- 1 overhead transparency or slide of each of the following sheets:
  - "Kids on Love"
  - "Sun Moon Observation Chart"
  - "Strategies for Addressing Student Ideas"
  - "The Learning Cycle"
  - "Aims of Constructivist Science Teaching"
  - "Small Group Discussion Question"
- 1 marker for writing on overhead transparencies
- 1 overhead projector
- 1 lamp socket with plug—no shade
- 1 25-foot extension cord
- 1 40-watt clear light bulb or 1 75-watt clear light bulb

### For each group of 3–5 participants:

- 1 copy of the "Research Cards" (master on page 27)
- 1 envelope

### For each student:

- 1 copy of "Strategies for Addressing Student Ideas" (master on page 28)
- 1 copy of the "Pre-unit 4 Questionnaire, page 1" (master on page 29)
- 1 two-inch polystyrene ball.

*Note: Styrofoam balls will work if painted with white latex or other water-based paint. Just about any other balls will also work, as long as they are opaque.*

- 1 unsharpened pencil to hold polystyrene ball

## Preparation

**1. Get balls and pencils for Moon Phases exemplar.** Get one polystyrene ball and one pencil for each participant. Polystyrene balls may be purchased inexpensively from:

Molecular Model Enterprises  
116 Swift Street  
P.O. Box 250  
Edgerton, WI 53534  
(608) 884-9877

Styrofoam balls will also work if painted with white latex or other water-based paint and have the advantage that participants can stick the balls on the ends of pencils for easy holding.

### Session 3: Constructing Understanding

**2. Prepare Research Card sets.** For each group of 3-5 participants, make one copy of the "Research Cards" sheet (master on page 27). Cut one sheet up and place the set of cards in an envelope. Do the same with the other sheets.

**3. Duplicate questionnaires and handout.** For each participant, make one copy of the "Pre-unit 4 Questionnaire, page 1" (master on page 29) and one copy of "Strategies for Addressing Student Ideas" (master on page 28).

**4. Make overhead transparencies.** You will need one of each of the following transparencies:

- "Kids on Love"
- "Sun Moon Observation Chart"
- "Strategies for Addressing Alternate conceptions"
- "The Learning Cycle"
- "Aims of Constructivist Science Teaching"
- "Small Group Discussion Question"

*Note: Both the "Kids on Love" and the "Strategies for Addressing Student Ideas" transparencies need to be revealed one line at a time. With an overhead projector you can do this with a piece of paper. With a PowerPoint, you will either need to "fly in" each line, or make a separate slide for each line.*

#### 4. Prepare for the Moon Phases exemplar.

**Prepare the room.** Find a room that you can darken completely by drawing curtains or taping black paper over the windows. Use the extension cord to plug in the lamp. Make sure the cord is long enough for the lamp to be placed in the center of the room. Tape the cord down to the floor for safety. Have a box of balls and a bag of pencils on hand to give your participants.

**Test to see which light bulb to use.** Before class, determine which light bulb is best by placing one of them into the socket and darkening the room. Stand about the same distance from the lamp as the participants will stand. Hold a "moon ball" in your hand and move it to one side until you see a crescent. Observe the contrast between dark and light sides of the ball, then change the bulb and again observe the contrast. Brighter light bulbs usually provide more contrast if you have a large room, or if there is some light coming into the room from outside. Dimmer bulbs provide greater contrast in smaller rooms with white walls.

## Session 3: Constructing Understanding

# Instructor's Guide

## Session Objectives

In this session, participants gain evidence for the following research-based viewpoints:

- learning is an active process of engaging and manipulating objects, experiences, and conversations in order to construct a mental picture of the world.
- learners come to learning experiences with preconceived ideas and explanations for things, and these mental frameworks affect how they assimilate new information.
- alternate conceptions come from intelligence and are often impressively reasoned (even when inaccurate); these alternate conceptions are born of an irrepressible need that humans have to make sense of the world and are the product of not having all the experiences and information that are needed to construct more accurate explanations.
- mental frameworks (sometimes incorrect) can be quite persistent and resistant to change.
- uncovering student ideas is very valuable for teachers so they can more effectively design experiences to challenge inaccurate ideas and build new understandings.
- uncovering student ideas is very valuable for students, so they can connect new knowledge to what they already know, and actively build their own mental frameworks.
  - social and cultural interactions with peers and educators (or with novice and experienced individuals) are necessary for the construction of knowledge to take place.

Participants will also:

- learn a variety of strategies that research has shown to be effective in helping learners build and modify their understandings.
- gain a working knowledge of a constructivist approach to learning and teaching.
- reflect on their own ideas about teaching/learning and/or scientific conceptual understanding.

**Time Frame:** Total Workshop: 2 hours

Kids Ideas on Love (10 minutes)

Introducing Constructivism (20 minutes)

Exemplar: Modeling a Constructivist Approach to Teaching Moon Phases (40 minutes total)

    Questionnaire & Observing the Moon (10 minutes)

    Modeling Moon Phases (15 minutes)

    Modeling Lunar and Solar Eclipses (5 minutes)

    Discussing Moon Phase explanations (10 minutes)

Debriefing the Moon Phases Exemplar Experience (10 minutes)

Watching and Discussing *A Private Universe* Video (30 minutes)

Strategies for Addressing Students' Ideas (5 minutes)

Constructivist Goals, and Individual Quick Write (5 minutes)

### Session 3: Constructing Understanding

#### Session Activities at a Glance

**Kids on Love.** This session begins with humorous quotes from young children describing their understandings of love. This serves as an engaging “hook,” and inspires a brief discussion that encourages participants to think about how people learn and change their ideas. This leads them into bringing up some basic tenets of constructivism and serves as a segue into the main lesson.

**Introducing Constructivism.** In small groups, participants read aloud research cards, each of which contains a piece of relevant information from research on how people learn, and how classroom teaching is structured. For each piece of information, they discuss how classroom teaching might be better structured taking this piece of research information into account.

**Exemplar: Modeling a Constructivist Approach to Teaching Moon Phases and Eclipses.** They participate in an active modeling activity on the phases of the Moon. Activities from the GEMS *Space Science Core Curriculum Sequence, (Unit 4: Moon Phases and Eclipses)* are modeled to illustrate several strategies for uncovering students ideas and helping them examine and either change or reinforce those ideas. The first strategy is a questionnaire that probes for students’ initial ideas about Moon phases, followed by students making Moon observations, performing shadow explorations, using a model to explore Moon phases and eclipses, and finally a discussion about different explanations for Moon phases. These activities are directly related to the video participants are shown later in the session.

**Debriefing the Moon Phases Exemplar Experience.** Participants brainstorm strategies from the exemplar lesson and from their own experiences that can help find out children’s ideas, and may help deal with alternate conceptions.

**Watching and Discussing *A Private Universe* Video.** Participants then watch and discuss a 20-minute video, *A Private Universe*, which features interviews of university graduates and faculty, as well as high school students who are asked to explain the phases of the moon and the seasons. The video shows how students can be taught a seemingly effective lesson on a topic—and even perform well on a test—while still retaining, in full or in part, their previous alternate conceptions. The video also shows the effectiveness of hands-on, minds-on experiences in developing these complex concepts more fully and overcoming persistent misunderstandings.

**Strategies for Addressing Students’ Ideas.** After discussing the video, participants are presented with methods and strategies for addressing students’ inaccurate scientific ideas, and are offered some further approaches to setting up effective learning situations. They discuss how these ideas fit in with the learning cycle model highlighted in the previous session.

**Constructivist Goals, and Individual Quick Write.** After sharing an overhead about goals of constructivist science teaching, each participant does a quick write on how the session has affected their ideas about teaching and learning.

### Session 3: Constructing Understanding

## Introduce Session

### Discussing Kids' Ideas on Love

(Alternative introductory activity, "Fish is Fish," see page 42)

**1. Display slides titled "Kids on Love."** Tell participants you're going to show them some responses children gave to an interviewer asking about their understanding of love. Unveil each response one at a time, as you read the questions aloud.

<b>Kids on Love</b>
<p>WHAT IS THE PROPER AGE TO GET MARRIED:</p> <ul style="list-style-type: none"><li>• "Eighty-four! Because at that age, you don't have to work anymore, and you can spend all your time loving each other in your bedroom." (Judy, 8)</li><li>• "Once I'm done with kindergarten, I'm going to find me a wife!" (Tom, 5)</li></ul>
<p>WHAT DO MOST PEOPLE DO ON A DATE:</p> <ul style="list-style-type: none"><li>• "On the first date, they just tell each other lies, and that usually gets them interested enough to go for a second date." (Mike, 10)</li></ul>
<p>WHEN IS IT OKAY TO KISS SOMEONE:</p> <ul style="list-style-type: none"><li>• "You should never kiss a girl unless you have enough bucks to buy her a big ring and her own VCR, 'cause she'll want to have videos of the wedding." (Jim, 10)</li></ul>
<p>CONCERNING WHY LOVE HAPPENS BETWEEN TWO PARTICULAR PEOPLE:</p> <ul style="list-style-type: none"><li>• "No one is sure why it happens, but I heard it has something to do with how you smell. That's why perfume and deodorant are so popular." (Jan, 9)</li><li>• "I think you're supposed to get shot with an arrow or something, but the rest of it isn't supposed to be so painful." (Harlen, 8)</li></ul>
<p>ON THE ROLE OF GOOD LOOKS IN LOVE:</p> <ul style="list-style-type: none"><li>• "If you want to be loved by somebody who isn't already in your family, it doesn't hurt to be beautiful." (Jeanne, 8)</li><li>• "It isn't always just how you look. Look at me. I'm handsome like anything and I haven't got anybody to marry me yet." (Gary, 7)</li><li>• "Beauty is skin deep. But how rich you are can last a long time." (Christine, 9)</li></ul>

**2. Lead a brief discussion about children's conceptions of love.** Ask the participants how they think children came up with these ideas. As participants comment, help them generalize or translate their responses to the context of learning situations they may encounter in the classroom. Here are a few examples:

**Participant:** They'll eventually change their ideas about love, because they'll see or experience their own relationships, and find out what's wrong with their ideas.

### Session 3: Constructing Understanding

**Presenter:** So with direct experience or further observations they may come across conflicting information, and that helps them to replace their old ideas with new ones.

**Participant:** You could tell them about love until you're blue in the face, but they probably won't really believe it until they experience it for themselves.

**Presenter:** So you're saying that until they have direct experience with something, they can hear a lot about other viewpoints, but they may not truly believe them.

*Note: Of course knowing or understanding love does not have the same degree of objectivity as scientific understanding, but it makes the point in an engaging way.*

**3. Ask for suggestions for how one could change student ideas.** Ask participants what they could do to change these children's ideas about love. What will help these students evolve their understandings? Take a few responses.

**4. Point out difficulty in knowing what kids truly understand.** Explain that a person could try to explain love to a child, but even if the child says, "I understand," one could never be sure what their understanding really is, and how close it is to that of the person who explained it. This is true of adults as well, of course!

## Introducing Constructivism

**1. Set the context for the session.** Display Constructivism slide. Say that today the class is going to take a look at students' alternate conceptions in science through the lens of a useful theory about knowledge and learning called constructivism. This theory is based upon a vast body of research, and is commonly referred to in the educational community as being part of best practices. Explain that the points just made about kids' ideas on love served as a light-hearted introduction to constructivist theory.

**2. Introduce blank slates vs. clever minds.** Display blank slates slide. Explain that there are different ways to consider learners: as "blank slates" who are open to learning information just as it is transmitted to them; or as having "clever minds" already full of well-reasoned ideas and private explanations that affect how the learner understands new information. Point out that there is a large body of research supporting the "clever minds" view on learners, and refuting the "blank slates" view.

## Exploring and Discussing the Research

**1. Introduce research findings.** Display research findings slide. Tell participants they will receive a page of research findings that reflect a constructivist view of student learning. Each excerpt features a piece of information that research has revealed about learning and has contributed to acceptance of this theory. They should first take turns reading each finding aloud in their small group. Then they will examine one finding at a time and discuss how classroom teaching might be structured to take this information into account. Tell them to continue discussing the findings, until you tell them to stop.

### Session 3: Constructing Understanding

**2. Each group shares an idea.** After about 10–15 minutes of small group discussion, ask each group to share one idea of how classroom teaching might be structured to take the research on student learning into account.

**3. Refer to research base on student conceptions.** Much research has been done on ideas about science concepts that students of different ages bring with them into the classroom. When they are not accurate or are incomplete, these ideas are sometimes called “misconceptions.” They have also been called “preconceptions” to reduce the negative connotations and indicate that they precede more evolved concepts.

**4. Define the term “alternate conceptions.”** Research indicates that student’s prior knowledge based on their explorations and observations of the world is intelligent and useful. This view is not necessarily reflected in the term “misconceptions.” For this reason, students’ prior understandings are also often referred to as “alternate conceptions” to give more weight and value to the ideas students have worked out for themselves. Even though they may not be fully accurate, these ideas are often complex, and part of an extensive mental framework developed over time.

**5. Give example of how children’s ideas may reflect historical alternate conceptions.** As an example, point out that for more than a thousand years, many of the greatest thinkers in the world agreed that the Sun revolved around the Earth. Copernicus and Galileo famously challenged this notion, but their ideas met much resistance. We now know the earlier explanation is inaccurate, and have gathered much evidence demonstrating that the Earth revolves around the Sun. But it’s not surprising that a child who watches the Sun seem to pass through the sky and travel around the Earth would conclude that the Sun revolves around the Earth. It’s certainly not a sign of deficient thinking, for this explanation was shared by many great thinkers throughout history. It’s also not surprising that children, like many great thinkers, also resist the more accurate but less apparent explanation, and require repeated experiences with evidence and discussion in order to shift their understandings.

**6. Provide additional information about constructivism as appropriate.** You may want to point out that children (and adults) have alternate conceptions about all kinds of things. Research shows that the ideas and frameworks students bring into the classroom—even in the earliest grades—are already quite well developed. On their own, children make generalizations from their direct experience and through social interaction with other young people and adults. They have developed an impressive collection of “common sense” ideas about the world, based on their own observations and experiences. Since the domain of science involves trying to explain phenomena in the natural world, we can expect to directly encounter students’ common sense ideas when we teach science.

*Note: One area of science where considerable research has been done on student understanding (and misunderstanding!) is in astronomy. This research includes how children develop ideas about phases and eclipses of the Moon, which served as a basis for developing the questionnaire used in Unit 4.*

### Session 3: Constructing Understanding

## Exemplar: Modeling a Constructivist Approach to Teaching Moon Phases

**1. Introduce *Space Science Sequence Unit 4*.** Explain that many children and adults hold alternate conceptions about Moon phases. Say that the following activities are excerpted from the GEMS *Space Science Curriculum Sequence (Unit 4: Moon Phases and Eclipses)*, an astronomy unit for grades 3–5, but also adaptable for adults. In this session, the activities will be done in an abbreviated fashion.

*Note: Similar activity write-ups can also be found in the GEMS teacher's guide **Earth, Moon and Stars**, an astronomy unit for Grades 5–8.*

**2. Focus participants on strategies used.** Explain that the purpose in presenting this abbreviated unit is for participants to experience effective strategies for addressing students' ideas in a constructivist fashion. As they participate in the activities, participants should pay attention to the strategies used to deal with conflicting ideas. They should try to notice how the activities create situations in which students find evidence that makes them confront, and perhaps change, the mental constructs and frameworks they already have in place.

### Questionnaire & Observing the Moon (10 minutes)

**1. Reassure participants.** Explain that many children and adults hold alternate conceptions about moon phases. Reassure them that it's likely that many of them may have these ideas, as well. Through experiencing activities designed to help learners examine and confront their prior knowledge, they will have the benefit of personally experiencing the issues involved in struggling with new ideas.

**2. Administer the "Pre-Unit 4 Questionnaire."** Say that they will explore their current ideas on this topic by filling out a questionnaire. Hand out a copy of the questionnaire to each participant, and have them answer the questions. Allow time for everyone to finish. Tell them that in the unit, the teacher collects the questionnaires to find out what children are thinking, but you will not collect them for this session.

**3. Show Sun Moon Observations Chart.** Display the Sun Moon Observations slide. Tell participants that, at this point in the unit, students make observations of the Moon in the sky for about two weeks. They draw the Sun and Moon each day, and measure the distance between them using their fists. Explain that the teacher makes a similar chart from the data the students have collected.

### Modeling Moon Phases (15 minutes)

**1. Form large circle around light bulb in darkened room.** Set up the light bulb in the center of the room, and turn it on. Darken the room so that the only light comes from the light bulb. Tell participants to make one large circle around the bulb (you may need to move some tables and/or chairs).

### **Session 3: Constructing Understanding**

**2. Distribute balls and pencils.** Pass out one ball and pencil “handle” to each participant. Show them how to stick their pencil into their ball.

**3. Describe three parts of a shadow.** Explain that shadows can be described as having three parts. One part is the shadow cast by one object onto another object. Hold up your hand, and point out the shadow of your hand on the wall. Tell them this is the part of a shadow that most people notice. Ask if anyone can identify other parts of your hands’ shadow. If they don’t mention them, be sure to point out:

- The side of your hand facing away from the light bulb, which is dark.
- The area between the darkened side of your hand and the wall where the light is blocked. Draw their attention to this part of the shadow by moving your finger from your other hand into this space and letting students see that it is in shadow. Point out that this part of the shadow can only be seen when you move an object into the shade from your hand.

**4. Find three parts of shadow on balls.** Ask participants to find a partner, and locate the three parts of their ball’s shadow.

**5. Explain Sun, Earth and Moon model, and ask for inaccuracies.** Explain that in this model, the light bulb will represent the Sun and their heads will represent the Earth. The balls on the pencils represent the moon. Ask participants to share a few of the obvious inaccuracies of this model.

**6. Participants use model to explore phases of the Moon.** Tell them to use this model to begin to explore what might cause the phases of the Moon. Encourage them to work with others, and to talk to each other while they explore the model.

**7. Face the “Sun” and hold up the Moon ball.** After a few minutes, get the groups attention. Ask the participants to hold their Moon balls out in front of them, directly in front of the “Sun.”

**8. Demonstrate crescent Moon phase.** Tell participants that the Moon orbits the Earth. Instruct participants to move the moon ball to their left until they can see a thin, bright crescent lit up on the ball, and then stop. This is the crescent Moon phase.

**9. Check for understanding.** Tell them to show the crescent on their Moon ball to the person next to them. Check to make sure that everyone can see the crescent-shaped light on the Moon ball. The most common error that students make is not moving the Moon ball far enough to the left. Another error is looking at the light bulb and ignoring the “Moon.” Help individuals as needed.

**10. Ask which way the bright side of the Moon ball faces.** When everyone can see the crescent of light, ask, “Is the bright edge of your Moon that’s curved like the edge of a ball, facing toward the Sun, or away from it? [Toward the Sun, as in their observations of the real Moon.]”

**11. Continue the orbit to the quarter Moon phase.** Tell participants to continue orbiting their Moons around their heads in the same direction, until exactly half of the “Moon” is lit. (They will, of course, need to turn their bodies to the left, too.) This is the quarter Moon phase. Ask, “As the Moon appears fuller, does it move toward the Sun or away

### Session 3: Constructing Understanding

from it?" [Away from it, just like the real Moon.] Again, ask if the part of the Moon that is curved like the edge of a ball faces toward or away from the Sun. [Toward.]

**12. Demonstrate gibbous Moon phase.** Tell participants to continue turning and orbiting their moon balls in the same direction, until it is halfway between a quarter Moon and a full Moon. This is the gibbous Moon phase.

**13. Demonstrate full Moon phase.** Have them continue moving the Moon ball along its orbit until the part that they see is fully lit. Explain that they will have to hold the moon ball just above the shadow of their heads. This is the full Moon phase. Their backs should now be to the light bulb. Ask, "When the Moon is full, is it between the Earth and the Sun, or on the opposite side of the Earth from the Sun?" [It is on the opposite side of Earth from the Sun.]

**14. Demonstrate gibbous Moon phase, again.** Tell participants to continue moving the Moon ball in its orbit until it is in gibbous phase once again.

**15. Move to quarter Moon phase.** Instruct students to continue orbiting the Moon ball in the same direction until it is just half full again, another quarter Moon phase. Ask, "As the Moon moves toward the Sun, does it appear to get fuller or thinner?" [Thinner.] "Is the curved side facing toward or away from the Sun?" [Toward.]

**16. Model crescent and then new Moon phase.** Finally, tell participants to continue to move their Moon balls so that they see a very thin crescent again. Explain that most of the time the Moon does not pass directly in front of the Sun, but just above or below the Sun. When the Moon cannot be seen at all, this phase is called the new Moon. It is called "new" because it is at the beginning of its cycle. Tell them that they have now modeled one full cycle of the Moon, which takes a month.

**17. Do another Moon orbit, focusing on light and shadows.** Direct participants through another orbit of the Moon. This time, instruct them to pause at various points, and ask them questions about light and shadow.

*Q: What is making the bright side of the Moon bright?* [Light from the Sun]

*Q: What is making the dark side of the Moon dark?* [The beginning of the Moon's own shadow – the Moon's shadow on itself]

*Note: This is a particularly important question, because many people think that the dark part is caused by the shadow of the Earth.*

*Q: Using a finger from your other hand, can you find places around your Moon that are also in shadow?*

*Note: If participants ask questions about phases of the Moon, if possible, tell them to "ask the objects." Encourage them to attempt to figure out the answer for themselves using evidence from the model. Also encourage them to discuss their ideas and findings with each other.*

**18. Independently explore Moon balls in orbit.** Have participants turn and move their Moon balls in orbits several times on their own, exploring light, shadows and phases.

### Session 3: Constructing Understanding

#### Modeling Lunar and Solar Eclipses (5 minutes)

- 1. Stop at the full Moon phase.** Get the groups' attention, and tell them to move their moon balls around again until they reach the full Moon phase, with their backs to the light bulb. This time, have each participant move the moon ball into the shadow of her head.
- 2. Eclipse of the Moon/Lunar eclipse.** Explain that this is an *eclipse* of the Moon. It is sometimes called a *lunar eclipse*. Tell them that the word eclipse means "one object blocking the light from another." Ask, "What is blocking the light from falling on the moon ball?" [Their "Earth" heads.] Clarify that, unlike moon phases, lunar eclipses are caused by the Earth's shadow.
- 3. Look at the edge of Earth's shadow on the Moon.** Ask each participant to move the moon ball a little, so that he can see the edge of his head's shadow on the moon ball. Say that during a lunar eclipse, you can see the round edge of Earth's shadow move across the Moon.
- 4. Lunar eclipses only happen during the full Moon.** Ask, "Why does an eclipse of the Moon always happen during the full Moon?" [That's when the Earth is between the sun and Moon, so that the Earth's shadow can fall on the Moon.]
- 5. Explain why lunar eclipses don't occur every month.** Tell participants that as the Moon orbits the Earth, it usually passes somewhere above or below the Earth's shadow, so most of the time, we get a full Moon without an eclipse.
- 6. Everyone on the night side of Earth can see the lunar eclipse.** While participants continue to observe the eclipse of the Moon, point out that everyone who lives on the side of the Earth facing the Moon can see an eclipse of the Moon at the same time (weather permitting). Ask participants to raise their hands if they have ever seen an eclipse of the Moon.

#### Modeling an Eclipse of the Sun

- 1. Use Moon balls to block the light from the "Sun."** Now, ask your participant to face the light bulb. Tell them to hold their moon balls directly between their heads and the light bulb. Ask what object is being blocked. [The Sun] Ask what object is eclipsing the Sun. [The Moon.]
- 2. Define solar eclipse.** Say that when the Sun is blocked from our view, we call it a *solar eclipse*. Ask if anyone has ever seen a solar eclipse.
- 3. Note shadows on faces of classmates.** During the solar eclipse, have them glance around at other participants' faces. Ask, "What is making the round shadows on everyone's faces?" [It's the shadow of the Moon.] Point out that not everybody on that

### Session 3: Constructing Understanding

side of Earth can see the solar eclipse; the Sun is blocked only for the people who live where that shadow is. (The people who live on your chin can still see the Sun!)

**4. Partners explain Moon phases and eclipses to each other.** Tell participants to get a partner, and have one person use the model and their own words to explain to their partner what they think causes Moon phases. Then, the other partner does the same, but explaining eclipses. Encourage them to question each other and try to work it out using the model if there is disagreement.

### Discussing Moon Phase Explanations (10 minutes)

**1. Conclude Moon balls activity.** Turn on the room lights, and have participants be seated. Collect the Moon balls.

**3. Explain procedure for discussing question #2.** Explain that they will go back to their questionnaires, and work in small groups to discuss question #2. First, they should read aloud each possible answer to the question, discussing evidence that supports the explanation, and evidence against it. Then they should try to come to agreement, if possible, on the best response.

*Note: If you have time, an interesting question for participants to investigate is, "Can we see a full Moon during the day?" Give the question to your participants, and challenge them to attempt to figure it out using their moon ball models as evidence. Encourage them to work together, and talk to each other. Then have individuals share their ideas and evidence in the large group.*

### Discussing the Moon Phases Exemplar (10 minutes)

**1. Point out evaluative role of the questionnaire.** Let participants know that in the unit, to further evaluate students' understanding, the students would complete the questionnaire again, after two or three weeks of additional instruction, and the results would be compared to the initial questionnaire to measure the growth that occurred. Also point out that in the curriculum, there are more activities on this topic that there isn't time for in this session.

**2. Small groups discuss strategies used.** Have the participants get back together with their original small groups and discuss the following questions related to the Moon phase activities:

- What strategies were modeled that help find out children's ideas about the topic?
- What strategies were modeled that help deal with children's alternate conceptions about the topic?
- What strategies have you experienced or seen in other classroom situations that educators have used to help learners make better sense of the world?

**3. Large group discusses strategies used.** After about 5 minutes, get the attention of the entire group, and discuss the same questions, asking participants to share some of the ideas their group discussed. If they don't bring the following ideas up, do so yourself:

- Student observations and recording of real phenomena (the real Moon).

### Session 3: Constructing Understanding

- Helping students with fundamental understandings (parts of a shadow) that might block them from understanding phases of the Moon.

*Note: This activity was developed in response to teachers discovering that students were struggling with understanding shadows and Moon phases because they didn't understand that the dark side of the Moon could be made by its own shadow.*

- Use of models to represent phenomena (Moon simulation, moon balls)
- Encouraging students to use models to try out their ideas, and to figure out what's going on for themselves.
- Discussion of inaccuracies in the model used, to help prevent the model from creating additional alternate conceptions.
- Student-to-student discourse. Multiple opportunities for students to share their ideas with others, and to hear others ideas.
- Encouraging the use of evidence in discussions, and evaluating explanations based on *all* the available evidence.
- Use of questionnaire to find out what children's ideas are, including both multiple choice and more broad questions for children to write their ideas.

**4. List learning and teaching strategies they may have just experienced.** Say that you will read off a list of some learning and teaching strategies. Ask them to raise their hands if they found that they used that strategy in their **own learning** about the phases of the Moon during the exemplar lesson. Read off the following list, and pause briefly after each one for participants to think and raise their hands.

- Hands on, manipulation of the model
- Listening to & talking with peers
- Thinking on your own
- Listening & talking with the instructor in the whole group
- Overhearing other peers
- Discussing and testing out ideas that agree or disagree with your own understanding
- Asking new questions
- Explaining your ideas to peers or instructor
- Accessing prior knowledge & experiences

**5. Describe the constructive process for learning.** Point out that these types of complex ideas develop for students over long periods of time. Educators who share a constructivist viewpoint maintain that, in general, students do not acquire concepts simply by having a teacher tell them the content or even by performing a hands-on activity. In order to firmly grasp concepts, students must encounter multiple learning experiences that encourage them to question their assumptions, struggle with new ideas, and apply their new understandings in different contexts.

### Session 3: Constructing Understanding

#### Watching and Discussing *A Private Universe* Video (30 minutes)

**1. Introduce Private Universe video.** Tell participants you're going to show them an intriguing video that explores alternate conceptions that university and middle school students have about the phases of the moon and the seasons.

**2. Show the Private Universe video.** Show the video, *A Private Universe* (running time about 20 minutes).

*Note: You may want to halt the video after Heather has explained how she was able to change her ideas about lunar eclipses. The rest of the video (particularly the ending) paints a somewhat discouraging picture with regard to challenging student misconceptions. Ending the video at this point does not prevent participants from hearing and discussing the critical points from the video as are relevant to current constructivist theory.*

**3. Discuss the Private Universe video.** After the end of the video ask the following discussion questions:

- What did you find interesting in the video?
- What motivated Heather to change her ideas about the phases of the Moon? [when she got to figure it out for herself, using hands-on materials—the moon balls—to model the Earth, Moon and Sun]
- Do you think it's possible to teach a concept to every child in a class, and to know they "got it?" Is it important? Is it desirable?
- When asked to explain what causes Moon phases, one boy in the video answered, "clouds." If you were the teacher, what might you do with that information?

*Note: In the video, students are interviewed about phases of the Moon and seasons. In the same way that they just modeled moon phases, a model of the Earth and Sun can also be used to help students achieve a more accurate understanding of the seasons. Both the GEMS Space Science Sequence for Grades 6–8 (Unit 2) and the GEMS teacher's guide, The Real Reasons for Seasons, include a series of modeling and hands-on activities to help students work through and overcome alternate conceptions about the seasons and arrive at a more accurate understanding.*

#### Strategies for Addressing Students' Ideas and Quick Write (10 minutes)

**1. Sharing strategies for addressing student ideas.** To conclude the discussion, tell participants you're going to introduce some general strategies for addressing student ideas. Use a piece of paper to uncover the items one at a time on the overhead transparency, or "fly them in" on a PowerPoint slide.

**Session 3: Constructing Understanding**

- Find out what students already think, elicit their prior ideas.
- Use what you learn about student’s ideas to inform your teaching. Be flexible and adapt your curriculum to be relevant and responsive to student needs.
- Cultivate a classroom environment that celebrates good thinking and struggling with evidence-based explanations, more than knowing the “right answer.”
- Provide multiple opportunities for meaningful conceptual learning.
- Focus on reasoning, comprehension, and depth, not memorization of information.
- Set up learning situations and/or discrepant events where students need to grapple with conflicting ideas and alternate conceptions.
- Facilitate open discussion of alternate ideas.
- Rather than only provide evidence that shows why a certain explanation is “correct,” also provide opportunities and evidence for students to see why other explanations are inaccurate.
- Use real-world investigations and materials.
- Make use of models, but be aware of and discuss their limitations.
- Give students ample chance to think, re-think, discuss, reflect, and apply their ideas to new situations. It takes time to construct new concepts.

**2. Connecting constructivism to learning cycle.** Display the learning cycle overhead transparency from the “Teaching and Learning” session. Describe how constructivist teaching connects with and relates to the learning cycle phases. Through these phases students can have the opportunity to access their prior knowledge, gain observations and information that can challenge their ideas, construct and apply new frameworks, and reflect on how new and prior frameworks are connected. In this way, a learning cycle-based model for instruction supports constructivist teaching.

**3. Review Aims of Constructivist Science Teaching.** Show them the overhead transparency, “The Aims of Constructivist Science Teaching,” and read it aloud:

**The Aims of Constructivist Science Teaching**

...”what are, or should be, the aims of science teaching? While there can be many possible answers to this question, it is our view that one of the main aims of science teaching, at any level, is to help people make better sense of their world. Better in that in acquiring a new perspective on a topic or situation the learner considers it to be more satisfactory, that is, more intelligible, plausible and useful, than his or her earlier ideas.”

— Roger Osborne  
from *Taking the Plunge*, edited by Wynne Harlen

*Note: If you have an additional 20 minutes, you may want to spend some time having participants apply these ideas to a classroom dilemma. (See page 41, Alternative Activities.)*

**4. Distribute Handout.** Give each participant a copy of “Strategies for Assessing Student Ideas/The Aims of Constructivist Science Teaching.”

**5. Quick Write about session.** Have participants get out a piece of paper and write their thoughts about how the session has affected their ideas about teaching and learning.

**Session 3: Constructing Understanding**

Summarize your thinking about constructing understanding. If you can, include:

- How have your ideas about constructing understanding changed.
- What do you think made your ideas change?
- How might you use this in your science teaching?

**Session 3: Constructing Understanding**

**Session Handouts**

- Research-based information on Teaching and Learning (“Research Cards”)
- Strategies for Addressing Student Ideas/The Aims of Constructivist Teaching
- Pre-Unit 4 Questionnaire

### Session 3: Constructing Understanding

## “Research Cards”—Research-Based Information About Student Learning

- Students all arrive at school with their own often quite elaborate ideas and explanations about a variety of natural phenomena. They are not “blank slates.” Some of these ideas are difficult to change. (Osborne, R. J. & Gilbert, J. K. A technique for exploring students’ views of the world, *Physics Education*, 1980)
- Students can “parrot” and memorize explanations and ideas without believing or fully understanding them. When ideas are not fully understood or connected with pre-existing knowledge, they are difficult for students to retrieve or apply to new situations. (Fisher, K.M. & Lipson, J.I. Twenty questions about student errors, *Journal of Research in Science Education*, 1986)
- Students can learn a concept to pass a test, but go back to their old ideas outside the classroom. (Wandersee, J.H., Mintzes, J.J., & Novak, J.D. Research on alternative conceptions in science, in *Handbook of Research on Science Teaching and Learning*, 1994.)
- If you teach new ideas and explanations—without first dealing with alternate conceptions that students already have—students will frequently revert to their old ideas. (Nussbaum, J. & Novick, S. Alternative frameworks, conceptual conflict and accommodation: towards a principled teaching strategy, *Instructional Science*, 1982)
- Students’ prior ideas, their “common sense,” and “everyday thinking,” are intelligent and useful. If those ideas are not engaged, students often dismiss science teaching as irrelevant. (Hammer, D. & Van Zee, E. *Seeing the Science in Children’s Thinking*, 2006)
- The American classroom is dominated by teacher talk. (Flanders, N. *Analyzing Teaching Behaviour*, 1970. Goodlad, J. *A place called school: Prospects for the future*, 1984)
- Teachers vastly overestimate the gain in knowledge their students achieve after their course. This is especially true with concepts (as opposed to facts) for which students have strong, underlying misconceptions. (Lightman, A. & Sadler, P. Teacher Predictions Versus Actual Student Gains, *The Physics Teacher*, 1993)
- There is a “perseverance effect:” the finding that people’s beliefs persist even after the evidence supporting these beliefs is discredited. (Aronson, E., Wilson, T.D. & Akert, R.M. *Social Psychology*, 2004)
- Learning is perceived as an active process of engaging and manipulating objects, experiences, and conversations in order to construct a mental picture of the world. (Dewey, 1938; Piaget, 1964; Vygotsky, 1986)
- Social and cultural interactions with peers and educators (or with novice and experienced individuals) are necessary for the construction of knowledge to take place. In this way, learners are constructing their own learning within a social context where they share ideas, and meaning making is created and expanded by interaction with their environment (Rogoff, B., *Cognition as a collaborative process*, in *Cognition, perception and language: Handbook of child psychology*, 1998)

### Session 3: Constructing Understanding

## Strategies for Addressing Student Ideas

- Find out what students already think, elicit their prior ideas.
- Use what you learn about student's ideas to inform your teaching. Be flexible and adapt your curriculum to be relevant and responsive to student needs.
- Cultivate a classroom environment that celebrates good thinking and struggling with evidence-based explanations, more than "knowing the right answer."
- Provide multiple opportunities for meaningful conceptual learning.
- Focus on reasoning, comprehension, and depth, not memorization of information.
- Set up learning situations and/or discrepant events where students need to grapple with conflicting ideas and alternate conceptions.
- Facilitate open discussion of alternate ideas.
- Rather than only provide evidence that shows why a certain explanation is "correct," also provide opportunities and evidence for students to see why other explanations are inaccurate.
- Use real-world investigations and materials.
- Make use of models, but be aware of and discuss their limitations.
- Give students ample chance to think, re-think, discuss, reflect, and apply their ideas to new situations. It takes time to construct new concepts.

## The Aims of Constructivist Science Teaching

..."what are, or should be, the aims of science teaching? While there can be many possible answers to this question, it is our view that one of the main aims of science teaching, at any level, is **to help people make better sense of their world**. Better in that in acquiring a new perspective on a topic or situation **the learner considers it to be more satisfactory, that is, more intelligible, plausible and useful, than his or her earlier ideas.**"

— Roger Osborne  
from *Taking the Plunge*, edited by Wynne Harlen

**Session 3: Constructing Understanding**

Name: \_\_\_\_\_

## Pre-unit 4 Questionnaire

1. Which picture below is wrong: A or B? (Circle one.)

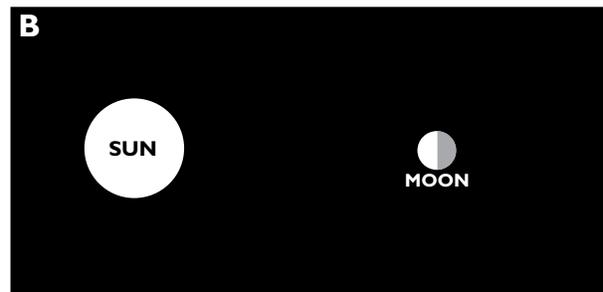
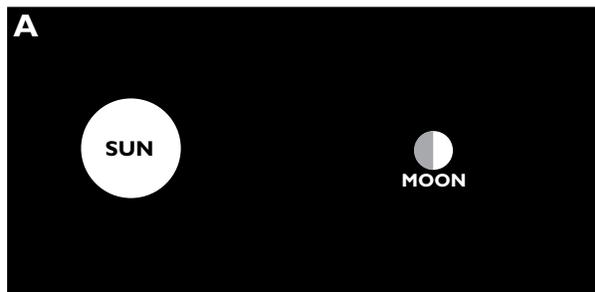
*Drawings are not to scale.*

It is wrong because. . . \_\_\_\_\_

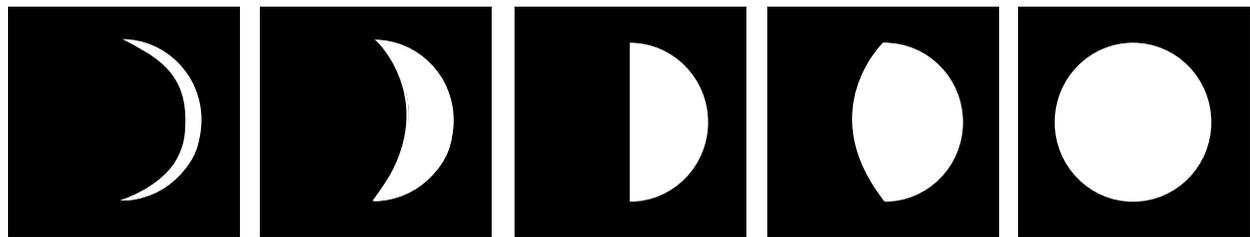
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2. Here are some pictures of how the Moon looks at different times of the month.



Why does the Moon seem to change its shape during the month? (Circle A, B, C, or D.)

- A. The Moon gets smaller and bigger.
- B. Clouds block part of the Moon from our view.
- C. The Earth's shadow covers part of the Moon.
- D. We see portions of the sun-lit side of the Moon.

Continued on next page

**Session 3: Constructing Understanding**

## **Presentation Slides**

- Kids on Love
- Constructivism
- Blank Slates or Clever Minds?
- Research Findings
- Sun Moon Observation Chart
- Discussing Moon Phases Activity
- Strategies for Addressing Student Ideas
- The Learning Cycle
- Aims of Constructivist Science Teaching
- Small Group Discussion Question

## **Kids on Love**

### **WHAT IS THE PROPER AGE TO GET MARRIED:**

- “Eighty-four! Because at that age, you don’t have to work anymore, and you can spend all your time loving each other in your bedroom.” (Judy, 8)
- Once I’m done with kindergarten, I’m going to find me a wife!” (Tom, 5)

### **WHAT DO MOST PEOPLE DO ON A DATE:**

- “On the first date, they just tell each other lies, and that usually gets them interested enough to go for a second date.” (Mike, 10)

### **WHEN IS IT OKAY TO KISS SOMEONE:**

- “You should never kiss a girl unless you have enough bucks to buy her a big ring and her own VCR, ‘cause she’ll want to have videos of the wedding.” (Jim, 10)

### **CONCERNING WHY LOVE HAPPENS BETWEEN TWO PARTICULAR PEOPLE:**

- “No one is sure why it happens, but I heard it has something to do with how you smell. That’s why perfume and deodorant are so popular.” (Jan, 9)
- “I think you’re supposed to get shot with an arrow or something, but the rest of it isn’t supposed to be so painful.”(Harlen, 8)

### **ON THE ROLE OF GOOD LOOKS IN LOVE:**

- “If you want to be loved by somebody who isn’t already in your family, it doesn’t hurt to be beautiful.” (Jeanne, 8)
- “It isn’t always just how you look. Look at me. I’m handsome like anything and I haven’t got anybody to marry me yet.”(Gary, 7)
- “Beauty is skin deep. But how rich you are can last a long time.” (Christine, 9)

**Session 3: Constructing Understanding**

**Constructivism** — a widely accepted,  
research-based theory of learning

# Blank Slates or Clever Minds?

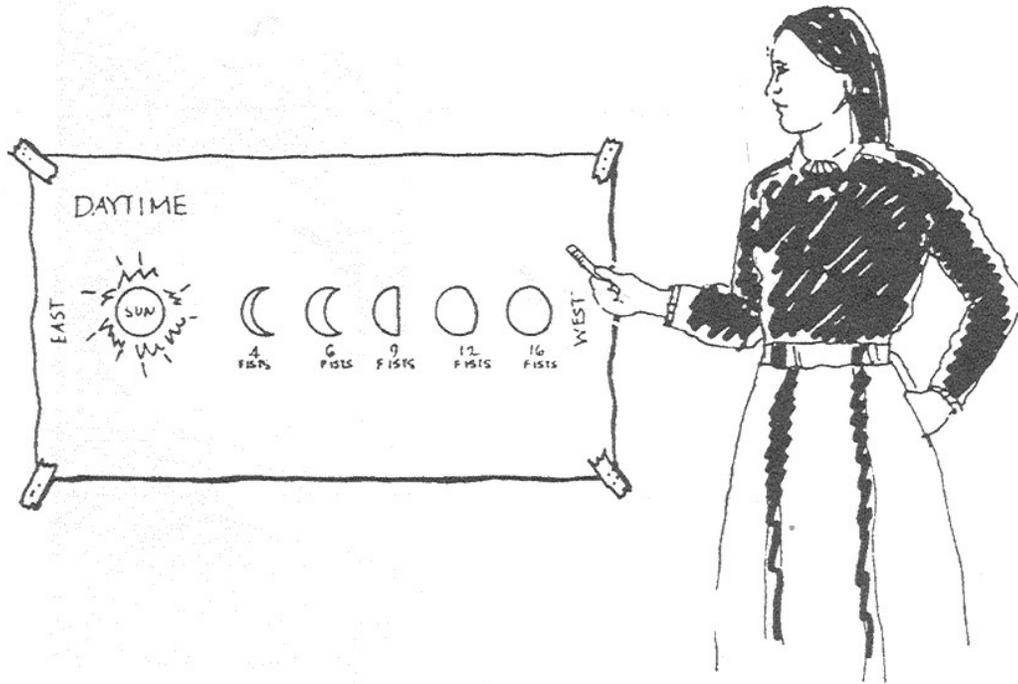
**Session 3: Constructing Understanding**

Read each research finding aloud.

Discuss each finding and how classroom teaching could be structured to take this information into account.

Session 3: Constructing Understanding

# Sun Moon Observation Chart



## **Discussing Moon Phases Activity**

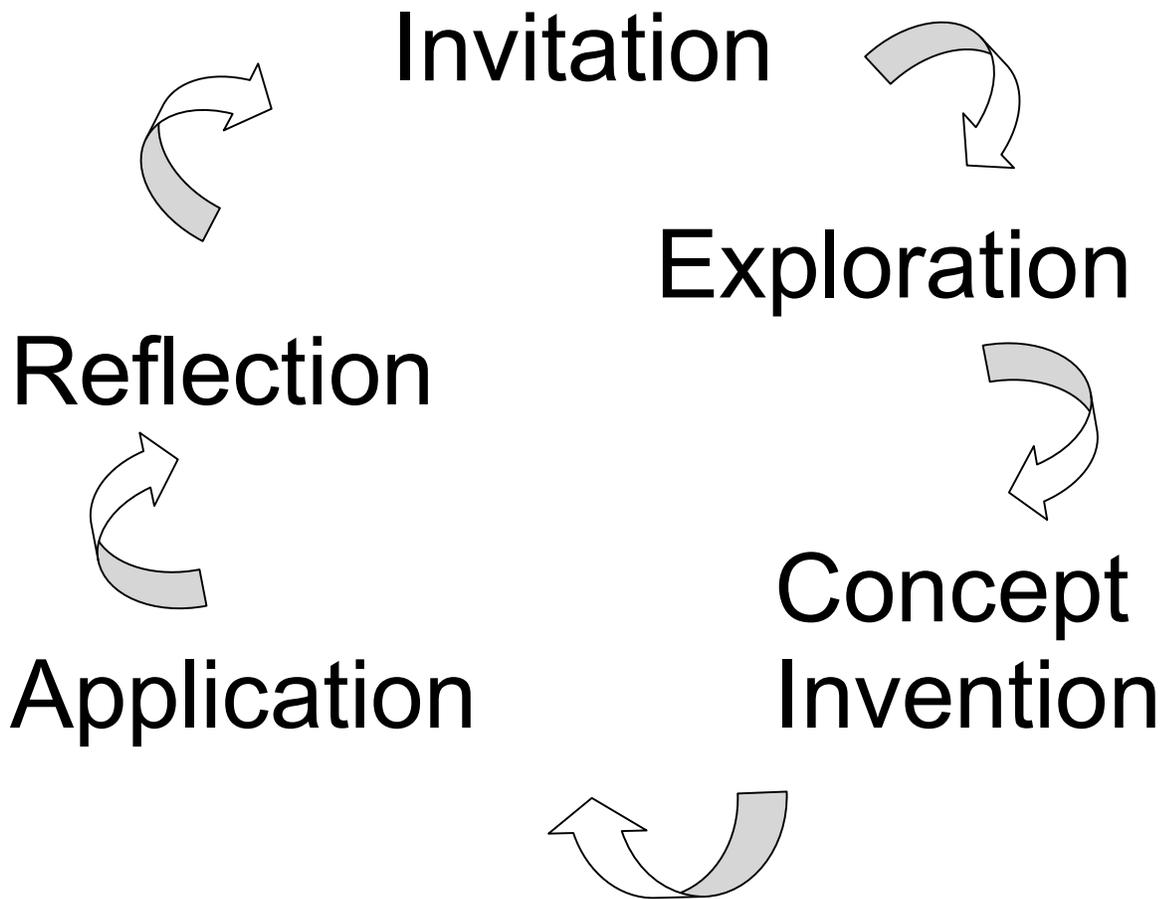
- What strategies were modeled that help find out children's ideas about the topic?
- What strategies were modeled that help deal with children's alternate conceptions on the topic?
- What strategies have you experienced or seen in other classroom situations that educators have used to help learners make better sense of their world?

**Session 3: Constructing Understanding**

## **Strategies for Addressing Student Ideas**

- Find out what students already think, elicit their prior ideas.
- Use what you learn about student's ideas to inform your teaching.
- Cultivate a classroom environment that celebrates good thinking and struggling with evidence-based explanations, more than "knowing the right answer."
- Provide multiple opportunities for meaningful conceptual learning.
- Focus on reasoning, comprehension, and depth, not memorization of information.
- Set up learning situations and/or discrepant events where students need to grapple with conflicting ideas and alternate conceptions.
- Facilitate open discussion of alternate ideas.
- Be flexible and adapt your curriculum to be relevant and responsive to student needs.
- Rather than only provide evidence that shows why a certain explanation is "correct," also provide opportunities and evidence for students to see why other explanations are inaccurate.
- Use real-world investigations and materials.
- Make use of models, but be aware of and discuss their limitations.
- Give students ample chance to think, re-think, discuss, reflect, and apply their ideas to new situations. It takes time to construct new concepts.

# The Learning Cycle



## The Aims of Constructivist Science Teaching

“ ... what are, or should be, the aims of science teaching? While there can be many possible answers to this question, it is our view that one of the main aims of science teaching, at any level, is **to help people make better sense of their world.** Better in that in acquiring a new perspective on a topic or situation **the learner considers it to be more satisfactory, that is, more intelligible, plausible and useful, than his or her earlier ideas.**”

— Roger Osborne

from *Taking the Plunge*, edited by Wynne Harlen

## **Small Group Discussion Question:**

If there's only five minutes left in class, and some students still have the "wrong" answer, what do I do?

**Session 3: Constructing Understanding**

## Alternative Activities

### Applying Constructivist Ideas to the Classroom (20 minutes)

**1. Display discussion prompt.** Tell small groups of participants to spend a few minutes discussing the question below. Remind them to consider what they have discussed and experienced about teaching and learning so far in the course.

*Question: If there's only five minutes left in class, and some students still have the "wrong" answer, what do I do?*

**2. Groups share out key points.** Ask one person from each small group to briefly share with the class a few key points from what their group discussed.

**Session 3: Constructing Understanding**

## ***Fish is Fish* Introductory Activity (10 minutes)**

**1. Read aloud and show the *Fish is Fish* book.** Using either the actual book or a PowerPoint slide of selected pages, read aloud and show the images of the children's book, *Fish is Fish*. Begin with the page that starts with "Then one day, with a happy splash that shook the weeds, the frog jumped into the pond." Continue reading the next nine pages (stopping at the two-page pictorial spread showing the fish's ideas about birds, cows, and people).

*Note: In the book, a frog tries to explain birds, cows, and people to a fish. The fish imagines each of these as fish-like creatures. This can serve as an engaging introduction to some of the ideas of constructivism. A similar discussion can be used as an introduction to this session using the children's book August Explains by Phil Ressner.*

**2. Lead a brief discussion about thinking, learning, and the fish's conceptions of birds, cows, and people.** Ask the participants the following questions as appropriate in order to stimulate and direct a discussion about the book:

- How do you think these pages might relate to how children think and learn?
- What might the frog be able to do to find out what the fish's ideas are?
- How might the frog be able to lead the fish to more accurate understandings?
- Would simply telling the fish more information be effective? Why or why not?

**3. Point out difficulty in knowing what kids really understand.** Explain that a person could try to explain something to a child, but even if the child says, "I understand," one could never be sure what their understanding really is, and how close it is to that of the person who explained it. Of course, this is also true of adults as well!

## ***Session 4: Questioning Strategies***

# **Contents**

<b>Session Overview</b>	2
<b>Background Information for the Presenter</b>	3
<b>Materials and Preparation</b>	5
<b>Instructor's Guide</b>	8
<b>Presentation Slides</b> (also in separate PowerPoint)	23
<b>Session Handouts</b>	35

## Session 4: Questioning Strategies

### Session Overview

*Questioning Strategies* is the first of four sessions in the course that involve participants in exploring the effective use of questions in leading discussions in the science classroom.

- This first questioning session provides some initial experiences using various types of questions to guide and encourage discussion, and also introduces practical concepts and questioning strategies.
- The second session, *Questions Lab*, provides an opportunity for real-life application, where the class has the chance to try out various questions with students of the same age course participants will be working with. They also observe an experienced instructor leading a discussion with these students.
- The third questioning session, *Promoting Discussion*, demonstrates how to effectively respond to student answers, and provides further examples of model teaching and questioning.
- The fourth questioning session, *Classroom Conversations*, focuses on the role of dialogue in learning and the importance of peer-to-peer discussions.

**We strongly suggest that you read through all four sessions before presenting them, or at least review all the overviews, overheads, and handouts. This will give you a sense about how the sessions intertwine and how you might choose to facilitate some of the discussions.**

This first session focuses on two main categories of questions—“broad” and “focused” questions—also referred to in some education literature as “open-ended” and “closed.”

- The interactive activities in this session introduce the appropriate use of both types of questions and are not intended to portray either type as “good” or “bad.” The emphasis is on analyzing the impact of both kinds of questions on student thinking and behavior, and using this information to help decide how and when to best use them.
- In addition, we explore the effects of sequencing questions, both to guide students through learning cycle-based explorations, and to help lead discussions. We also explore typical approaches teachers can take when answering questions (“sage on the stage” or “guide on the side”) and how these approaches can either draw out student questions or, in the extreme, shut them down.

**Session 4: Questioning Strategies****Background Information for the Presenter**

Questioning is a vital and powerful teaching strategy, and a crucial component of just about any teaching situation. This is especially the case when learning situations derive from student experience, where questions and reflections about that experience are used to develop and refine concepts. Questions can open doors at every stage of the learning experience—inviting students into activities and ideas by creating interest in a new topic; helping guide students' active explorations; stimulating reasoning and sense-making of new concepts; and encouraging students to apply their ideas to different situations. Well-sequenced questions can initiate the sharing of ideas, encourage development of multiple hypotheses or alternative explanations, help students recall prior knowledge, allow them to synthesize new information, and help guide logical thinking.

There's an art to employing questioning strategies and to balancing the amount of asking and telling used in a teaching situation. There's no one formula for what this balance should be, and it changes from situation to situation. Experience and practice can hone teachers' expertise and questioning know-how. Skilled instructors use questions to find out what students think, encourage discussion, and draw attention to diverse viewpoints and interpretations. However, one can also observe veteran teachers who do not take advantage of questioning strategies that could elevate their classes to interactive learning experiences, but instead resort to perfunctory question-and-answer drills. Research indicates that teachers who are specifically trained to ask high-quality questions show significant improvement in constructing and using such questions in the classroom (Angletti 1991, as quoted by Cecil 1995). Reflection and analysis of the effect on learning of various kinds and sequences of questions is essential for teachers to develop this type of expertise.

**Questions that Encourage or Discourage Discussion**

An analysis of questioning strategies can begin with noting the effects of using focused and broad questions during a discussion. The model lessons in this session demonstrate how using focused questions, that have specific, prescribed answers, can shut down a class discussion by requiring students to try to guess what the teacher is thinking. In contrast, beginning the conversation with broad questions, that have multiple acceptable answers/responses, can encourage more students to participate and offer various ideas for the discussion. Of course, if consensus has been reached as the result of a discussion, it can be appropriate to wrap-up with focused questions that help students summarize their ideas and conclusions. Once an instructor develops a feel for how these questions affect learners, they can then make thoughtful adjustments to their questioning strategies during their teaching.

**Considering Goals When Asking Questions**

When planning for questions, another thing to consider is the instructor's purpose or possible goals for engaging the learner in a particular teaching situation. When beginning a new activity or science topic it's often useful to engage students in observing and noticing details. Questions such as, "What did you notice when...?" can be used to guide students to make certain observations, but should be broad in order to

## Session 4: Questioning Strategies

encourage multiple points of view. Questions such as, “What do you think will happen if...?” can be used to stimulate productive activity during an investigation. Once students have explored a phenomenon or performed an investigation, questions can then be used to guide students to make comparisons or quantify their observations. Given adequate experience and exploration of a topic or phenomenon, students may then be ready to draw conclusions and make sense of their investigations, responding to questions, such as, “What do you think is the explanation for...?” or “Why do you think this happened?” can be used to encourage sense-making. Questions can be used to challenge students to apply what they’ve learned in order to generalize their knowledge or test their hypotheses. Asking students to reflect on their thinking and investigation processes helps them become more aware of their own strengths and weaknesses in the subject area, as well as encouraging them to take charge of their own learning.

### Role of the Instructor

The final factor considered during this session, that can definitely impact an instructor’s questioning strategies, is how they view their role in the classroom. A “sage on the stage” type of instructor has the point of view that it is their responsibility to impart or transmit knowledge directly to students and that the teacher or text must provide the necessary information for understanding. This view of the learning process can emphasize rote memory and regurgitation of ideas from sources other than the students themselves. A “guide on the side” type of instructor embodies a more constructivist view of learning—one which accepts that students must be encouraged to create their own personal frameworks through discussion and interactions with materials and various sources—in order for them to develop a deeper understanding that can be flexibly applied to different learning situations.

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## Session 4: Questioning Strategies

**Materials and Preparation****Materials Needed****For the class:**

- 1 overhead transparency or PowerPoint slides of each of the following sheets:
  - “?”
  - “Questions for Discussion” questionnaire
  - “Types of Questions”
  - “Discussion Map”
  - “Discussion Map Example”
  - “Quick Write”
  
- 1 overhead or LCD projector

**For each participant:**

- 1 copy of the “Questions and the Learning Cycle” sheet
- 1 copy of the “Types of Questions Defined” sheet
- 1 copy of the “Discussion Map” sheet
- 1 copy of the “Questions Planning Worksheet”
- 1 copy of the “Sample Questions” sheet

**For the *Describe the Object* Activity:****For the class:**

- three distinct and interesting items, such as a large shell, a skull, and a bone.

*Note:* These are three different items you’ll hold up for all to see as they briefly discuss their observations in teams of two. These can be any items you have handy, as long as they are large enough to be visible to the group and interesting to discuss and compare. These items could also be topically related to each other, such as a shell, a skull, and a bone (to inspire discussion about the hard parts of organisms), or a rock, a piece of plastic, and a shell (to inspire discussion about natural and man-made objects) or simply three containers, one with a solid, one with a liquid, and one with air inside.

**For the Skits:****For the class:**

- 3 copies of the Scripts—one for yourself and one for each of the two role play participants

**For the Sink/Float stations:****For each group of 4–6 participants:**

- approximately 9 ft. of yarn or string to make sorting circles
- one dishtub

## Session 4: Questioning Strategies

- ❑ a diverse collection of sink/float test objects, such as:
  - small and large pieces of wax
  - wooden objects
  - metal objects
  - crayons (for younger children, do not use crayons, as some colors sink and some float, which can be confusing)
  - fresh egg (in the shell of course)
  - balloon
  - aluminum foil
  - soda can (unopened) diet and non-diet
  - full bottle of water with cap
  - paper clips
  - plastic film canister with lid
  - sponge
  - sand
  - marble
  - spoon
- ❑ salt (*optional*) This would be useful for high school or university age groups—not as a sink/float item—but in case any choose to increase the density of the water.

## Preparation Before the Session

**1. Assemble materials for Describing Object activity.** Gather and set out the objects for the activity.

**2. Make overhead transparencies or prepare PowerPoint slides.** You'll need one of each of the following transparencies or slides:

- “?”
- “Questions for Discussion”
- “Types of Questions”
- “Questions and the Learning Cycle”
- “Discussion Map Example”
- “Discussion Map”
- “Quick Write”

**3. Duplicate handouts.** For each participant you'll need one of each of the following handouts:

- “Questions and the Learning Cycle”
- “Types of Questions Defined”
- “Discussion Map”
- “Question Planning Worksheet”
- “Sample Questions”

**4. Duplicate scripts.** Make three copies of the Skit scripts, one for yourself and two for the role-play participants.

**5. Prepare sorting circles.** Cut pieces of yarn or string, about 3 feet long, and tie the two ends together to make circles. Each group will lay 3 yarn

## Session 4: Questioning Strategies

circles out on the table—one to designate items that float, one for those that sink, and the third for groups who decide they need a third category. Each group of 4–6 participants will need three sorting circles.

**6. Set up sink/float stations.** You'll need one sink/float station for each group of 4–6 participants. For each station, set aside:

- a dishtub half-filled with water
- three sorting circles
- a collection of sink/float test objects

**Important Note to Presenter:** You will need to plan to recruit some students for the next session, the *Question Lab* session. In that session, course participants each have the opportunity to present a brief activity to a small group of students and try out their questioning strategies—with real live students. This experience is invaluable. It provides a safe and controlled context for participants to gain firsthand experience trying out different questioning strategies, without the pressure of needing to do so with a large or high-stakes group. They gain the further advantage of being able to reflect on what worked and what didn't with their fellow participants and you. **We strongly recommend that you make the effort to recruit students for the Question Lab.** If you do decide to skip the *Question Lab* session, go ahead and have your participants prepare questions in this session, as if they would be presenting sink-float activities to students, to provide at least some practice with this important exercise.

## Session 4: Questioning Strategies

# Instructor's Guide

## Session Objectives

In this session, participants:

- experience and reflect on the different effects of focused and broad questions on student thinking and discussions;
- note teacher behaviors that reflect when a teacher sees his/her role as either “guide on the side” or “sage on the stage;” and the impact this may have on students;
- participate in a sink/float activity they will help present to students in the next session; and
- apply what they've learned about questioning strategies as they prepare their own set of questions to guide visiting students when they take part in sink/float investigations during the *Question Lab* session.

## Time Frame

Total Workshop: 2 hours

Describe the Object Activity (20 minutes)

Role of the Instructor and Debrief Discussions (35 minutes)

Introducing the Discussion Map (10 minutes)

Sink/Float Activity (30 minutes)

Planning Sink/Float Questions (20 minutes)

Concluding the Session (5 minutes)

## Session Activities at a Glance

### Describe the Object Activity

This session starts off with a brief activity in which the presenter asks participants a series of guiding questions. The participants are then asked to notice the different effects that broad and focused questions had on their own thinking and participation in discussion. The effects are quite striking, as discussion emerges naturally when broad questions are used, and tends to end abruptly with focused questions.

### Considering the Role of the Instructor

Two brief dramatizations are presented, depicting the interactions between a professor and a student who has come for help during office hours. The first illustrates the instructor taking a “sage on the stage” role, while the second portrays the “guide on the side” role. During a discussion, participants learn how a teacher's view of their role and their assumptions about learning may influence the types of questions they ask students.

## Session 4: Questioning Strategies

### Introducing Discussion Map

The class is then introduced to the idea of using a “map” to lead successful discussions in which they learn to:

- Ask a broad question
- Listen to response and thinking
- Ask for evidence or explanation
- Ask for alternative opinions or ideas
- Lead back to the main topic

### Sink/Float Activity and Planning Sink/Float Questions

Next, participants plunge into an activity exploring sink/float concepts. Participants apply what they’ve learned about questioning strategies as they work in small groups to plan a series of questions to ask students who will take part in the next session—when participants will guide students through the same sink/float activity they’ve just experienced.

### Concluding the Session

The session ends with participants reflecting on what they have experienced and how this may influence their teaching.



### *Begin Session: Introducing Questioning (20 minutes)*

- 1. Display “?” slide (or transparency).** Project the transparency or PowerPoint slide that shows a large question mark—to intrigue students as they enter the room, and as the lesson begins.
- 2. Explain importance of questioning strategies.** Explain that teaching is a language-based profession, and that the ability to lead/facilitate successful meaning-building discussions, to inspire higher-level thinking, and to find out how students are developing their understanding are all grounded in the teacher’s ability to ask questions.
- 3. Describe how skillful questioning can enhance an educational experience.** While the topic of “how to ask questions” may seem unimportant to some, developing good questioning strategies is what elevates teachers to the level of being an “artist of discourse” in the classroom. To put it another way, a lack of good questioning strategies can seriously undermine a teacher’s effectiveness. Even the best activities can lead nowhere if they do not involve the thoughtful use of questions.
- 4. Carefully planned questions used in the course.** Point out that in previous sessions of this course, carefully thought-out questions were used to inspire higher-level thinking and further investigation.

## Session 4: Questioning Strategies

**5. Statements requiring a response can be categorized as questions.** Tell participants that a question can be defined broadly as any utterance that requires a response. Show how a question can be re-phrased as a directive statement, and alternatively how a directive statement can be re-phrased as a question. Refer to the examples below.

Question: What did you observe when you mixed the chemicals?

Statement: Describe what you observed when you mixed the chemicals.

Explain that in this session you will be using this broader definition of question—as any statement requiring a response.

### Describe the Object Activity

**1. Ask partners to describe first object.** Hold up the first object. Ask, “What do you observe about this object?” and “How might you describe this object to your partner?” Tell each team of two to observe and describe what you are holding up to their partner.

**2. Ask partners to describe second object; compare with first.** After about one minute, hold up the second object with your other hand. Ask, “What do you observe about **this** object?” and “How might you describe this object to your partner?” Tell them to observe and describe what you are holding in this hand, and compare it with what you are holding with the other hand. Ask, “How is this object the same or different from the other object?”

**3. Ask partners to describe third object; compare with first and second.** After another minute, set down the first two objects where they can be easily seen by the group, and hold up the third object. Ask them to observe and describe this object, and compare it to the other two objects.

**4. Ask what each object is in succession.** After about one minute, hold up the first object again and ask the fourth question: “What is this object?” Do this with each of the three objects in succession.

**5. Ask other focused questions about the objects.** Ask any other focused questions that seem appropriate, such as:

Which of these is from inside the body of an animal?

What kind of animal is this object from?

### Introducing Broad and Focused Questions

**1. Display “Two Types of Questions” slide.**

**2. Introduce broad and focused questions.** Explain that the questions you just used can be put into the two general categories—**broad** and **focused** questions.

## Session 4: Questioning Strategies

**3. Each type generates a different kind of response.** Emphasize that neither type of question should be considered “good” or “bad,” but that the two different types tend to generate different types of responses. For this reason, teachers need to try to be aware of the particular circumstances in which it’s best to use different types of questions.

**4. Identify questions 1–3 as *broad* questions.** Display *Questions for Discussion* transparency or slide, and say questions 1–3 fall into the category of *broad* questions:

**Questions 1–3:**

1. What do you observe about this object?
2. How might you describe this object to your partner?
3. How is this object the same or different from the other object(s)?

**5. Discuss how broad questions influenced discussion.** Ask participants to reflect on how these broad questions influenced them in their discussions. Allow ample wait time for participants to begin sharing their thoughts and observations. Their ideas may include the following:

- encouraged interacting with or observing the materials
- evoked more than one acceptable response
- opened up the discussion
- encouraged divergent thinking or different points of view

**6. Identify questions 4 and beyond as *focused* questions.** Tell them that questions 4–6 are in the category of *focused* questions:

**Questions 4 and beyond:**

4. What is this object?  
Any other focused questions you asked, such as:
5. Which of these is from inside the body of an animal?
6. What kind of animal is this from?

**7. Discuss how focused questions influenced discussion.** Ask about the effect of these focused questions on the small group discussions. Again, allow for a few participants to share their reflections. Among other responses, they may say:

- required recall of specific information
- focused responses on the topic of types of organisms
- kept the interchange short and to the point
- encouraged single, correct responses

## Session 4: Questioning Strategies

### Discussing How Teachers Use Broad and Focused Questions

**1. Display research quotes.** Have participants read the quotes and discuss with a partner what they think of these ideas.

True dialogue occurs when teachers ask questions to which they do not presume to already know the correct answer. (Lemke 1990, p. 55)

Seventy-five percent of the questions teachers ask are of a factual or literal nature. (Bromley 1992:139)

Teachers ask an average of seventy literal or factual questions in an average thirty-minute lesson. (Bromley 1992:139)

**2. Share what they discussed.** Ask if anyone would like to share with the group any thoughts that were discussed. Take several responses and encourage a dialogue among participants.

**3. Explain disadvantage of focused questions for initiating discussions.**

Suggest to participants that, in general, focused questions are not good for starting discussions. A common mistake made by educators is to attempt to begin a discussion by asking a focused question. When students do not readily respond, the teacher may then reword the initial question and provide hints about the specific response they expect. This clearly communicates to students that there are “wrong” ways of participating in the discussion and may discourage those who are not so certain about the answer from joining in.

**4. Ask several focused questions.** In order to graphically illustrate the effects of focused questions, ask the following questions, fairly rapidly, one right after the other:

- What kind of question usually works best for starting a discussion? [a broad question]
- What kind of question usually doesn't work well for starting a discussion? [a focused question]
- Am I using broad questions right now? [no]
- A discussion isn't starting, is it? [no]

**5. Ask a broad question.** Now pose a broad question and allow some time for participants to respond.

- What are some situations or goals for which narrow questions might be appropriate?

**6. Participants notice effects of different questions.** Point out that the first four questions you just asked were obviously all focused questions, and the last one was a broad question. Once again, ask participants to describe the different effects that the questions had on the class discussion.

## Session 4: Questioning Strategies

**7. Emphasize importance of using questions appropriately.** Introduce the idea that, just as focused questions are generally inappropriate for initiating discussion, teachers should not ask a broad question if they are looking for a specific answer or want to wrap-up a discussion. The important thing for a teacher to consider is the purpose for posing the question. Emphasize that focused questions are not inherently bad, but it seems that most educators under-utilize broad questions in the classroom.

**8. Focused questions are not necessarily easier to answer.** In thinking about why teachers ask so many focused questions, we should consider how a teacher's perspective can influence their choice of questions. To a teacher, it may seem as though a focused question is simpler and safer for students to answer than a broad question. Therefore, they may think they are making it easier for students to respond. The problem with this premise is that students may have differing abilities for remembering specific kinds of factual knowledge. For example, some may be very capable at recalling "big picture" ideas relating to a topic, but not be very good at remembering specific details. Focused questions can be more difficult for these students.

**9. Teachers may not feel comfortable with open discourse.** Another reason teachers may avoid using more broad questions could be their worries about fielding student responses that may be inaccurate or unpredictable. Many teachers also view the classroom environment as a place where it's necessary for the teacher to maintain control at all times. They see focused questions as a way to ensure that students engage in a briskly-paced exchange with the teacher, presumably helping to avoid behavioral disruptions. They may also be worried that open-ended discourse may lead to topics they themselves do not understand or that the discussion may range away from the main topic they seek to teach.

**10. Importance of encouraging student discussions.** However, the disadvantage in preventing students from raising divergent viewpoints and engaging in authentic discussion is that it may deprive students of the opportunity to exercise their critical thinking skills while participating in an open exchange of ideas. If we accept that students need to discuss and weigh new ideas to fully construct knowledge and understand science in a meaningful way, then we must provide opportunities in the classroom for this type of discussion to occur.

**11. Display Karen Gallas quote.** Call attention to the quote and explain that it's from a book that promotes what she calls "Science Talk" sessions with students, where they freely discuss their ideas without a lot of intervention from the teacher.

"Inquiry alone does not suffice. Children can construct rich meanings when presented with rich materials, but the meanings they construct, without reflection and discussion, are often diffuse, mysterious and laden with misconceptions." (Karen Gallas, *Talking Their Way Into Science*, 1995, p. 54)

## Session 4: Questioning Strategies

**Considering the Role of the Instructor (35 minutes)****Enacting and Discussing Skit #1**

**1. Introduce importance of teachers' role identification.** Tell participants that in addition to being aware of how different types of questions can influence classroom discussion, it's also very important to consider the impact of how instructors see/perceive their role, as related to student learning.

**2. Introduce skits.** Let them know that they will now watch two skits involving the interactions between a university astronomy professor and a student seeking help during office hours. Each skit illustrates a different viewpoint regarding the instructor's role, as well as some examples of both broad and focused questions.

*Note: Volunteers for the skits should be recruited before class, so that especially "the professor" has a chance to read the script ahead of time and prepare. When recruiting, select students you think able to project their voices and present the skit as per the written instructions. Or, the instructor of the class or an assistant can play the professor.*

**3. Volunteers present first skit.** Ask the two volunteers who were assigned to the roles of professor and student to come to the front. Give them their scripts for Skit #1 and keep one for yourself. Remind the volunteers to read their parts loudly and clearly, and to refer to the "acting" instructions in the script. Ask them to begin when they are ready.

*Note: Since you will later be using the questions from the following discussion as examples of a "discussion map," it's important to ask the following first four questions exactly as in the script.*

**4. Discuss the first skit using scripted questions.** Lead a discussion with the students asking the following questions:

- **How would you describe the interaction between the professor and student in the first role play?**
- **What about what the professor said or acted makes you think that?**
- **Does anybody have a different idea or opinion?**
- **How do you think the professor saw his/her role as an educator?**

**5. Focus on behavior of professor.** Consider bringing up some of the following points about the professor in Skit #1, as is appropriate:

- The professor's attitude was intimidating and condescending, i.e., "That's easy," "You mean *you're* confused," "Nope. Pay attention in the next lecture and you'll get it," and "Well, that's your problem. If you would just stop thinking and would listen, you'd understand."

## Session 4: Questioning Strategies

- The professor did not attempt find out what the student was thinking by using probing questions.
- The professor used a barrage of focused questions that could be “parroted back” without evidence of any real understanding:

**Professor #1:** That’s when we see the full Moon, right?

**Student:** Right.

**Professor #1:** So do you see that during the full Moon the Moon is always on the opposite side of the Earth from the Sun?

**Student:** Uh yeah. Yeah I see it. That’s when it’s full.

- The professor used a broad question when they were expecting a particular answer.

**Professor #1:** So now, knowing that, give me an explanation for tides on Earth.
- When the student responded to the broad question “incorrectly,” the professor gave a potentially demoralizing response:

**Professor #1:** Nope. Pay attention in the next lecture and you’ll get it.

## Enacting and Discussing Skit #2

**1. Volunteers enact second skit.** Tell participants they’ll now see how the same situation might play out with a different approach. Either use the same volunteers or ask for two new volunteers. Give them the scripts for Skit #2 and keep one for yourself. Remind the volunteers to read loudly and clearly, and have them begin.

**2. Use same questions to discuss second skit.** Following the skit, ask students to describe the interaction between the professor and student in the second skit, and how they think the professor saw his/her role as an educator. Use the following series of questions:

- **How would you describe the interaction between the professor and the visitor in the first skit?**
- **What about what the professor said or did makes you think that?**
- **Does anybody have a different idea or opinion?**
- **How do you think the professor saw his/her role as an educator?**

**3. Focus on behavior of professor.** Consider bringing up some of the following points about the professor in Skit #2, as is appropriate:

- The professor made an effort to validate the student’s point of view so as not to intimidate them:

## Session 4: Questioning Strategies

**Professor #2:** "That's understandable. Everybody gets confused, because it's difficult."

*and*

**Professor #2:** "You'd think that's what it would be called."

- The professor acted as a collaborator in investigating the answer:

**Professor #2:** "Let's try to figure this out."

- The professor handed the marker to the student:

**Professor #2:** "What side of the Moon do you think would be lit up?"

*and*

**Professor #2:** "What do you think the Moon would look like to us on Earth?"

- The professor provided a guided opportunity for the student to figure out the ideas for themselves:

**Professor #2:** "So where do you think the Moon would be when it appears full to us?"

- The professor acknowledged the reasonable nature of the student's less than accurate idea:

**Professor #2:** "A lot of people get confused by that, and sometimes it does. That's what we call a lunar eclipse."

- The professor asked questions that were appropriately focused, since the student's question was about a specific piece of information with a clear "right" answer.

**Professor #2:** "If the Sun is shining from this direction, and the Moon was here, what side of the Moon would be lit up?"

- The professor also asked a broad question to encourage thinking, but without expecting a particular response:

**Professor #2:** "Looking at the position of the Moon and Sun in relation to the Earth in this drawing, how do you think they might affect tides on Earth?"

- The professor replied to the student's response to the broad question with an accepting response, encouraging the student to continue grappling with the ideas.

**Professor #2:** "Again, that seems to make sense. It's more complicated than that but keep thinking about it, and we'll get to it in class."

## Session 4: Questioning Strategies

### Discussing the Role of the Instructor

**1. Introduce “guide on the side” and “sage on the stage.”** Explain that an educator’s use of questions in learning situations is often based on the role they adopt as an instructor. Share two well-known expressions used as shorthand to describe two possible roles—A instructor can act either as a “guide on the side,” or as a “sage on the stage.”

**2. Point out how “sage on stage” sees her/himself as transmitter of knowledge.** The first skit represents the “sage on the stage” instructor role, admittedly in an extreme version. The instructor sees him/herself as the *transmitter of knowledge*. The teacher sends out the information—the student receives it. There is a sense that the instructor is the recognized authority and the repository of information on whatever subject is being taught. This attitude can be described as, “I know about this and you don’t, so I’m going to tell you the right answer.” This reflects an idea of education as a process of an expert (the teacher) directly providing their knowledge to the novice (the student).

**3. Point out how “guide on side” sees her/himself as facilitator of learning.** The second skit represents the “guide on the side” instructor role. The instructor’s attitude in this case is one of shared inquiry, or of collaborators in an investigation, trying to figure out something together. In this role the instructor is a *facilitator of learning*. This mode of teaching focuses on the thinking, or cognition, of the student—the instructor allows students to express their ideas, encourages them to identify and confront any obstacles or conflicts, and then guides them to reinforce, alter, or replace their ideas.

**4. Pose question about whether it might ever be useful to be a sage on the stage.** Ask participants to turn to a partner and discuss this question:

Can you think of any situation where it might be appropriate to be a sage on the stage?

**5. Participants share ideas.** After partners have a few minutes to discuss the question, ask them to report any interesting ideas that came up in the discussion.

*Note: The above distinction is useful to get a very important point across, but in a fuller discussion it of course needs to be qualified and placed into non-stereotypical context. It’s also not intended to imply that these two approaches are mutually exclusive. Teaching takes place along a continuum that combines many approaches. Even the most seemingly straightforward classroom situation is made up of many complex learner-educator interactions. As with questions, there is a time and a place for many different pedagogical approaches.*

### Introducing the Discussion Map (10 Minutes)

**1. Introduce discussion map.** Educators have studied effective strategies for leading discussions, and have developed the idea of a “discussion map” to reflect how skilled discussion leaders tend to guide and encourage discourse. This map can be applied to discussions with any age group.

## Session 4: Questioning Strategies

**2. Display discussion map.** Project the overhead transparency or slide, *Discussion Map*, and read each step aloud:

- Ask a broad question
- Ask about the evidence for their explanation
- Ask for alternative opinions or ideas
- Lead students back to the main topic

Listen carefully to each student response and try to figure out their thinking.

**3. Point out importance of listening carefully after each response and following students' line of thinking.** Explain that these steps represent a useful *sequence* of questions a teacher can use, but they don't show how a teacher determines *which exact questions* to ask. The questions that are asked depend on carefully listening to each student response and doing your best to understand their thinking. The purpose is to raise ideas and encourage students to discuss their thinking. The most important factor in discussion-leading is following (and guiding) the natural flow of the exchange of ideas.

**4. Relate discussion map to the skit discussions.** Explain that the discussions you just led with them about the skits were structured using this map. Display the Discussion Map Example and review how they follow the discussion map.

**Ask a broad question:**

How would you describe the interaction between the professor and student in the first role-play?

**Ask about the evidence for their explanation:**

What about what the professor said or acted makes you think that?

**Ask for alternative opinions or ideas:**

Does anybody have a different idea or opinion?

**Lead students back to the main topic**

How do you think the professor saw his/her role as a teacher?

**5. Discussion map modeled throughout course.** Point out that other discussions from previous sessions of the course were also designed with this kind of discussion map in mind. Suggest that this discussion map model is well-suited for a teacher who seeks to facilitate students in constructing their own conceptual understanding. It allows for diverse ideas to emerge and for students to compare evidence for varying points of view.

**6. Describe flexible use of discussion map.** The discussion map idea is very useful, but it's not intended to be a full description of discussion-leading strategies. It works best when used as a flexible model to guide discussions, rather than a rote procedure to be followed step-by-step. Often each step of the cycle can involve multiple student responses, and student-to-student exchanges without the teacher intervening between each response.

## Session 4: Questioning Strategies

**Sink/Float Activity (30 minutes)****Introducing the Activity**

- 1. Describe plans for next session.** Say that a group of “questioning experts” will attend the next session to help them practice their questioning skills. Reassure them that the “experts” will actually be students (of whatever age is appropriate for *your* participants to teach). Tell participants they will have a chance to practice guiding student investigations using thoughtful questions.
- 2. Explain rationale for doing activity themselves.** Emphasize that before the students visit, it’s important for participants to engage in the activity they will be facilitating with the visiting students. Afterward, they will write up a plan for the questions they will use to guide their students’ explorations.
- 3. Explain the science content of the activity.** Tell participants that the fundamental idea students will explore in their sink/float investigations involves testing different objects in a tub of water. Objects dropped in the air will usually fall to the ground, but when some objects are placed in water they float. Students will investigate which types of objects float—and how an object’s shape, size, or composition may affect whether an object floats or sinks.
- 4. Point out different levels of access to science concepts.** Explain that this sink/float activity provides an opportunity for students of all ages to grapple with concepts relating to density, buoyancy, and surface tension. Point out that the science content can be approached at different levels—this seemingly simple activity can be used to initiate young children’s thinking about characteristics of floating and sinking objects, or it can involve older students in exploring more complex scientific concepts about forces that counteract gravity’s pull on objects.
- 5. Explain purpose of leading activity with students.** Testing objects in water will intrigue younger students who can investigate and explain it at an observational level, and it may also inspire them to explore and expand on their foundational understandings about surface tension, buoyancy, and density. Because the activity can be approached from different levels of experience and understanding, as a facilitator you’ll be challenged to try figure out “where” your students are. **The goal is to focus on questions that facilitate taking students further in their explorations and understanding.**

**Demonstrating the Activity**

- 1. Gather participants.** Ask all participants to gather around a sink/float station. Make sure they are standing in a large enough arc or circle so the materials are visible to everyone.
- 2. Explain first steps.** Tell them that their first task in their small groups will be to decide on a definition for sinking and floating. In other words, they need to develop the criteria that they will use to judge if an object sinks or floats.

## **Session 4: Questioning Strategies**

**3. Demonstrate making predictions.** Show participants how they will take turns picking up an object, predicting if it will float or sink, asking others in the group for their predictions, and then placing it in one of the sorting circles on the table depending on whether they think it will float or sink.

**4. Suggest what to do if they disagree.** Let them know that group discussion is encouraged, but if there is a disagreement about where an object should be placed, the person holding the object gets to decide where it belongs.

**5. Demonstrate testing objects.** After they've made predictions about every item, they will receive a tub of water to test each one. They will take turns picking up an item, testing it in the water, and deciding how to sort it. Depending on the results of their tests, they may choose to place objects in the circle they predicted, or they may change their decision. Multiple tests may be necessary before deciding where to place an object.

**6. Caution against students testing objects too quickly.** Point out that children are often tempted to simply toss all the items in the water, and test them all at once. It can be challenging to get them to slow down and think about each item, but this will be important for students to do to get the most out of the activity.

**7. Explain they may use a third sorting circle if necessary.** Point out that there is a third circle provided in case their group decides they need another classification grouping. Let them know that in their groups, they may also need to adjust or refine their definitions for sink and float as they perform their tests.

## **Experimenting at Sink/Float Stations**

**1. Form small groups and begin investigating.** Divide students into small groups so they are equally distributed at each station. Say they can begin exploring the objects as soon as they are assigned to a group and station. (A convenient method is six stations with groups of five to six participants at each.)

**2. Model using guiding questions to encourage investigations.** Circulate among the participants and pose questions to help guide their investigations. Some sample questions are:

- What kinds of things float?
- What kinds of things sink?
- Do small things float?
- Do large things sink?
- Will wax float?
- Will a large and heavy piece of wax float?
- Will metal float?
- Will a metal paperclip float?
- Will aluminum foil sink or float? Can you figure out a way to make it sink?
- How can a large and heavy ship float?
- What do you notice when you press down on something that is floating?
- Which seems more important, the material an object is made of, or its size?
- Why will some containers float when closed, but sink when open?

## Session 4: Questioning Strategies

**3. Provide more challenges.** If any groups finish the task, challenge them to try to :

- Make sinkers float
- Make floaters sink
- Make an object “fink” (remain suspended between the surface of the water and the bottom of the container)
- Explain why certain items float and others sink.

**4. Conclude sink/float activity.** After most of the small groups have finished testing and sorting their objects, either ask them to gather at a separate discussion area or collect the sink/float materials from their tables.

## Planning Sink/Float Questions (20 minutes)

**1. Describe preparing for the session with students.** Tell participants that they will spend the last part of this session preparing questions for the students who they will be interacting with in the next session.

**2. Emphasize reasons for planning questions.** Explain that when working with any students, it’s important to be able to think on your feet and improvise questions and responses, but it’s also a good idea to have an overall plan for questioning. Add that this exercise is helpful for several reasons:

- studies show that most teachers ask broad and focused questions randomly, or use only one type at a time.
- students can derive more meaning from a lesson when questions are thoughtfully planned to address specific learning objectives.
- without a plan, teachers often fall back on teaching in the manner in which they were taught.

**3. Display the Questions and the Learning Cycle slide.** Refer to the *Questions and the Learning Cycle* handout to describe how specific questions can work well for different parts of the learning cycle. Remind participants that each phase of the learning cycle has specific goals and thoughtfully asking questions can help students to achieve those goals. Explain that, for the most part, the visiting students will be in the invitation and exploration phases of the learning cycle while investigating the sink/float materials.

**4. Explain task.** Tell participants that, for the next 15 minutes or so, they will come up with a list of questions they will try out with students while they are doing the sink/float activities. Encourage them to focus on the goals for the earlier stages of the learning cycle (invitation and exploration), as well as using the discussion map as they plan their questions. They should also remember to include ample broad questions to encourage divergent thinking

**5. Distribute handouts.** Give participants the following handouts:

- Questions and the Learning Cycle
- Types of Questions Defined
- Discussion Map
- Question Planning Worksheet
- Sample Questions

#### **Session 4: Questioning Strategies**

**6. Explain recording questions.** Tell them they should describe their plan for questions on the *Question Planning Worksheet* provided. They can use some of the questions from the sample sheet, or write their own original questions.

**7. Provide time for writing questions.** Give participants a chance to work on the assignment in their groups. If there's not enough time, they can finish planning their questions as a homework assignment.

#### **Concluding the Session (5 minutes)**

**1. Participants write a Quick Write response for the session.** Tell each participant to get out a piece of paper and write their thoughts about how the session has affected their ideas. Display the following slide:

Summarize your thinking about questioning strategies, leading discussions, and the role of the instructor.

If you can, please include:

- How have your ideas changed?
- What do you think made your ideas change?
- How might you use this in your science teaching?

**Session 4: Questioning Strategies**

**Presentation Slides**

Slide 1: “?”

Slide 2: Questions for Discussion

Slide 3: Two Types of Questions

Slide 4: Research Quotes

Slide 5: Karen Gallas quote

Slide 6: Discussion Map

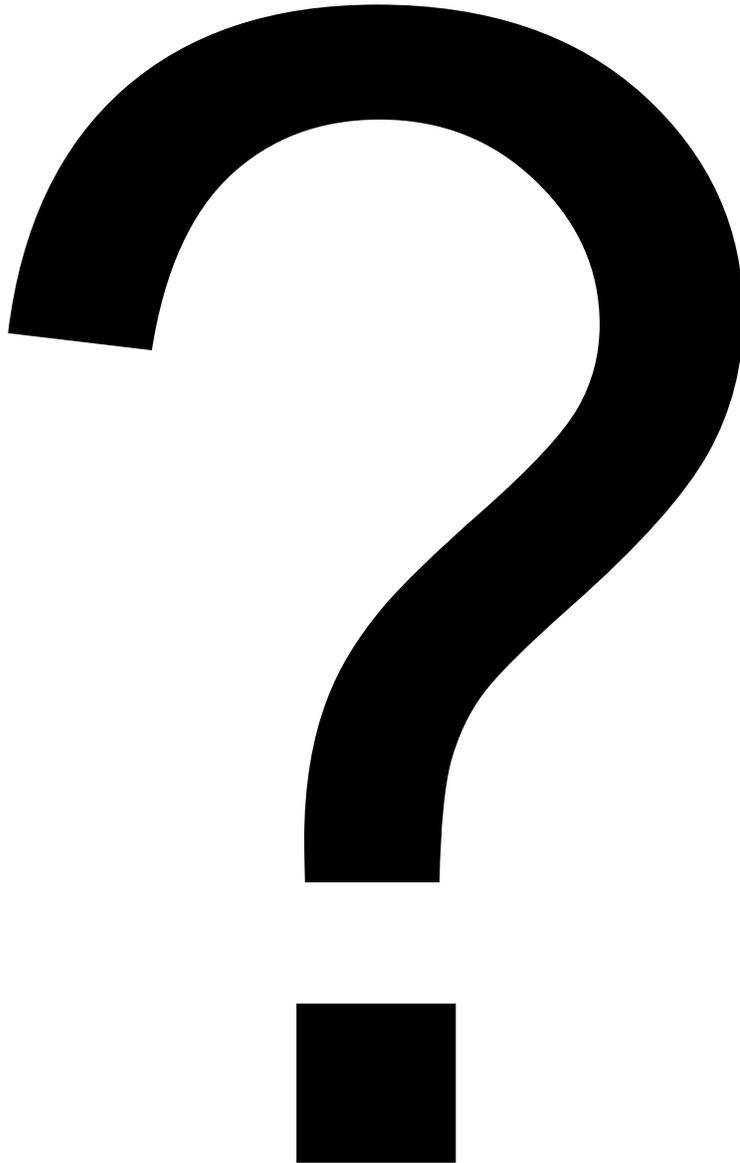
Slide 7: Discussion Map Example

Slide 8: Questions and the Learning Cycle

Slide 9: Use of Broad Questions

Slide 10: Use of Focused Questions

Slide 11: Quick Write prompt



# Two Types of Questions:

- Broad
- Focused

## **Questions for Discussion:**

- 1. What do you observe about this object?**
- 2. How might you describe the object to your partner?**
- 3. How is this object the same or different from the other object(s)?**
- 4. What is this object?**
- 5. Which of these is from inside the body of an animal?**
- 6. What kind of animal is this from?**

# Research Quotes:

True dialogue occurs when teachers ask questions to which they do not presume to already know the correct answer. (Lemke 1990, p. 55)

Seventy-five percent of the questions teachers ask are of a factual or literal nature. (Bromley 1992:139)

Teachers ask an average of seventy literal or factual questions in an average thirty-minute lesson. (Bromley 1992:139)

“Inquiry alone does not suffice. Children can construct rich meanings when presented with rich materials, but the meanings they construct, without reflection and discussion, are often diffuse, mysterious and laden with misconceptions.”

–Karen Gallas from *Talking Their Way Into Science*, 1995, p. 54

# Discussion Map

- Ask a broad question
- Ask about the evidence for their explanation
- Ask for alternative opinions or ideas
- Lead students back to the main discussion topic

**Listen carefully to each student response and try to understand their thinking**

## **Discussion Map Example**

### **Ask a broad question:**

- How would you describe the interaction between the professor and student in the first role play?

### **Ask about the evidence for their explanation:**

- What about what the professor said or acted makes you think that?

### **Ask for alternative opinions or ideas:**

- Does anybody have a different idea or opinion?

### **Lead students back to the main discussion topic:**

- How do you think the professor saw his/her role as an educator?

## **Questions and the Learning Cycle**

- **Invitation Stage**
- **Exploration Stage**
- **Concept Invention Stage**
- **Application Stage**
- **Reflection Stage**

## **Broad Questions**

- Have more than one possible answer
- Invite students to interact with materials and/or ideas
- Open up discussion and analysis
- Encourage divergent thinking and multiple points of view
- Involve higher-level thinking

## **Focused Questions**

- Have a certain response that is expected
- Help students recall specific information
- Focus discussion on a particular topic
- Keep discussion short and to the point

## Quick Write Prompt

Summarize your thinking at this point about questioning strategies, leading discussions, and the role of the instructor.

If you can, please include:

- How have your ideas changed?
- What do you think made your ideas change?
- How might you use this in your science teaching?

**Session 4: Questioning Strategies**

**Session Handouts**

Handout 1: Questions and the Learning Cycle

Handout 2: Types of Questions Defined

Handout 3: Discussion Map

Handout 4: Question Planning Worksheet

Handout 5: Sample Questions

## Session 4: Questioning Strategies

# Questions and the Learning Cycle

Consider the possible purposes for asking questions during different phases of learning.

**Invitation Stage:** Use questions to help generate interest, and help students focus on observations. Help students to connect past experience to a new topic of study.

- Have you ever seen...?
- Have you ever wondered...?
- What did you observe?
- Did you notice...?

**Exploration Stage:** Use questions to encourage students to explore new materials, properties and events. Guide students to engage in productive investigations.

- What happened when...?
- What did you discover?
- What do you think will happen if...?
- What do you think made that happen?
- What questions do you have about...?
- What could we do to find out?

**Concept Invention Stage:** Use questions to help students synthesize new understandings and make sense of investigations. Help students classify, categorize, quantify or order their observations. Have students use evidence from investigations to make explanations. Help students to draw conclusions, and make connections.

- What did you find out about...?
- How is this the same or different from..?
- Can you compare this to something else?
- What do you think is the explanation for...?
- Why do you think that...? What is your evidence?
- What might another explanation be?

**Application Stage:** Use broad questions to encourage reasoning and analysis. Involve students in authentic problem-solving situations and critical thinking. Help students to generalize their knowledge and test their hypotheses. Encourage students to apply new learning to other situations.

- What do you now know about the characteristics of...?
- What other factors do you think might be involved?
- Can you find a way to...?
- How can we use what we found out to solve a problem?
- How could you be more sure about...?

**Reflection Stage:** Use questions to encourage students to think back on what they have done and how they have made sense of what they have explored.

- How did you arrive at your solution or conclusion?
- Did you change any of your initial thinking?
- What caused you to see things differently?
- How did you figure out...?

## **Types of Questions Defined** (handout)

**Broad Question - A statement or question that anticipates a variety of acceptable and generally unpredictable responses.**

When an instructor asks such questions, they are hoping for unplanned, divergent outcomes. These questions require that the students utilize thinking processes in ways that are unique to the individual rather than planned by the instructor. Broad questions allow the student to make sense of and explore their own ideas freely, in their own terms, without restrictions and with only minimal guidance by the instructor. These questions are useful to encourage students to synthesize ideas, extend ideas, deduce and predict, or organize elements of what they've learned into a fresh pattern. Broad questions encourage students to share various ideas during a discussion and to value other students' ideas as they are expressed.

**Focused Question - A statement or question that anticipates a particular, predictable response planned by the instructor.**

A specific "correct" response or set of responses is anticipated when a teacher asks a focused question. Focused questions can require the student to remember information or recognize information that is readily at hand. This is useful to help students to recall a fact, define a term, identify something, or review a topic that has been learned. Focused questions can be used to confirm previous classroom experiences in order to help establish a base of information for new experiences. Focused questions can also help students to synthesize information in a particular way as guided by the instructor. Focused questions that ask students to integrate what they have previously learned are useful if you want students to compare, contrast, associate, explain, state relationships, or arrive at particular conclusions. "Compare," "tell," and "explain" can begin these kinds of integrating statements. Even though a predictable answer is asked for, students may give an explanation in their own words.

## Discussion Map

A teacher encouraging students to construct their own conceptual understanding can use a structure for questioning that encourages discussion and helps to “unpack” their ideas.

- Ask a broad question
- Ask about the evidence for their explanation
- Ask for alternative opinions or ideas
- Lead students back to the main discussion topic

**Listen carefully to each student response and try to understand their thinking**

### Roles for Teachers

*Guide on the Side:* Teachers who see themselves as facilitators of student learning, helping to direct individual student discoveries and acting as co-collaborators while investigating topics together.

*Sage on the Stage:* Teachers who see themselves as the primary bearers of information and understanding, experts whose role is to fill students’ “blank slates” with correct information.

**Session 4: Questioning Strategies**

# Question Planning Worksheet

## Invitation Stage —

Example: What kinds of things do you think will stick to a magnet?

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## Exploration Stage —

Example: Do you think this object will stick to a magnet?

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**Session 4: Questioning Strategies**

**Concept Introduction Stage -**

Example: Why do some things stick to magnets and others don't?

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**Application Stage –**

Example: Can you figure out a trick to get paper to stick to a magnet?

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**Session 4: Questioning Strategies**

**Sample Questions** (handout)

What is the first object you will test at the station?

What do you predict will happen?

Is that what you thought would happen?

Did any of the objects do something different than what you guessed?

What surprised you?

What have you discovered?

Is that what you thought would happen to the object?

Do you think this ball will float in water?

Do you think it will float if we try the same test again?

Are there more sinkers or floaters so far?

How many floaters are there?

Can you figure out a way to make the spoon float?

Why do some things float, and others don't?

Do you think all metals sink?

Do you think all soaps float?

Do you think all waxes float?

Do you think all wood floats?

Session 4: Questioning Strategies

## Script for Skit #1

**Student:** There are a couple of things I didn't understand about the phases of the Moon.

**Professor #1:** Why do you think you're having such a hard time with it?

**Student:** Uh, I dunno. The lecture was confusing.

**Professor #1:** You mean *you're* confused. OK, What didn't you understand?

**Student:** Well, when the Moon is full, what position is it in relation to the Sun?

**Professor #1:** (*Draws diagram of the Sun and Moon, and explains*) When the Moon is between the Earth and the Sun, that's the new Moon, when all we see is the dark side. As the Moon moves away from the Sun it waxes—we can see more of the Sun's reflected light. As it moves around to the side of the Earth opposite from the Sun, that's when we see the full Moon, right?

**Student:** Right. But wouldn't the Earth's shadow...

**Professor #1:** So do you see that during the full Moon the Moon is always on the opposite side of the Earth from the Sun?

**Student:** Uh yeah. Yeah I see it. That's when it's full.

**Professor #1:** Do you have any other questions?

**Student:** Yeah, when is it a quarter Moon and a half Moon?

**Professor #1:** That's easy. We call it a quarter Moon when it's here or here. It's called a quarter Moon because it's a quarter of the way around the Earth. Got it?

**Student:** Uh, yeah. Sure.

**Professor #1:** So now, knowing that, give me an explanation for the tides on Earth.

**Student:** Um. I don't know. I guess when it's a full Moon it would be high tide?

**Professor #1:** Nope. Pay attention in the next lecture, and you'll get it.

**Student:** But I thought that...

**Professor #1:** (*Spoken gently*) Well that's your problem. If you would just stop thinking and would listen you'd understand.

Session 4: Questioning Strategies

## Script for Skit #2

**Student:** There are a couple of things I didn't understand about the phases of the moon.

**Professor #2:** Well, that's understandable. Everybody gets confused, because it's difficult. What's your question?

**Student:** Well, when the Moon is full, what position is it in relation to the Sun?

**Professor #2:** Let's try to figure this out. (*Draws Moon between the Earth and Sun*). If the Sun is shining from this direction, and the Moon was here, what side of the Moon do you think would be lit up?

**Student:** The side towards the Sun.

**Professor #2:** And what do you think the Moon would look like to us on Earth?

**Student:** We would be looking at the dark side, so it would be a new Moon.

**Professor #2:** So where do you think the Moon would be when it appears full to us?

**Student:** Oh, on the opposite side of the Earth?

**Professor #2:** That seems to make sense.

**Student:** But wouldn't the Earth's shadow make it look dark?

**Professor #2:** A lot of people get confused by that, and sometimes it does. That's what we call a lunar eclipse. But usually all three are not exactly in the straight line necessary for the Earth to block the light from the Sun.

**Student:** Oh, I get it.

**Professor #2:** So what do you think the Moon would look like to us on Earth if it was here? (*Draws moon in quarter moon position.*)

**Student:** Hmm. I guess we'd see half of it lit up. Is that a half moon?

**Professor #2:** That is what you see, and you'd think that's what it would be called, but how far around the Earth is the Moon from the full Moon position to here?

**Student:** It's a quarter of the way around.

**Professor #2:** That's why it's called a quarter Moon. A little confusing, I know.

**Session 4: Questioning Strategies**

**Student:** No, I think I get it now.

**Professor #2:** Great. Now in our next class, we'll be talking about tides on Earth. Looking at the position of the Moon and Sun in relation to the Earth in this drawing, how do you think they might affect tides on Earth?

**Student:** I don't know. I guess the gravity of the Moon and Sun affects it somehow. Would it be higher tides on the sides the Moon and Sun are on?

**Professor #2:** Again, that seems to make sense. It's more complicated than that, but keep on thinking about it, and we'll get into it next class.

## ***Session 5: Question Lab***

# **Contents**

<b>Session Overview</b>	<b>2</b>
<b>Background Information for Presenter</b>	<b>3</b>
<b>Materials and Preparation</b>	<b>5</b>
<b>Instructor's Guide</b>	<b>7</b>
<b>Presentation Slides (also in separate PowerPoint)</b>	<b>18</b>

Session 5: Question Lab

## Session 5: Question Lab

### Overview

The *Question Lab* can be one of the most exciting and rewarding sessions of the *Communicating Science* course, because the course participants have the opportunity to interact directly with young students. The goal for participants is to attempt to put theory into practice in a safe environment—to apply their questioning plans in a real-life teaching context.

- If the invited students are children, participants get an added benefit in that some college students have not had much opportunity to be around much younger students, and may be a little nervous about how to work with and talk with them. Course participants quickly learn whether or not their questioning strategies are effective—the students let them know by the ways they respond.
- Through working with young students, participants also learn the importance of being flexible and realistic with their instructional plans.
- In addition to interacting directly with the students, in this session course participants have the opportunity to watch an instructor (one of the course presenters or someone of your choice) model how to lead a discussion with students.

The suggested Sink-Float activity is an excellent platform for this purpose. Some brief scientific background is provided on the next two pages.

The opportunity to see ideas about teaching and learning put into practice can be quite powerful. Just by watching how eager and excited children get about simple materials and discoveries—and seeing how hard it is for them to wait to be called upon when they raise their hands—can be an eye-opener for some course participants.

## Background Information for Presenter

### Possible Concepts to Focus on During the Sink/Float Activity

**There are a number of concepts and ideas that may come out of a discussion of the sink/float activity with visiting students.** In order to assist in making the discussions as fruitful as possible, we've provided a large number of conceptual goals and possible lines of questioning to guide the discussion, ranging from extremely simple to quite complex. Be sure to read through them to foresee some of the possible pathways for discussion. Choose one or more that you think will be appropriate for the visiting students, depending on whether they are elementary school children or university students.

The main science concepts that tend to emerge from this activity involve understandings about *density* and *buoyancy*. *Surface tension* can also influence their investigation results, and may also be a topic for discussion. Each of these concepts can be approached from an observable "macroscopic" level, or a more theoretical "microscopic" level dealing with the particulate nature of matter. Therefore, depending on the background and experience of the visiting students, the discussions can be approached at different levels of complexity and detail. Elementary school students tend to grapple with these concepts primarily on an observational level, starting with more basic observations and ideas, but they can often raise questions about the theoretical constructs as well. A few "sub-concepts" or "precursor concepts" for each of these topics are outlined below to illustrate how to build upon foundational ideas.

It's important, however, to acknowledge that these ideas are quite challenging, and to keep your expectations reasonable. During the session, elementary school students may have rich investigations and discussions on sinking and floating, but it's highly unlikely that they will leave the room understanding density. More likely, they will have made observations that add to their growing mental frameworks on this topic, and will have acquired a bit more experience and information that will help them understand the concept more fully in the future.

Older students may also approach these concepts from a macroscopic level, but with the added benefit of a larger conceptual framework and more exposure to generalized inferences. They may be able to gain a better understanding of more complex ideas through their discussions. Keep in mind, though, that older students with significant science background and opportunities to learn may *seem* to understand these concepts on a more theoretical level, but may still be limited in their understanding of molecules and how the molecular arrangement affects density and/or buoyancy. They may also be able to repeat formulas and definitions for density and buoyancy, without fully understanding the concepts.

## Session 5: Question Lab

### Concepts Involving *Density*

**Density:** a property of a substance that can be used to predict whether it will sink or float.

***Density Concept 1:*** Some materials tend to float, other materials tend to sink.

***Density Concept 2:*** You can predict whether or not something floats or sinks based on the material it is made of, as opposed to the size of the object.

***Density Concept 3:*** If the average density of an object is less than the density of water, it will float. If the average density of an object is more than the density of water, it will sink.

***Density Concept 4:*** Materials made up of molecules more tightly packed than those in water are more dense, and will sink. Materials made up of molecules more loosely packed than those in water are less dense, and will float

### Concepts Involving *Buoyancy*

**Buoyancy:** the upward forces involved in keeping something afloat

***Buoyancy Concept 1:*** Objects float when water pushes up on them and keeps them from sinking. Sometimes packing them into a smaller, more compacted shape can cause them to sink, and flattening them can cause them to float.

***Buoyancy Concept 2:*** An object floats if it pushes aside or *displaces* a certain amount of water to support its weight. An object sinks if the water that is displaced is less than the weight of the object.

***Buoyancy Concept 3:*** The upward force of a liquid on an object placed in the liquid is called buoyancy. For an object to float, the buoyancy force directed upwards must be equal to the downward force of gravity on the object, i.e., its weight.

***Buoyancy Concept 4:*** Increasing the amount of surface area of an object that is in contact with a liquid increases the liquid's ability to support the object, by increasing the amount of buoyant force that can be applied.

## Session 5: Question Lab

# Materials and Preparation

## Materials Needed

### For the class:

- one name-tag for each student and participant.
- dark-colored broad-tipped felt markers for making name-tags

### For the Sink/Float Activity:

- same materials as for the previous session (see Materials and Preparation for Session 4, *Questioning Strategies*)

### For the model discussion:

— one large transparent container, such as an aquarium. A plastic container is better than glass, because heavy objects dropped in the water could break the glass, unless you gently lower them in the water with your hands. (Note: the *Cambro 22SFSCW 22 Quart Square Food Storage Container – Clear* works well)

— A collection of rocks made of similar materials, but of many different weights, from grains of sand and pebbles to about 5 pounds.

— A collection of pieces of wax of many different sizes, from tiny pieces to about 2 pounds. (note: you can make the smaller pieces by breaking up a larger piece)

— A few different sets of *pairs* of objects made of the same material, with one of the objects being heavy (about 2–5 pounds) and the other being so light its weight is hard to even feel (like a tiny pebble). Multiple sets of each type will allow multiple teams of students to use them in their investigations. For example”

- wood (e.g., small log and sliver of wood or piece of toothpick)
- metal (e.g., large steel bolt and BB or tiny washer)

**Note:** It’s important that both objects in each pair of objects behave the same way in water (sink or float). Test your objects in advance. If you use a material like plastic, of which there are some types which float, and some that sink, make sure that both objects in your pair are made from the same kind of plastic, or at least behave the same way in water.

## Session 5: Question Lab

### Preparation Before the Session

#### For the Sink/Float stations:

- 1. Calculate materials needed.** Make sure that you have enough materials to set up as many stations as will be needed to accommodate one or two course participants working along with a few invited students at each work table.
- 2. Gather additional materials for investigations.** So that students can test both large and small samples of different types of materials, gather together materials on separate trays: on one tray place the rocks of different sizes you gathered (including sand grains), on another place the wax of different sizes. On other trays place wood, metal and whatever else you gathered.
- 3. Prepare questions for discussion.** Read through the Sink/Float discussion suggestions for sample questions and to decide which level of concept development you will attempt to pursue with the visiting students.

*Note on selecting the model discussion leader:* Since two parts of this class are designed as an opportunity for the course participants to witness and critique discussion-leading strategies, you'll need to have someone who is skilled and experienced at leading discussions with the age-level of students involved. This could be you but if this is not your strength, we suggest bringing in a guest teacher to do the modeling. Keep in mind, however, that no teacher is perfect and that, when analyzed, every teaching situation has room for improvement. That's one of the important lessons communicated in this session!

Regardless of who is doing the model teaching, it's of course, important to think through concepts you wish to highlight, and guide the students toward, as well as what kinds of ideas and responses you might expect from the students. For this particular discussion, it's also important to think about what discussion strategies to model for course participants. We've provided some examples in the script to assist in facilitating the discussions. The model teacher should review these prior to the session. There are additional notes to refer to in the Background for Presenter section.

- 4. Review discussion leading techniques.** Read through the "Discussion Leading Strategies" sheet to remind yourself of the important techniques that you will be demonstrating.

### Preparation on the Day of the Session

#### For the Sink Float Activity:

- 1. Set out materials for the Sink/Float stations.** Gather materials for groups of four to six as described in the Materials and Preparation section of the *Questioning Strategies* session.
- 2. Fill the dish tubs with water.**

## Session 5: Question Lab

**3. Set transparent water container and sink/float objects at front.** Set up the transparent container of water and some sink/float objects where everyone can see them. Set your trays of rocks, wax, wood, steel etc. in this same area.

**4. Assign a number to each table.** For each table, assign a number for the table, write this number on a piece of paper or sign, and set this paper on the table so the number can be easily seen.

**5. Number and set out name-tags.** Write numbers on name-tags to indicate which table students should go to as they enter.

**6. Set out name-tag instructions and pens.** Make a large sign with the following instructions on it, and set it next to the name-tags, along with some broad-tipped, dark-colored felt markers.

— Write your first name on a name-tag using big letters.

— Go sit at the table that matches the number on your name-tag.

## Instructor's Guide

### Session Objectives

In this session participants:

- experience the challenge and appreciate the importance of employing both planned and improvised questions.
- practice the use of different discussion-facilitating strategies including the discussion map, questioning directed toward specific concept understandings, and open-ended discussion of student discoveries;
- observe modeling of different discussion-facilitating strategies: including the discussion map, questioning directed toward specific concept understandings, and open-ended discussion of student discoveries.
- gain a sense of the diversity in student developmental levels, science backgrounds, and learning styles.
- observe classroom management approaches used with students.

### Time Frame

Total Workshop: 2 hours

Tape Recorder Activity (10 min.)

Sink/Float Activity (35 min.)

Sink/Float Debrief Discussion with students (25 min.)

Additional Sink Float Investigations (20 min.)

Wrap-up Discussion (25 min.)

Reflecting on the Session (5 min.)

## **Session 5: Question Lab**

### **Session Activities at a Glance**

#### **Introductory Tape Recorder Activity**

The session begins with a “tape recorder” activity that serves the main purpose of initiating interaction between course participants and the students, but also gets them to focus, and think about some of the subject matter in the subsequent activities. Participants also get a chance to find out a little about what their student knows about solids, liquids, and gases. Course participants pair up with visiting students and take turns telling everything they can think of about the given topics. The person not talking is the “tape recorder,” and their job is to listen attentively, and then attempt to repeat all that the other person said.

#### **Sink/Float Activity**

Course participants use the question plans crafted during the previous session to guide students in an investigation of which objects sink and which float in water.

#### **Model Discussion with Students**

The children then gather in the front of the room and sit facing the model teacher with the group of course participants seated behind them. The teacher leads the students through a discussion of the activity while demonstrating effective discussion-leading techniques for the participants to observe. The goals of the discussion for the visiting students are: to encourage them to share their ideas and discoveries so far, to seek evidence to answer their questions, and to leave them with ideas and questions for further sink/float investigations.

#### **Additional Sink/Float Investigations**

The visiting students return to their tables and the class participants guide them through more investigations as they try to answer questions that arose from the discussion.

#### **Wrap-up Discussion**

After the visiting students leave, the course participants debrief the whole experience in both small and large group discussions.

#### **Reflecting on the Session**

Finally, the participants write about how the session has influenced their ideas on questioning and teaching.

## Session 5: Question Lab

 **Starting the Class**

- 1. Seat participants in working groups.** Ask course participants to sit at the activity tables with the same group they worked with in the previous session. Let them know that a few visiting students will be joining their teams—remind them to welcome them, and engage them in conversation as they arrive.
- 2. Seat visiting students at tables.** As the students arrive, ask them to make a name-tag, with their first name in large letters. Explain that the number that's pre-written on their name-tag assigns them to a table. Have them find the table with that number and join that group.
- 3. Signal for attention from whole group.** Once all the students are seated, use some sort of signal to get the attention of the whole group. Ideally, this should be done by modeling a student-appropriate strategy, such as hand clapping rhythms or quiet hand signals. Continue to use this attention-getting strategy throughout the lesson.

### **Tape Recorder Activity (10 minutes)**

- 1. Introduce activity.** Let everyone know they'll be starting off with a quick activity called "tape recorders" to get to know each other. One person in each pair will be the "talker," the other the "tape recorder." Later, they'll switch roles.

*Note: Ideally this activity should involve teams of two, with one student and one course participant in each pair. If you do not have enough students, then you could have teams of three or more, but with only the student and one of the course participants actually doing the activity. The others would be mainly observers..*

- 2. Explain roles.** Explain that the "talkers" role will be to say all they can think of about the topic you give them, until you say, "stop." The "tape recorders" job will be to listen to everything the "talker" says until you say, "stop," then they should try to repeat back as much of what the "talker" said as possible, as if they were a tape recorder.
- 3. Have participants begin.** Say that the course participants will be the first "talkers," and students the first "tape recorders." Give course participants a few seconds to check in with their students and make sure they understand their role.
- 4. Introduce first topic.** Tell course participants that when you say, "record" they are to share experiences in science they remember from their time in elementary school. Repeat the topic, then announce, "tape recorders—ready—record," then say, "talkers—start talking."
- 5. Students repeat back what participants said.** After a couple of minutes, announce, "stop." When all have stopped, tell them to "rewind" (some

## **Session 5: Question Lab**

instructors have fun making rewinding tape noises here) and have students “play back” what they heard.

**6. Students and participants switch roles.** After a couple of minutes gain the attention of all groups, and tell them they will now switch roles. The students will be the “talkers” and the course participants will be the “tape recorders.”

**7. Students talk to participants.** Tell the “talkers” that they will tell all they can think of about solids, liquids, and gases. Repeat the topic, and make sure everyone is clear on their role. Repeat the topic again, then announce, “tape recorders ready—record,” and “talkers start talking.”

**8. Repeat process for playing back recording.** Have them talk for a couple of minutes. Then again announce, “stop,” then “rewind” and “play.”

## **Conducting Sink/Float Activity (35 minutes)**

**1. Introduce Sink/Float activity.** Regain the attention of the whole group and tell them that the visiting students will be doing a science activity led by the course participants.

**2. Provide last-minute instructions.** Remind course participants to have students work with one object at a time, and not rush through the activity. Explain that when they’ve finished with their predictions, they can come up and get a tub of water for their investigations.

**3. Participants guide students in Sink/Float activity.** Have the course participants begin working with the students at their tables, using the questions they’ve prepared beforehand. They should continue engaging the visiting students until you call time.

## **Discussing Sink/Float Activity (25 minutes)**

**1. Gather students for discussion.** Have visiting students move to an area away from the work tables, where the course participants can watch you lead the discussion. It works well to have the students sitting in a close group at the front of the room with the course participants sitting behind the group.

**2. Set transparent water container and sink/float objects at front.** Set up the transparent container of water and some sink/float objects where everyone can see them. Use these throughout the discussion by periodically having students come up and show others what they’re talking about. If your group disagrees about a particular object, or are unsure, test it together. Before testing objects, have the students predict what will happen using partner shares (telling a person near them) or hand signals (thumb down for sink, thumb up for float, thumb to the side for unsure).

**Session 5: Question Lab**

*Note: Doing occasional tests of objects in the tank in front of the group helps keep the students interested, settles disagreements, and keeps the discussion focused on **evidence** from their investigations. Periodic predictions with partner-shares or hand signals helps keep everyone engaged and focused on what is being tested.*

*Note: If you are using a glass container, be sure not to drop heavy objects in it. Instead, use your hands to gently lower heavy objects to the bottom of the container.*

**3. Lead discussion about discoveries.** Model how to lead an open-ended discussion with the visiting students. Focus on trying to encourage them to make sense of and synthesize what they've learned from the sink/float activity. Encourage students to speak loudly when it's their turn, and if they do not, repeat what they've said loud enough for course participants to hear. You may want to use a general discussion map format to lead the discussion about what they discovered about sinking and floating objects.

**4. See notes for leading a content-driven discussion.** If you want to focus further on specific concepts related to understanding density, you may want to refer to the following examples of possible discussions that could be pursued. With elementary school students a combination of discussions #1, #2, or #3 often works well. Discussion #4 is more appropriate for middle school or higher. If you're working with older students, they may also refer to concepts related to surface tension and or buoyancy.

***NOTE:** Due to the nature of an open-ended discussion, it's not possible to predict exactly where the conversation will lead. It's important to have goals for the discussion, but it's just as important to be flexible, to listen to students' thinking, to stop or redirect questions before students get frustrated or bored, and to be ready to head in a completely different direction, if necessary. For a more focused and productive discussion, you may also want to plan some specific science concepts to address in your discussion. See the notes below for more information about various science topics related to the activity that might be appropriate for your students.*

**5. Write statements with investigation potential on board.** During the discussion, if students make statements, such as, "pointy things sink, but things that are spread out float," write them on the board if they seem like ideas students might be able to investigate in their follow-up investigations to see if they are accurate.

**Discussion Example #1:****Which Kinds of Materials Tend to Float or Sink?**

**1. Ask a broad question about floating and sinking objects.** Direct attention to the tray of sink/float objects at the front of the room. Challenge them to make a statement about what kinds of things float or sink without "tricks." For young students, ask, "Can you make a statement like—all yellow things float?" Then add, "That's a silly example, because we know that all yellow things don't float. But can you think of an accurate statement like that, but that isn't silly?" Here are examples of some possible student responses:

Session 5: Question Lab

Heavy things sink  
 Metal things sink.  
 Plastic things float.  
 Big things sink.  
 Small things float.  
 Things with air in them float.

*Note: The reason we used the phrase “without tricks” for this discussion is because a floater can be made into to sink by putting something on top of it, or a sinker made to float by placing it on something that floats, and so on. With young students, we’ve referred to these as “tricks.” For this to be a focused discussion the “tricks” would distract. There may well be other hands-on situations, however, when a teacher might encourage such inventive tricks, asking, for example, “Can you find a way to make that sinker float?”*

**2. Ask students for evidence or examples.** With each response, either ask the student(s) to demonstrate examples of their statement with the provided materials, or go ahead and show them yourself using the materials.

**3. Ask about alternative ideas.** After a few corroborating examples, ask if any students can demonstrate an example that doesn’t fit the statement. For example, if a student says “plastic things float,” ask if anyone found any plastic that didn’t float. Or you can show how a plastic spoon, a plastic container, and a plastic toy all float, but then demonstrate a sinking piece of plastic. You can then help them modify the statement to make it more accurately reflect your data, for example, “most of the plastics we tested float.”

**4. Encourage students to summarize their conclusions from the discussion.** Ask, “So what can we now say about the types of objects that float.” [e.g., things made of certain kinds of plastic, and of wood, float.] In the same way, you may want to move on to discussing the kinds of things that sink. With very young children it may be sufficiently challenging for them to conclude that some materials tend to float and others to sink.

**Discussion Example #2:**

**Do heavy things sink and light things float?**

**1. Write question on board.** Write the following question on the board, and ask it aloud:

**Do heavy things sink and light things float?**

**2. Challenge students to use examples from their investigations to help answer the question.** With each testable example they bring up, have other students predict what will happen, test it together, then help them use the results to try to answer the question. For example, if a student says, “I tested a rock, and it sank. Rocks are heavy, and heavy things sink,” ask the child to demonstrate with a rock, ask others who tested other rocks to either report what happened or to show with their rocks what happened.

## Session 5: Question Lab

**3. Challenge students to use examples from their lives to help answer the question.** Encourage students to think of examples they have observed in their lives, though they may not be testable in the classroom. For example, a student may say, “ships are heavy, but they float.”

**4. Introduce testing a rock and a piece of sand.** Now show students a rock and a tiny piece of sand and explain that they are both made from the same material. Before testing them, allow some students to compare the weight of the two, to verify that one is “heavy,” and the other is “light.”

**5. Ask for predictions.** Ask students to predict to a partner whether each will sink or float, knowing that they are both made of the same material, but one is heavy and one is very light. Have students explain their thinking to a partner and then have a few students share out their explanations for their predictions.

**6. Do the sink/float test with rock and sand.** One at a time test the rock first, and then the sand grain, and let them notice that they both sink. Ask if it’s true that heavy things sink. Ask if it’s true that light things float.

*Note: When some students say, “heavy things sink and light things float,” they may actually be referring to the fact that more dense materials sink, and less dense materials float. Make sure to ask probing questions to try to reveal students’ thinking.*

### Discussion Example #3:

#### Can you tell if something will sink or float by knowing what material it is made of?

**1. Write question on board.** Write the following question on the board, and ask it aloud:

**Can you tell if something will sink or float by knowing what material it is made of?**

**2. Challenge students to use examples from their investigations and their lives to help answer the question.** As before, with each testable example, have other students predict what will happen, test it together, then help them use the results to try to answer the question. Encourage them to also use examples they’ve observed in their lives, but that may not be testable in the classroom, to help answer the question.

**3. Predict if tiny and large pieces of wax will sink or float.** Show students a small piece of wax and ask them to predict whether they think it will sink or float. Test it in water for them, and point out that it floats. Now show them a large piece of wax (for example, a large candle). This time allow a few students to hold it and feel its weight before predicting.

## Session 5: Question Lab

**4. Do the sink/float test with large, tiny, and other sizes of wax.** Test the large piece of wax, and point out that it floats. (This will probably be surprising to younger students.) Hold up other pieces of wax of different sizes and ask for quick predictions about sinking and floating, and test each one. Tell them that even a piece of wax the size of a house (or larger) would float, even though they can't test it here.

**5. Bring them back to main question.** Ask if they could tell if the objects would sink or float by knowing what material they were made of (wax).

**6. Ask if knowing something is made of rock material helps predict if it will sink or float, then test them.** Show students rocks of different weights, and ask students if they think they could predict if they will sink or float by knowing what material they are made of (rock). Ask for their predictions, and quickly test them.

*Note: There are some rocks, such as pumice, that do float, which may confuse the issue with children. If students mention these examples, acknowledge them, and help them to adjust their statements to include this information. For example, write "Most rocks sink, but not all rocks." This is also true for crayon wax, e.g., some crayons sink, and some float. If this seems confusing to students, point out that there can be different types of crayons.*

**7. Extend concept to other materials.** Ask students if they tested any other objects that were made of the same material, but were different weights (i.e., objects made from wood or plastic). Ask them if the different size objects behaved the same, as far as floating and sinking in water.

### Discussion Example #4:

#### What is it about a material's make-up that causes it to float or sink?

**1. Have students generate explanations about sinking.** Ask students what they think it is about a rock that makes it sink? Accept several responses and encourage them to share their reasoning. If they say that a rock is heavy, you can ask if they think a tiny piece of sand is heavy.

**2. Discuss various explanations for floating.** What is it about wax that makes it float? Take several responses. If they focus on its weight, you can ask if a large piece of wax is very light.

**3. Point out properties of Styrofoam and wood.** Ask—What is it about Styrofoam or wood that makes them float? Students may say these materials have more air in them. If so, point out examples that support the idea, such as the air spaces in Styrofoam or in a sealed container. You may also point out a material like wax, which seems to contradict the "contains air" hypothesis, and ask them what else could explain how wax behaves.

## Session 5: Question Lab

**4. Discuss arrangement of particles or molecules.** Ask students how they think the particles or molecules that make up a substance might affect its floating or sinking properties. Students may say that materials that sink are more tightly packed together, or that the molecules in the substance are closer together. They may say that closer-packed substances are more dense.

**5. Raise the idea of density, as appropriate.** Be careful not to give out vocabulary or ideas students are not yet ready for. However, if they do use the term “density,” be sure to ask them to describe what they mean by the word. If they are expressing a fairly concrete understanding of the concept, then you may want to introduce density as a scientific term related to how molecules are arranged in a substance.

**6. Encourage students to summarize their conclusions from the discussion.** Have students try to create statements that describe what molecules have to do with whether an object floats or sinks. They may say—Materials made up of molecules that are more tightly packed than those in water are more dense, and will sink. Materials made up of molecules that are more loosely packed than those in water are less dense, and will float.

### **Additional Sink/Float Investigations (20 minutes)**

**1. Introduce further investigations.** While students are still seated at the discussion area, let them know that they’ll have another chance to explore some of their questions about floating and sinking. Back at their tables they will try to test their ideas using the same or new materials.

**2. Describe available materials.** Say that you have some large and small pieces of wood, wax, steel, and rock to use in their tests, and show them these materials. They must first describe their investigation to the adults at their table and then they will gather any materials they need. Have an adult class participant from each table come to retrieve the materials as requested by the visiting students.

**3. Assist as they investigate.** Circulate to all the groups, ask questions, lend a hand, make suggestions, and enforce classroom rules.

**4. Conclude sink/float investigations.** Provide the class with a 5-minute warning before they have to conclude their investigations. At the designated stopping time, use a signal to get their attention. You may also want to give instructions for cleaning up materials.

**5. Excuse visiting students.** Thank the visiting students (and any chaperones who accompanied them) for their participation and have them leave the room.

## Session 5: Question Lab

**Wrapping Up the Session (25 minutes)****Debriefing the Experience with Students**

**1. Display “Discussion Prompts about Experiences with Invited Students” slide.** Have partners share their ideas and observations with each other. After a few minutes, have the partners share their reflections with the group sitting at their tables.

**Discussion Prompts About Experiences with Invited Students**

1. Describe the interactions with students that went well. What is your evidence that they went well?
2. What kinds of questions proved to be most successful? What is your evidence that they were successful?
3. Describe interactions that *didn't* go well, and what kinds of questions were *not* successful. What is your evidence?
4. What would you like to do differently next time?
5. In what ways do you think this experience will be different in the classroom? What do you think you will have to do differently?
6. What did you learn from this experience?
7. What do you think your students took away from the experience? How do you know?

**2. Lead a whole group discussion.** Ask participants to share what they discussed in small groups. Be sure to ask them how their plans went, and if they had to improvise and/or diverge from them.

**Debriefing the Modeled Discussions**

*Note: It can put some course participants in a slightly awkward position to ask them to critique the model teacher's performance, and they may be reluctant to say much. This discussion is much easier if the person who did the model teaching is able (and willing) to share self-critiques, including ideas about how they could have been more effective.*

**1. Describe challenges.** Point out that the whole group discussion was an unusually challenging situation for the instructor. If you had a variety of ages of children in your group, point out that some of the activities and discussion may have seemed inappropriate for some of the students. Explain that at various times, the discussion was geared to different levels of students to try and keep everyone involved.

**2. Lead whole group discussion.** Ask participants to share any part of the modeled discussion they found particularly interesting. During the discussion, you may decide to use the discussion map as a format to help expand on the participants' ideas.

## Session 5: Question Lab

### Discussion Map:

- *Ask a broad question*
- *Ask for evidence or explanation*
- *Ask for alternative opinions or ideas*
- *Ask a question leading back to the topic*

**4. Focus on teaching strategies used.** Ask what teaching strategies they noticed being modeled, including attention-getting, discipline-related, and discussion-leading strategies. If they don't bring them up, point out any discussion strategies that were modeled (discussion map, specific concept questioning, and/or concept discussion based on asking what students discovered).

**5. Discuss how strategies impacted discussion.** Ask how they think these strategies affected the discussion and the students' participation.

**6. Offer feedback.** Ask the person who did the model teaching to share any part of the discussion where they wished they had dealt with a situation differently. Invite the students to offer their ideas about alternate choices as well.

## Reflecting on the Session

**1. Participants reflect on what they have learned from the session.** Display the Quick Write slide, and ask them to write for a few minutes on the topic.

**Write about how the session has influenced your ideas on questioning and teaching.**

**2. Preview topic for next session.** Tell participants that in the next session they'll have an opportunity to witness additional model teaching, and to learn more about how best to respond to a variety of student responses.

**Session 5: Question Lab**

## **Presentation Slides**

— **Discussion Prompts**

— **Quick Write**

## Discussion Prompts

1. Describe the interactions with students that went well. What is your evidence that they went well?
2. What kinds of questions proved to be most successful? What is your evidence that they were successful?
3. Describe interactions that *didn't* go well, and what kinds of questions were *not* successful. What is your evidence?
4. What would you like to do differently next time?
5. In what ways do you think this experience will be different in the classroom? What do you think you will have to do differently?
6. What did you learn from this experience?
7. What do you think your students took from the experience? How do you know?

# Quick Write

Write about how the session has influenced your ideas on questioning and teaching.

**Session 6: Promoting Discussion**

# **Session 6: Promoting Discussion**

## *Contents*

<b>Session Overview</b>	<b>2</b>
<b>Background Information for the Presenter</b>	<b>3</b>
<b>Materials and Preparation</b>	<b>7</b>
<b>Instructor's Guide</b>	<b>9</b>
<b>Session Handouts</b>	<b>16</b>
<b>Presentation Slides (also in separate PowerPoint)</b>	<b>29</b>

## Session 6: Promoting Discussion

### Overview

Perhaps the only thing as important to good teaching as questioning strategies is *responding* strategies! There is much research supporting the idea that the ways in which a teacher responds to students' questions, answers, and ideas can profoundly influence the learning environment and tone in a classroom.

Is the environment one in which it is safe to share your ideas and to ask what you don't know? Is critical and original thinking valued by a teacher, or just right answers?

Promoting discussions that draw in all students can help a teacher understand what students are thinking, and help to create an open intellectual environment where students learn through discourse.

This session focuses on how teachers can build upon students' diverse responses to questions to engage them in learning through discussions. It offers a number of practical discussion-leading strategies. Through a series of engaging activities, these strategies are modeled and background information supporting their use is provided.

## **Session 6: Promoting Discussion**

### **Background Information for the Presenter**

Forums for discussions of ideas have the potential of providing the most powerful experiences for learning. But sometimes discussions can also be frustrating experiences. From the student's perspective, most of us only need to remember back to the humiliation of: being told one's idea was wrong; the embarrassment of being singled out for an answer; the frustration of being constantly overlooked in favor of a more vocal student; or the feeling of being left behind in a discussion that you don't quite understand. From the teaching perspective, one learns very quickly how a few very vocal students can dominate a discussion; how challenging it can be to engage the reluctant-to-speak student in discussion; how off-track responses, if not handled well, can derail a discussion; and of how tricky it can be to communicate accurate information without discouraging participation by students who contribute inaccurate information. The response strategies discussed in this can make a huge difference in the number of students who respond, as well as the quality of their responses.

#### **Using Wait Time**

The concept of "wait-time" as an instructional variable was originated by Mary Budd Rowe (1972). The "wait-time" periods she found—periods of silence that followed teacher questions and students' completed responses—rarely lasted more than 1.5 seconds in typical classrooms. She discovered, however, that when these periods of silence lasted at least three seconds, many positive things happened to students' and teachers' behaviors and attitudes. To attain these benefits, teachers were urged to "wait" in silence for three or more seconds after their questions, and after students completed their responses (Casteel and Stahl, 1973; Rowe, 1972; Stahl, 1990; Tobin, 1987).

These studies found that when students are given three or more seconds of undisturbed "wait-time," there are certain positive outcomes: the length and correctness of their responses increase; the number of their "I don't know" and no answer responses decreases; the number of volunteered, appropriate answers by larger numbers of students greatly increases; and the scores of students on academic achievement tests tend to increase. When teachers wait patiently in silence for three or more seconds at appropriate places, positive changes in their own teacher behaviors also occur: their questioning strategies tend to be more varied and flexible; they decrease the quantity and increase the quality and variety of their questions; they ask additional questions that require more complex information processing and higher-level thinking on the part of students. Considering the benefits of implementing such a simple strategy in the classroom, we highly encourage course participants (and instructors!) to employ wait time after asking questions in class.

#### **Handling Dominating Students**

Dominant students can be a real problem during open-ended classroom discussions. As reported in "The One or Two Who Talk Too Much" (1988), researchers Karp and Yoels found that in classes with fewer than forty students,

## Session 6: Promoting Discussion

four or five students accounted for 75 percent of the total interactions per session. In classes with more than forty students, two or three students accounted for 51 percent of the exchanges. In the session handout, we offer several ways to handle dominating students. Classroom structures such as discussing in small groups, assigning specific roles for students or placing a time limit on responses can help provide more space for less dominant students to participate. Providing an initial pre-thinking activity such as talking with a partner or jotting down ideas, can help more quiet students to gather their thoughts. Being transparent about your intentions to have everyone participate and asking for other students to contribute ideas can also encourage the dominant student to step-down and others to step-up to the discussion.

### Hand Raising During Discussions

The use of hand raising can be controversial in the classroom, as there are both benefits and drawbacks to employing this strategy. According to Dixon, Egendoerfer, Taylor, and Clements, when students were observed conversing with their friends in an informal setting prior to the introduction of the new social norms, they were animated, excited, quick to correct each other, and they appeared to be consumed by whatever topic was at hand. This was a stark contrast to what was observed during the phase of the study during which the “raise your hand” rule was in place in their mathematics classrooms.

They noticed that students had consistent, observable patterns established in regard to raising their hands. The videotapes confirmed that many students would raise their hand to speak, but as soon as a student was selected to speak, the other students appeared to disengage. It was as if they assumed that if they were not chosen, they no longer needed to be active participants in instruction. It appeared at times that students were completely uninterested in the lesson being taught. The same students would raise their hands to participate while other students would sit daydreaming or drifting during instruction. It was observed frequently that while one student was answering a question, others would sit with their hand up. This may have been an indication that although they were engaged in the topic at hand, they were most likely thinking of what they wanted to say next, instead of listening to the student who was speaking.

However, when students were given the ability to talk directly to one another without first needing to raise their hands, several things happened. First, students stayed engaged in the conversations. They seemed to realize that they would have an equal opportunity to share their ideas. Within the context of this setting, they were invigorated and excited to converse with their peers. Most importantly, they began to understand that mathematics was something to explore. Perhaps they could see that getting correct answers was not as important as sharing ideas and exploring the mathematical concepts.

On the other hand, in her book *The Art of Inquiry* (1995), Nancy Cecil offers this advice: “When you ask questions, do not recognize students who shout out responses; instead, insist that they raise their hands and wait to be called upon before they respond. Though many teachers worry that such rules are unnecessarily rigid and other teachers are delighted when they hear immediate

## Session 6: Promoting Discussion

responses shouted out, such behavior results in unequal interactions. Boys tend to be more vociferous than girls in class, for example. On the other hand, children from certain cultural groups are taught at home to be polite and even self-effacing; they too are usually overshadowed by children who shout out answers. (Davidman, 1994)“

In addition, Michael Linsin (*Dream Class*, 2009) points out several drawbacks to allowing students to “call out “ in response to a question. He points to effects on the overall discussion, interrupting the flow of ideas, and possibly halting it completely. He also emphasizes the equity issues involved in having more vociferous students or those who are more socially confident—and sometimes even rude—receive undue recognition for their classroom contributions. However, his most compelling argument is that good teaching allows students to form their own ideas, opinions, and conclusions before an answer is revealed or a thought expressed. He points out that students need time—even if it’s just a few seconds—to puzzle over presented material before discussion takes place.

### Calling on Boys versus Girls

Current research confirms that teachers tend to call on boys more often than girls, accept more call-out responses from boys than girls, give boys more wait-time to respond, and give boys more praise and remediation than girls (Sadker & Sadker, 1994; Biklen & Pollard, 1993). Teachers usually are not aware that they favor the boys in their classroom over girls and are genuinely surprised when they learn of these inequities as they conference with trained observers or watch videotapes of their teaching. (Wellhousen & Yin, 1997). Becoming more attentive to the issue of balance between boys’ and girls’ participation can be helpful for all teachers.

### Encouraging Students

In her book *Tools for Teaching* (1993), Barbara Gross Davis offers some very useful information about encouraging reluctant students to participate in discussion. She suggests using simple, yet effective, non-verbal cues that indicate interest such as smiling expectantly, nodding as people talk, and maintaining eye contact with students. There are also various less-threatening ways to include students, by asking simple or casual questions of quieter students, asking what others think about a previous statement, or even having students use hand signals to indicate agreement and disagreement on a topic. She also points out that quiet students are not necessarily uninvolved and to avoid “picking on them” to draw them out. You may also provide these students with opportunities to participate in a small group discussion and assign them to report out for the rest of the group. Something as simple as writing their responses on the board can help to boost their confidence in making contributions to the class.

Many educators also emphasize the importance of avoiding any type of disapproval for unexpected answers, which may inhibit student participation or interrupt their thinking and learning. More supportive ways of responding to incorrect answers are: asking probing questions to try to understand the thinking behind the response; offering an empathetic response showing you

## Session 6: Promoting Discussion

understand how they arrived at that answer and/or how difficult it is to understand; and merely suggesting re-testing to be sure of results.

### Types of Teacher Responses

As stated before, how a teacher responds to students can contribute greatly to creating a classroom climate that is open to inquiry and discussion. A teacher who takes on a collaborative role during a meaning-making discussion and emphasizes hearing a variety of voices and collectively sorting out ideas, allows students to be responsible for their own learning and to express themselves more freely. One way to encourage this type of higher-level thinking and active engagement with students is for the teacher to offer accepting responses. By communicating that all answers are important and contribute to group understanding, an accepting response indicates that everyone's ideas and thinking are valued. According to Cecil (*Art of Inquiry*, 1995) "non-judgmental acceptance of all ideas generates the greatest amount of critical and creative reflection." This is why broad questions, for which a variety of responses are possible, go hand-in-hand with accepting responses. In fact, if a student responds to a broad question and is met by an evaluative or corrective teacher response, it indicates to the student that the teacher is really fishing for the right answer, and not trying to engage in open discussion.

In contrast, if a teacher has posed a focused question, for which there is an expected response, and students attempt to answer, it is more appropriate for the teacher to indicate if the student has correctly understood and answered the question. It may actually confuse students if they are met with an accepting or neutral response to an answer they have made for a factual question. The teacher should simply inform them if they are correct and/or otherwise indicate that they are on the right path. Teachers may also choose to judiciously use praise as a way of acknowledging a student's response to a focused question, however, the goal should be for students to find their own intrinsic motivation for responding during a discussion.

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## Session 6: Promoting Discussion

# Materials and Preparation

## Materials Needed

### For the class:

- an LCD projector (or overhead projector)
- 1 slide or transparency of each of the following:
  - Focus Topics for Session
  - Student Responses
  - Quick Write Prompt

### For the Dry Ice Discussion Skit

- 6 highlighted copies of the script for each of the characters in the *Dry Ice Discussion*
- 1 copy of the *Dry Ice Discussion* script for each participant
- 1 copy of the *Research Related to Promoting Discussion* handout for each participant
- 6 3"x 5" cards
- yarn for making name tags
- a highlighter pen

### For the Brainstorming Responses Activity

- 1 copy of the *Student Responses* sheet for each participant

### For the Swirling Colors Role Play

#### For each table group:

- 1 *Swirling Colors* teacher's sheet
- 2 cups of water, one labeled, "plain," and the other labeled, "salt"
- 1 teaspoon
- 1 popsicle stick
- approximately 5 teaspoons of kosher salt in a paper cup (note: iodized salt will appear cloudy in the water, whereas kosher salt will dissolve clear)
- 1 squeeze bottle (or dropper) of blue food coloring (note: green or red food coloring will also work, but yellow is too light to see well)

### For the class:

- 1 pitcher

## Preparation of Materials

### For the Dry Ice Discussion Skit

1. Make name tags. Note: If you make necklace-style name tags using 3 x 5 cards and yarn they can be re-used. Label the six name tags, "MALE #1", "MALE #2", "MALE #3", "FEMALE #1", "FEMALE #2," and "TEACHER."

## Session 6: Promoting Discussion

2. Duplicate and highlight scripts. Duplicate six copies of the dry ice script, one for each character. Write one of the following character titles at the top of each of the scripts: TEACHER, MALE STUDENT #1, MALE STUDENT #2, MALE STUDENT #3, FEMALE STUDENT #1, and FEMALE STUDENT #2. On each character's script, use a highlighting pen to indicate the lines and the instructions in italics pertaining to that character.
3. Duplicate one 3-page copy (on one-sided sheets) of the *Dry Ice Discussion* script for each participant.
4. Duplicate one copy of the *Research Related to Promoting Discussion* handout for each participant.
5. Duplicate one copy of the *Student Responses* handout for each participant.
6. Set up the LCD or overhead projector and have the overhead transparencies on hand.
7. Write these on the board or chart paper beforehand. Keep them posted throughout the session:
  - A. types of teacher responses to students
  - B. how students respond to the teacher
  - C. timing of teacher responses
  - D. strategies for involving everyone in the discussion

### For the Swirling Colors Role-Play:

#### Prepare trays for each table:

1. Label one cup, "Plain," and the other cup, "Salt" water
2. Use your pitcher to fill each cup three-quarters full with water.
3. Place at least 4 teaspoons of kosher salt in the paper cup.
4. Place small bottle of food coloring on tray, along with Swirling Colors teacher's sheet.

## **Session 6: Promoting Discussion**

### **Instructor's Guide**

#### **Session Objectives**

In this session, participants:

- learn about and analyze a variety of teacher response strategies including:
  - using “wait time” to encourage more students to respond, and to respond more thoughtfully;
  - the use of hand raising and the importance of clearly defining student response expectations;
  - calling on equal numbers of boys and girls;
  - asking “safe” questions to encourage participation of reluctant-to-speak students;
  - strategies for dealing with dominating students;
  - supportive ways of dealing with incorrect answers;
- learn that asking broad questions requires an accepting response from the teacher
- learn that asking focused questions requires a confirming response from the teacher
- observe student/ teacher interactions that model effective teacher response strategies, and experience some negative examples of less effective techniques that should be avoided
- practice leading a discussion and formulating responses to students

#### **Session Activities at a Glance**

##### **Introduction**

This session starts off with small groups discussing a list of focus topics related to effective teacher response strategies.

##### **Skit: Dry Ice Discussion**

Volunteers then read a short skit depicting seventh grade students involved in a teacher-led discussion after they have investigated dry ice. The skit illustrates a variety of important teaching and learning behaviors related to discussion.

##### **Relating Research to Dry Ice Discussion**

After observing the skit, each small group selects a specific topic to focus their discussion. Each group is then given copies of some research cards related to promoting discussion. After discussing what they noticed during the skit, and reading and discussing the research cards, each group summarizes what they discussed, and what they learned from the research.

##### **Brainstorming Responses to Students**

Participants are then shown a variety of student responses to a question asked by the teacher. They are challenged in small teams to brainstorm appropriate responses to these sample student answers. In the large group, the course instructor plays the part of each child, and challenges participants to respond to the child, engaging in a mock teacher-student dialogue with the participants.

## Session 6: Promoting Discussion

### Swirling Colors Activity Role-Play

One person in each table group plays the part of “teacher,” while the others play the parts of first through third graders. The “teacher” leads the “students” through the Swirling Colors activity, attempting to incorporate effective questioning and discussion-leading strategies. Afterwards each group discusses successes and issues, and other ways in which the activity could have been led. The session concludes with a large group discussion, and finally a Quick Write in which the participants reflect on their learning as a result of the session.

### Time Frame

Total Workshop: 2 hours

Discussing Response Strategies (5 minutes)

Dry Ice Discussion Skit (10 minutes)

Relating Research to Dry Ice Discussion (30 minutes)

Brainstorming Responses to Students (20 minutes)

Enacting Response Ideas (20 minutes)

Swirling Colors Role-Play Activity (30 minutes)

Quick Write (5 minutes)



**Begin Session: Discussing Response Strategies (5 minutes)**

**1. Introduce focus topics for the session.** Seat participants in groups of six. Tell them that in today’s session they will continue with the topic of questioning strategies and leading classroom discussions. They will be exploring some additional facilitation techniques involving how to respond to students during a discussion. Display list and point out some issues or focus topics to consider for today’s session:

- A. Types of Teacher responses to Students
- B. How students respond to the Teacher
- C. Timing of Teacher responses
- D. Involving everyone in the discussion

**2. Partners discuss topics.** Ask participants to discuss their ideas regarding the topics on the list with another person at their table. Give them about five minutes to share their initial thoughts with a partner.

### Dry Ice Discussion Skit (10 minutes)

**1. Prepare for skit.** Recruit six participants to read the parts in the script. Ask them not to show their scripts to other members of the class. Do your best to select participants who are able to read and speak in a voice loud enough for the class to understand them. The ability to “ham it up” certainly improves this activity, but is not necessary. Make sure that they read the notes at the top of the skit describing the role of their character.

*Note: There is a teacher’s role in the script that should be read by someone other than the course instructor. The instructor will be sufficiently occupied with reading the part of the narrator, and prompting the actors as necessary.*

## Session 6: Promoting Discussion

**2. Gather actors in the front of the room.** Ask the participants in the skit to put on their name-tags, and to sit or stand at the front of the room facing the audience. Remind them to read loudly and clearly. Give them a few minutes to read through the description of their character's role and the stage directions (written in italics) so they'll have an idea of what to do.

**3. Instruct participants to consider focus topics while observing skit.** Tell the participants they'll be watching a short skit simulating a classroom discussion. As they watch it they should be looking for the kinds of behaviors that they have just discussed. Remind them that they will be looking for both effective and ineffective teacher behaviors.

**4. Begin the skit.** Tell them that this skit is based on actual teacher-student interactions that have been observed in classrooms. Start by reading the part of the narrator. Follow along with the readers, prompting them as necessary until they have read through the entire Dry Ice Discussion script.

### Relating Research to the Dry Ice Discussion Skit (30 minutes)

**1. Groups discuss topics.** Remind participants that they had various topics to consider as they watched the skit. Ask them to select one of the topics to discuss in their group.

- A. Types of Teacher responses to Students
- B. How Students respond to Teacher responses
- C. Timing of Teacher responses
- D. Involving everyone in the discussion

**2. Small groups discuss script.** Distribute a copy of the script to each person and instruct the table groups to look for teacher-student interactions that are related to the focus topic they've chosen. Point out that each line of the script is numbered, to make it easier to refer to particular statements during their discussion.

**3. Hand out copies of research sheet to each table.** After they have had a few minutes to discuss their ideas about the focus topic, distribute a copy of the *Research Related to Promoting Discussion* sheet to each person.

**4. Explain the task.** Describe to participants how they will first read the research sheet, then discuss how this information might influence their ideas about teaching in the classroom. Ask: How could this information potentially inform your approach to leading a discussion in the classroom?

**5. Each group decides on something to share with the class.** After 15-20 minutes of small group discussion, tell each group to try to summarize their thoughts regarding the research and their focus topic. Each group should be prepared to describe the main ideas from their group for the whole class discussion.

## Session 6: Promoting Discussion

- 6. Each group shares discussion points.** Have each group assign a member to present their ideas to the class and call on them to report about their discussion.
- 7. Whole class discussion.** Ask the participants what they noticed about the interactions between the teacher and the students in the skit. Provide an opportunity for participants to share out questions or comments about any topics and research they discussed. You may also wish to share some examples from your teaching experience that are relevant to the focus topics.

### Brainstorming Responses to Students (20 minutes)

- 1. Introduce teacher question to group.** Display the *Student Responses* slide (or overhead transparency) and “fly in” (or uncover) the teacher’s question. Tell participants to imagine that they are a teacher who has just led an activity about sinking and floating objects with her class and they ask this question.

**Teacher:** “What can you tell me about things that float in water without using tricks?”

- 2. Reveal each student response one at a time.** Tell them that five different students respond to the question in different ways. Reveal and read aloud each student response, one by one.

#### Student Responses:

**Student #1:** Spoons float.

**Student #2:** The mocusas they’re moving. But then they stop. And when they stop, it floats.

**Student #3:** Light things float.

**Student #4:** Things that are less dense than water float.

**Student #5:** My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn’t like to fish, ‘cause he thinks they’re gross.

- 3. Small groups will brainstorm teacher responses to the student responses.** Introduce the task of developing responses to these student statements. Tell your participants they’ll have around 10 minutes to discuss each of the student responses in small groups and decide what they think are appropriate teacher responses.
- 4. Distribute *Student Responses* sheet and begin brainstorming.** Give each participant a *Student Responses* sheet, so that they can read and record their ideas. Suggest that they look at the section of the research sheet describing various types of teacher responses to help identify the types of responses that might be appropriate. Ask them to begin.

## Session 6: Promoting Discussion

### Enacting Response Ideas

**1. Have groups share ideas.** Once groups have finished brainstorming responses, tell participants you'd like them to share some of the ideas they had for responding to each of the student answers. Explain that you will take on the role of the student and respond back to them as a student might, in order to help them evaluate the effect of the teacher response.

**2. Improvise a dialogue with participants based on teacher response.** As the first group shares their response, take on the role of the child and try to respond in an authentic manner. Invite individuals to continue to respond and carry on a conversation, attempting to create a realistic back and forth discussion between child (you) and teacher (participants). Keep up this dialogue with the participants until the exchange seems to have run its course.

*For example:*

Teacher (played by a participant): What can you tell me about things that float in water without using tricks?

Child (played by the instructor): Spoons float.

Teacher: How do you know spoons float?

Cause I put a spoon in the water, and it floated.

Teacher: What was the spoon you tested made of?

Child: Plastic

Teacher: Do you have spoons made of other materials at home?

Child: Yeah, we have metal spoons.

Teacher: Do you think the metal spoons would float?

Child: I think they might sink

Teacher: Why don't you try testing one at home, and tell us what happens.

Child: OK.

*Note: Playing the role of the child and improvising a discussion in the manner that each child might respond gives participants practice engaging in dialogue, and allows other participants to observe and note the different strategies and their effects. The more effectively and authentically you play this role, the more potentially valuable the experience for your participants. Be careful not to try to "stump" your students, but simply keep up the dialogue in an authentic manner.*

**3. Conduct additional conversations based on different teacher responses.**

Challenge another group to come up with a different response for the same student statement, and play out this conversation as well. Continue enacting various teacher-student dialogues based on various teacher responses to the student statement.

**4. Analyze the effectiveness of different teacher responses.** After several teacher-student dialogues, help participants to identify the teacher responses as *accepting, probing or confirming*. Discuss the benefits/drawbacks of each of the teacher responses you enacted. Refer to the *Notes for the Presenter: Brainstorming Responses* handout for more information about possible teacher responses.

*Note: See "Notes for the Presenter: Brainstorming Responses" handout for ideas on how to analyze each type of teacher response. Refrain from reading the information out loud, but try to incorporate it into the discussion as you discuss each student response.*

## Session 6: Promoting Discussion

### 5. Continue improvising dialogues using the other student statements.

Continue improvising conversations while taking on the role of the student until the group has explored all five of the student responses. Allow some time between enacting each teacher-student dialogue to discuss the advantages and disadvantages of various types of responses.

## Swirling Colors Role-Play Activity (30 minutes)

**1. Introduce discussion-leading activity.** Tell the participants they'll now get a chance to take turns trying their hand at leading a discussion with their peers acting as students. Explain that they will have the opportunity to try to apply what they have been learning about promoting discussion and using effective questioning strategies.

**2. Explain roles for the activity.** Show them the *Swirling Colors* sheet, and explain that it is adapted from the GEMS curriculum guide, *Liquid Explorations* for first through third grade students. Tell them one member of each table group will be the "teacher," and the rest will play the parts of first grade students. Remind participants to continue to play the part of *well-behaved* seven year olds, and not to give their "teachers" a hard time.

**3. Describe the focus on discussion for the activity, including observations and explanations.** Tell them the "teacher" will direct the "students" to do the activity as described on the sheet. The "teacher's" main focus, however, will be leading discussions about their predictions, observations and explanations. It will be up to the "teacher" to improvise how to best do this, incorporating strategies they have learned in this session.

**4. "Teachers" can switch roles or ask for suggestions from peers.** If a "teacher" gets "stuck" or frustrated, suggest that they ask others in their group for suggestions on how to lead the discussion, or allow someone else in the group to be "teacher" for a while. If a group finishes early, tell them to choose a different person be the "teacher," and lead them through the discussion again, using the same cups as before.

**5. Teachers conduct the activity.** Allow fifteen minutes for "teachers" to practice leading the activity with their "students." Call time after fifteen minutes, and tell the groups to stop the activity and discussion, whether or not they have finished.

**6. Collect materials while groups discuss the activity.** Instruct the table groups to discuss what worked well, as you circulate and collect all the materials from the tables. They can also discuss any issues that might have come up, and what a teacher might do to avoid or address those issues. Ask them to try to brainstorm other possible ways the activity and discussion might have been led. Allow about five minutes for this discussion.

## **Session 6: Promoting Discussion**

**7. Large group share of what worked well, issues, ideas.** After five minutes, get the attention of the class. Ask participants to share with the whole group what worked well in their discussion. After a few participants have shared, ask them to share any issues that came up, as well as ideas they discussed about how to address those issues.

**8. Emphasize the power of developing a strategy for using particular response strategies in the classroom.** Tell participants that through selective use of appropriate response strategies and awareness of the effects of different types of responses, a teacher can effectively support student participation in classroom discussions as well as other activities.

### **Reflecting on the Session (5 minutes)**

**1. Introduce Quick Write prompt for the session.** Tell each participant to get out a piece of paper and write their thoughts about how the session has affected their ideas about teaching and learning. Display the following slide:

Summarize your thinking about responding to students during a discussion. If you can, include:

- How have your ideas about teacher responses changed?
- What do you think made your ideas change?
- How might you use this in your science teaching?

**Session 6: Promoting Discussion**

## **Session Handouts**

- **Notes for the Presenter:  
Modeling Effective Discussion-Leading**
- **Dry Ice Discussion Skit Script**
- **Research Related to Promoting Discussion**
- **Notes for the Presenter: Brainstorming Responses**
- **Student Responses**
- **Swirling Color Activity**

## **Session 6: Promoting Discussion**

### **Notes for the Presenter: Modeling Effective Discussion-Leading Techniques**

Some general strategies to keep in mind while leading a discussion:

- create a safe, non-intimidating environment
- use wait time (pause ~3-5 seconds after asking a question before calling on students)
- try to call on as many females as males
- try to include the whole group in the discussion
- offer safe questions to shy students
- use the discussion map:
  - Ask a broad question:
  - Listen to response and thinking
  - Ask for evidence or explanation:
  - Ask for alternative opinions or ideas
- use broad (open-ended) questions to encourage participation
- encourage student-to-student talk by suggesting that they direct their statements to each other
  - when appropriate, employ hand-raising or hand signals to ensure that aggressive students do not dominate
  - try to find out what students are thinking
  - show students you value what they are saying, by incorporating what they have said into what you say, and building on previous comments creating continuity in the discourse
  - consider your role as the teacher to be a collaborator with the students, trying to figure things out together
  - provide a chance for students to figure things out for themselves, rather than telling them the answer
  - give non-judgmental responses, even to seemingly outlandish ideas

## Session 6: Promoting Discussion

Dry Ice discussion, page 1

**Roles:***Teacher: Trying to get discussion going.**Male students #1 & #2: Enthusiastically raise their hands immediately after most questions by the teacher.**Male student #3: Shy and reluctant to participate. Easily embarrassed.**Female students #1 & #2: Interested in the discussion.***Dry Ice Discussion Skit**

**Narrator:** The scene is a seventh grade classroom. Students have recently conducted open-ended investigations using dry ice, and the teacher is now leading a discussion about their findings.

1. **Teacher :** What are some interesting things you did with dry ice?

*Male student #1's hand goes up immediately, and teacher calls on him immediately. (female students #1 and #2 and male student #3 do not raise their hands).*

2. **Male student #1:** I put it in a balloon, and it filled up the balloon.

3. **Teacher:** Really. So you put dry ice in a balloon, then tied it, and the balloon inflated?

4. **Male student #1:** Uh huh.

5. **Teacher:** Would someone like to try to explain why it would fill up the balloon? *Male student #2's hand goes up immediately, and teacher calls on him immediately.*

6. **Male student #2:** It gets hot inside the balloon.

7. **Teacher:** What makes you think it was hot in the balloon?

8. **Male student #2:** The steam.

9. **Teacher:** Did you feel the temperature of the balloon with your hand?

10. **Male student #2:** Yeah, it felt cold. Oops, I guess I was wrong.

11. **Teacher:** When we see steam it usually does mean something is hot, but it seems like in this situation it wasn't. I can see how the steam might make you think it was hot inside.

12. **Teacher:** Does anyone have a different explanation for why the balloon filled up? *Male student #1's hand goes up immediately, and teacher calls on him immediately.*

13. **Male student #1:** Gas.

14. **Teacher:** Gas from where?

15. **Male student #1:** Gas from the dry ice filling the balloon.

16. **Teacher:** So what do you mean it's from the dry ice?

17. **Male student #1:** I dunno. *Male student #2's hand shoots up, and teacher calls on him immediately.*

18. **Male student #2:** It's a chemical reaction.

19. **Teacher:** What do you mean by a chemical reaction?

20. **Male student #2:** The dry ice reacts with the water and makes gas.

21. **Teacher:** Can you explain a little more about what you mean?

Session 6: Promoting Discussion

Dry Ice discussion, page 2

22. **Male student #2:** The stuff that used to be water and dry ice - when they're put together, they change into gas.
23. **Teacher:** Hmm interesting. What do you think? *Calls on male student #3*
24. **Male student #3:** *He is surprised to be called on and very embarrassed. Huh? Uh, I dunno.*
25. **Teacher:** Does anyone have a different idea of what might be going on? *Male student #1's hand goes up immediately, and teacher calls on him immediately. Male student #3 continues to look embarrassed.*
26. **Male student #1:** Yeah, I think it's the dry ice itself that turns into gas as it's melting.
27. **Teacher:** Hmm. We have some different explanations here. Can anyone think of a way to test to see if it's the dry ice or the dry ice with water that is producing the gas? *Male student #2's hand goes up immediately, and teacher calls on him immediately.*
28. **Male student #2:** When we put dry ice in a balloon without water, it filled up the balloon.
29. **Teacher:** So inside the balloon was completely dry?
30. **Male student #2:** Yeah, and it still filled the balloon, so you don't need the water.
31. **Teacher:** Did anyone else try this? *Male student #1's hand goes up immediately, and teacher calls on him immediately.*
32. **Male student #1:** Yeah, actually I forgot that we did it without water and the balloon still filled up. So it must be the dry ice melting.
33. **Teacher:** Actually, other scientists have done similar tests as those you did, and they came to a similar conclusion; that dry ice is a frozen gas. They don't call it melting when it turns to gas though. As you remember it "melted" very differently from water ice when we compared the two, so they call it something different, but we'll get to that later. Now let's keep thinking about the dry ice changing to gas, 'cause I have another question. *Directs attention to male student #3.*
34. **Teacher:** Didn't I see you put dry ice in a balloon too?
35. **Male student #3:** Uh, huh.
36. **Teacher:** About how big was the piece of dry ice?  
*Male student #3 indicates ~1/2 inch with fingers*
37. **Teacher:** About how big was the balloon after it filled with the gases from the dry ice?  
*Male student #3 indicates ~5 inches with two hands.*
38. **Teacher:** So here's my question. If the piece of dry ice was this size *indicates ~1/2 inch with fingers*, how could it fill up a balloon that was this size? *Indicates ~5 inches with two hands.*

**Session 6: Promoting Discussion**

Dry Ice discussion, page 3

*Teacher waits 10 seconds. The two male students' hands are raised immediately, female student #1 raises hers after ~5 seconds, and female #2 after ~10 seconds. Teacher calls on Female student #1.*

**39. Female student #1:** The dry ice gas is bigger than the solid dry ice.

**40. Teacher:** That seems to make sense. But how could it be bigger?

*Teacher waits 10 seconds. The two male students' hands are raised immediately, female student #1 raises hers after ~5 seconds, and female student #2 after ~6 seconds. Teacher calls on female student #2.*

**41. Female student #2:** When dry ice is a gas, it takes up more space.

**42. Teacher:** So are you saying that when it's solid it takes up less space, and as a gas it takes up more space?

**43. Female student #2:** Yeah.

**44. Teacher:** How could this be the case? How could something that's small when solid take up more space as a gas? *Teacher waits 10 seconds. Male students #1 and #2 raise their hands immediately, female student #2 raises hers after ~5 seconds, and female student #1 after ~6 seconds. Teacher calls on Male student #1.*

**45. Male student #1:** The molecules are moving faster, and they push each other farther apart.

**46. Teacher:** Do molecules move faster or slower in a gas?

**47. Male student #1:** Faster.

**48. Teacher:** That's right they do move faster.

**49. Teacher:** So if that's the case, what do you think is going on with the molecules in the solid dry ice? *Teacher waits 10 seconds. Male students #1 and #2 raise their hands immediately, female student #2 raises hers after ~5 seconds, Male student #3 after ~6 seconds and female #1 after ~7 seconds. Teacher calls on Male student #3.*

**50. Male student #3:** They're not moving as much, so they're closer together.

## **Session 6: Promoting Discussion**

### **Research Related to Promoting Discussion**

#### **Using Wait Time**

The concept of “wait-time” as an instructional variable was invented by Mary Budd Rowe (1972). The “wait-time” periods she found--periods of silence that followed teacher questions and students' completed responses--rarely lasted more than 1.5 seconds in typical classrooms. She discovered, however, that when these periods of silence lasted at least 3 seconds, many positive things happened to students' and teachers' behaviors and attitudes. To attain these benefits, teachers were urged to “wait” in silence for 3 or more seconds after their questions, and after students completed their responses (Casteel and Stahl, 1973; Rowe 1972; Stahl 1990; Tobin 1987).

When students are given 3 or more seconds of undisturbed “wait-time,” there are certain positive outcomes:

- The length and correctness of their responses increase.
- The number of their “I don't know” and no answer responses decreases.
- The number of volunteered, appropriate answers by larger numbers of students greatly increases.
- The scores of students on academic achievement tests tend to increase.

When teachers wait patiently in silence for 3 or more seconds at appropriate places, positive changes in their own teacher behaviors also occur:

- Their questioning strategies tend to be more varied and flexible.
- They decrease the quantity and increase the quality and variety of their questions.
- They ask additional questions that require more complex information processing and higher-level thinking on the part of students.

#### **Handling Dominating Students**

As reported in “The One or Two Who Talk Too Much” (1988), researchers Karp and Yoels found that in classes with fewer than forty students, four or five students accounted for 75 percent of the total interactions per session. In classes with more than forty students, two or three students accounted for 51 percent of the exchanges. Here are some ways to handle dominating students:

- Break the class into small groups or assign tasks to pairs of students.
- Ask everyone to jot down a response to your question and then choose someone to speak.
- If only the dominant students raise their hand, restate your desire for greater student participation: “I'd like to hear from others in the class.”
- Avoid making eye contact with the talkative.
- If one student has been dominating the discussion, ask other students whether they agree or disagree with that student.
- Explain that the discussion has become too one-sided and ask the monopolizer to help by remaining silent: “Larry, can you hold off on talking for now, so that we can hear the reactions of other group members.”
- Assign a specific role to the dominant student that limits participation (for example, periodic summarizer/synthesizer for the group).
- Acknowledge the time constraints: “Jon, I notice that our time is running out. Let's set a time limit on everybody's comments from now on.”
- If the monopolizer is a serious problem, speak to him or her after class or during office hours. Tell the student that you value his or her participation and wish more students contributed. If this student's comments are good, say so; but point out that learning results from give-and-take and that everyone benefits from hearing a range of opinions and views.

## Session 6: Promoting Discussion

### Hand Raising during Discussions

When students were observed conversing with their friends in an informal setting prior to the introduction of the new social norms, they were animated, excited, quick to correct each other, and they appeared to be consumed by whatever topic was at hand. This was a stark contrast to what was observed during the phase of the study during which the “raise your hand” rule was in place.

Students had consistent, observable patterns established in regard to raising their hands. The videotapes confirmed that many of the students would raise their hand to speak, but as soon as a student was selected to speak, the other students appeared to disengage. It was as if they realized that if they were not chosen, they no longer needed to be active participants in instruction. It appeared at times that students were completely uninterested in the lesson being taught. The same students would raise their hands to participate while other students would sit daydreaming or drifting during instruction. It was observed frequently that while one student was answering a question, others would sit with their hand up. This was an indication that although they were engaged in the topic at hand, they were most likely thinking of what they wanted to say next instead of listening to the student who was speaking.

When students were given the ability to talk directly to one another without first needing to raise their hands, several things happened. First, students stayed engaged in the conversations. They knew that they would have an equal opportunity to share their ideas. Within the context of this setting, they were invigorated and excited to converse with their peers. Most importantly, they began to understand that mathematics was something to explore. Perhaps they could see that getting correct answers was not as important as sharing ideas and exploring the mathematical concepts. (Dixon, Egendoerfer, Taylor, Clements)

### On the other hand...

According to *The Art of Inquiry* (Cecil, 1995): When you ask questions, do not recognize students who shout out responses; instead, insist that they raise their hands and wait to be called upon before they respond. Though many teachers worry that such rules are unnecessarily rigid and other teachers are delighted when they hear immediate responses shouted out, such behavior results in unequal interactions. Boys tend to be more vociferous than girls in class, for example. On the other hand children from certain cultural groups are taught at home to be polite and even self-effacing; they too are usually overshadowed by children who shout out answers. (Davidman, 1994)

According to Michael Linsin (*Dream Class* 2009): Calling out is a momentum killer of the highest order and can turn a well-planned lesson into a halting mess.

**Calling out is unfair:** Every student has a right to participate, not just those who are more assertive. If calling out is allowed, a segment of your classroom will rarely be heard from.

**Calling out inhibits learning:** Good teaching allows students to form their own ideas, opinions, and conclusions before an answer is revealed or a thought expressed. Students need time—even if it's just a few seconds—to puzzle over the presented material before discussion takes place.

**Calling out tilts the playing field:** Students who participate are more recognized than those who are more reluctant. Allowing students to call out gives socially confident students an unfair advantage. Shy or less confident students, then, are left feeling unwelcome and disconnected from the rest of the class.

**Calling out is rude:** Allowing students to call out encourages selfishness. Students think, *if I want something in this class, I'm going to have to bully my way to the front because that's what everyone else is doing*. In this environment, rudeness, unhappiness, and misbehavior are commonplace.

### An Exception:

An exception to the hand-raising rule is when you're working with a small group of students. Guided reading or literature circles should allow for polite but free-flowing conversation.

## Session 6: Promoting Discussion

### Calling on Boys versus Girls

Current research confirms that teachers call on boys more often than girls, accept more call out responses from boys than girls, give boys more wait-time to respond, and give boys more praise and remediation than girls (Sadker & Sadker, 1994; Biklen & Pollard, 1993). Teachers usually are not aware that they favor the boys in their classroom over girls and are genuinely surprised when they learn of these inequities as they conference with trained observers or watch videotapes of their teaching. (Wellhousen & Yin, 1997).

### Encouraging Students

(Adapted from the hard copy book *Tools for Teaching* by Barbara Gross Davis; Jossey-Bass Publishers: San Francisco, 1993.)

**Use nonverbal cues to encourage participation.** For example, smile expectantly and nod as students talk. Maintain eye contact with students. Look relaxed and interested.

**Draw all students into the discussion.** You can involve more students by asking whether they agree with what has just been said or whether someone can provide another example to support or contradict a point: “How do the rest of you feel about that?” or “Does anyone who hasn’t spoken care to comment on the plans for People’s Park?” Moreover, if you move away from – rather than toward – a student who makes a comment, the student will speak up and outward, drawing everyone into the conversation. The comment will be “on the floor,” open for students to respond to.

**Give quiet students special encouragement.** Quiet students are not necessarily uninvolved, so avoid excessive efforts to draw them out. Some quiet students, though, are just waiting for a non-threatening opportunity to speak. To help these students, consider the following strategies:

- Arrange small group (two to four students) discussions.
- Pose casual questions that don’t call for a detailed correct response: “What are some reasons why people may not vote?” or “What do you remember most from the reading?” or “Which of the articles did you find most difficult?” (McKeachie, 1986).
- Assign a small specific task to a quiet student: “Carrie, would you find out for next class session what Chile’s GNP was last year?”
- Reward infrequent contributors with a smile.
- Bolster students’ self-confidence by writing their comments on the board (Welty, 1989).
- Stand or sit next to someone who has not contributed; your proximity may draw a hesitant student into the discussion.

**Tactfully correct wrong answers.** Any type of put-down or disapproval will inhibit students from speaking up and from learning. Say something positive about those aspects of the response that are insightful or creative and point out those aspects that are off base. Provide hints, suggestions, or follow-up questions that will enable students to understand and correct their own errors. Billson (1986) suggests prompts such as “Good—now let’s take it a step further”; “Keep going”; “Not quite, but keep thinking about it.”

## Session 6: Promoting Discussion

### Types of Teacher Responses

(From *The Art of Inquiry* Nancy Lee Cecil, 1995)

#### Accepting Teacher Responses

The teacher should give an accepting response after asking a broad question. The goal here is to bring about further thought and interactions between students. Accepting responses tend to:

- create a safe climate for participation
- encourage a variety of responses
- allow students to be responsible for deciding what to do for themselves, take risks, and learn consequences of their actions.

• **Passive Acceptance** A response that does not indicate agreement or disagreement with the student's answer. Allows the teacher to acknowledge the contribution made by the student. Can be useful to use when a student gives an unexpected answer and the teacher wants to encourage continued discussion.

Examples: "Interesting idea." "That's a possibility." "Does anyone have a different idea?"

• **Active Acceptance** Restating the student's answer in a way that shows understanding. Lets the student know that the idea has been received and is understood. Can also help to clarify the student's statement.

Example: "So Sara is saying that the wood floats."

• **Empathic Acceptance** Teacher attempts to explain the reasoning behind the student's answer. Lets the student know the teacher understands what they're saying as well as the evidence (or the emotion) behind it.

Example: "Oh, I see why you think that all spoons float, because look at all these spoons - they all float."

#### Probing Teacher Response

When students respond and it is not clear what is meant by their statement or how they have arrived at their understanding, the teacher should respond by asking follow-up questions to obtain more information. The goal is to reveal and better understand student thinking and also to encourage students to build on each other's ideas.

Example: "What makes you say that?" "I'm curious what you meant by 'chemicals are reacting'." "Can you say more about that?" "Can anyone else help to explain this idea?"

#### Confirming Teacher Responses

When students respond to a focused question, the teacher should give a confirming response. Both praising and informing responses can help to summarize or close the discussion, as well as confirm students' understanding.

• **Praising Response** The teacher indicates to the student that their response is correct. When the goal is for students to think critically and creatively, the teacher should be careful with the use of strong praise, as it tends to squelch higher-level thinking.

Examples: "Right!" "Good thinking!"

• **Informing Response** The teacher indicates that the student has correctly understood and responded to the question or that they need to think about it further.

Example: "Yes, you are on the right track, but have you thought about..."

**Session 6: Promoting Discussion**

## ***Student Responses***

**Teacher:** “What can you tell me about things that float without using tricks?”

### **Student Responses:**

**Student #1:** “Spoons float.”

**Student #2:** “The mocus they’re moving. But then they stop. And when they stop, it floats.”

**Student #3:** “Light things float.”

**Student #4:** “Things that are less dense than water float.”

**Student #5:** “My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn’t like to fish, ‘cause he thinks they’re gross.”

**Discuss how you might respond to each of these student responses.**

## Session 6: Promoting Discussion

### Notes for the Presenter: Brainstorming Responses

Below are some possible responses to the children's responses that your participants may bring up and the rationale for using specific teacher responses. You may refer to these notes as needed while leading your discussion.

**Student response:** "Spoons float." (*An inaccurate statement, but it could be merely based on limited testing.*)

**Possible teacher response:** Empathic response: "This spoon floats, and so does this one. That seems to be a pretty accurate thing to say based on the spoons we have tested so far. I wonder if all spoons will float? Let's test some more."

*Note:* By responding this way, the teacher validates the child's thinking, as well as the evidence their statement seems to be based upon. By guiding the students to test more spoons, the teacher allows the student to discover through additional evidence that the statement is inaccurate. If necessary, the teacher can bring in more spoons for the children to test, including at least one that sinks. There are certainly times when a teacher will find it best to verbally correct a student's inaccurate idea, but it is generally more effective to guide the students towards evidence that conflicts with their ideas, and allow them to discover inaccuracies themselves.

**Student response:** "The mocus they're moving. But then they stop. And when they stop, it floats." (*This response seems to indicate some confusion, including what's probably a mispronounced version of "molecules."*)

**Possible teacher response:** Active response: "What do you mean by 'mocus?'" "Do you mean molecules?" "Why would it float if the 'mocus or molecules' stop?"

*Note:* This response allows the teacher to probe more to find out what the student is thinking. The student may have some understanding of molecules and be hypothesizing that they have something to do with floating and sinking, or they may just be using a "science word." If the student's response to probing seems really convoluted and you have no idea what they are talking about, you may need to use a more passive response, such as, "could be," or "Hmm, interesting idea," and then just move along with the discussion.

**Student response:** "Light things float." (*It could be that the student is expressing a commonly held misconception about floating – that light things float and heavy things sink. However, it could also be that they understand that less dense materials float, but they just aren't using the more accurate phrasing.*)

**Possible teacher response:** Empathic response, while pushing them to go further: "This light thing floats, and so does this one. Can you give us an example of some other light things that float? I wonder if all light things will float? Would you call this grain of sand light? Let's test to see if it will float."

*Note:* This series of questions and testing can help guide other students in the class to formulate more accurate ideas about "light" versus "heavy" objects.

## Session 6: Promoting Discussion

**Student response:** “Things that are less dense than water float.” (The statement may indicate that this student has an understanding of density or it may simply be something they have heard before and not understood completely.)

**Possible teacher response:** Active response: “What do you mean by things that are less dense? Can you give some examples of things that we could test?”

**Note:** An active response allows the teacher to check the student’s understanding, and also to give other students the opportunity to listen to the child’s explanation, and perhaps expand their own understanding. Be sure to continue to take other responses as well, to indicate to the group that all responses are valued in the discussion. If you want the discussion and thinking in the group to continue, don’t get too excited in your response to this student or simply announce that they are correct. Other students may then stop participating for fear of providing wrong answers and you would not have the opportunity to see if they understand the concept. You can always come back to the density idea later and let them know that this is what scientists think, too.

**Student response:** “My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn’t like to fish, cause he thinks they’re gross.” (Very likely indicating the student is attempting to participate, but may not have anything to contribute to the topic or understand the focus of the discussion.)

**Possible teacher response:** Active response to highlight the one piece of relevant content in the statement: “So you’re saying that boats float? Does anyone have any ideas on why boats float? Do boats ever sink? Why?”

**Note:** Sometimes a student response like this one needs to be gently redirected, otherwise the student may dominate the discussion while others become bored and distracted. If you think the student is off task and is merely seeking attention, then you can say “We are not talking about boats or fish right now, unless you want to relate them to floating and sinking.”

Session 6: Promoting Discussion

## Swirling Colors Activity

### Notes to “teacher:”

- How will you get the “students” engaged with the activity?
- How will you communicate the procedure to your “students?”
- How will you keep all the “students” involved in the activity and the discussion?
- How will you encourage careful observation?
- How will you encourage discussion and thinking?
- How will you create an environment in which your “students” will feel comfortable sharing ideas?

The following is a “bare bones” procedure list for the activity. It is up to you to improvise and make it a rich and thoughtful experience for your “students.”

TRY NOT TO RUSH THROUGH THIS PROCEDURE

## Procedure

1. Student measures 4 teaspoons of salt into the cup labeled, “salt.”
2. Student stirs the water until they can’t see the salt anymore.
3. Remove the stir stick from the water, and *don’t stir the cups any more.*
4. Students observe and discuss what happened.
5. Teacher adds a drop of food coloring to the *other* cup labeled, “plain.”
6. Students observe and discuss what happened.
7. Teacher adds a drop of food coloring to the cup labeled, “salt.”
8. Students observe and discuss what happened.
9. Discuss differences between how the food coloring moved in the plain water and the salt water cups.
10. Discuss possible explanations for what was observed.

**Session 6: Promoting Discussion**

**Presentation Slides**

- **Focus Topics for Session**
- **Student Responses**
- **Quick Write Prompt**

**Session 6: Promoting Discussion**

## **Focus Topics for the Session:**

- A. Types of **Teacher** responses to **Students**
- B. How **Students** respond to **Teacher** responses
- C. Timing of **Teacher** responses
- D. Involving everyone in the discussion

## *Student Responses*

**Teacher:** “What can you tell me about things that float without using tricks?”

### **Student Responses:**

- “Spoons float.”
- “The mocus they’re moving. But then they stop. And when they stop, it floats.”
- “Light things float.”
- “Things that are less dense than water float.”
- “My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn’t like to fish, ‘cause he thinks they’re gross.”

**Discuss how you might respond to each of these student responses.**

## **Quick Write Prompt**

**Summarize your thinking about responding to students during a discussion.**

If you can, please include:

- How your ideas may have changed about teacher responses
- What do you think made your ideas change?
- How might you use this in your science teaching?

## **Session 7: Classroom Conversations**

### *Contents*

<b>Session Overview</b>	<b>2</b>
<b>Background Information for the Presenter</b>	<b>3</b>
<b>Materials and Preparation</b>	<b>7</b>
<b>Instructor's Guide</b>	<b>10</b>
<b>Session Handouts</b>	<b>19</b>
<b>Presentation Slides (also in separate PowerPoint)</b>	<b>30</b>

## **Session 7: Classroom Conversations**

### **Session Overview**

This session introduces participants to more pedagogical information and experiences highlighting the importance of classroom discussions, while also modeling strategies that participants can use with their own students.

Participants explore the role of dialogue in learning by: reading and sharing short excerpts from research; observing a video of a classroom lesson and analyzing coded transcripts; and taking part in a dry ice investigation and discussion. They examine common patterns of teacher student exchanges during discussion, the benefits of teacher guidance in learning science, and the importance of peer-to-peer discourse.

During the dry ice investigations, individual participants have the opportunity to take on the role of teacher, and to practice asking questions that encourage observations, investigations, and explanations. At the end of the session, they review all the strategies used in the session that they can also use in classrooms with children.

## Session 7: Classroom Conversations

### Background Information for the Presenter

From our own experiences in learning and teaching situations, we can all recognize the important role that conversation, discussion—TALK—plays in any socially connected group of learners. It is through such *discourse* that the meaning-making needed for the development of ideas and concepts can be accomplished. From the sociocultural viewpoint, learning occurs through discourse within social interactions (Rogoff, 1998; Vygotsky, 1978). Vygotsky emphasized the importance of discourse by arguing that higher mental functions have social origins that are first expressed between individuals *before* they are internalized within the individual—that learning relies on discourse. For students, engaging in discussions and conversations can foster more creative, complex thinking and enable them to practice crucial abilities, such as asking questions and communicating ideas effectively. For teachers, all manner of talk and discussion in the classroom provides a window into students' prior knowledge, skill-level, personality, previous experience, and ability to articulate ideas and reasoning. Such discourse happens in many ways.

#### **Reflective Discourse.**

When a teacher facilitates a conversation where students, as well as the teacher, pose questions, respond to one another's comments and questions, and seek to understand each other, this exchange can be referred to as reflective discourse. The student has the freedom to express his or her own thoughts, ideas, and questions while authentically engaged and curious about the subject of the discussion. The teacher and students can thus engage in a free-flowing exchange, asking and answering one another's questions, and trying to understand the thinking of the other person (van Zee & Minstrell, 1997).

#### **Dialogic Instruction**

In a dialogically organized classroom, the teacher uses reflective discourse to validate and elaborate upon student ideas and guides them to “negotiate” their understanding with the other students in the class. The teacher uses strategies such as uptake (Collins 1982) where a particular student's response is incorporated into a question to the group, in order to encourage students to build on others' ideas. The emphasis is on creating a “give and take” where student responses help shape the course of the discussion, as opposed to relying on the teacher asking questions to drive the exchange. A dialogic approach to instruction is often characterized by the use of broad questions, which do not have pre-specified answers and therefore convey a genuine interest in students' opinions and thoughts. The discourse in these classrooms is therefore less predictable and repeatable because it is jointly determined – in character, scope, and direction – by both teachers and students as teachers pick up on, elaborate and question what students say (Nystrand, 1990a, 1991a). Dialogic conversations engage students because they validate the importance of students' contribution to learning and instruction. The purpose of dialogic instruction is not so much the transmission of information through the teacher, as the interpretation and collaborative co-construction of understandings by the students themselves (Gamoran & Nystrand, 1992).

#### **Monologic Instruction.**

In what has been called monologic instruction, also termed a “teacher monologue,” the teacher explains, describes, clarifies, identifies, and questions. In this type of instruction the main goal is for the teacher to present scientific views and explanations. The teacher is doing most of the talking, although whose turn it is to talk may alternate between

## **Session 7: Classroom Conversations**

teacher and students. Monologic instruction can be criticized for reducing opportunities for students to derive and articulate their own understanding of scientific ideas. It can also be criticized for expressing the viewpoint that scientific knowledge is obtained primarily from the teacher (or another expert source), and for not giving students the opportunity to learn science by thinking scientifically, and exchanging and evaluating ideas against evidence as scientists do. Monologic instruction may be a fine method to achieve learning that consists of memorizing facts and information, but it can hinder a deeper more conceptually focused type of learning for students.

### **I-R-E and I-R-F**

Of course, there are variations in teacher directed talk. In one pattern, abbreviated as I-R-E, the teacher initiates the conversation with a question or comment (I), the student responds (R), the teacher evaluates the response (E), and then repeats the pattern with another question (Lemke, 1990; Mehan, 1979).

#### **IRE example:**

**Teacher:** Is this a solid, liquid or gas? (Initiate)

**Student:** It's a liquid. (Respond)

**Teacher:** Yes, it is a liquid. It takes the shape of its' container. (Evaluate)

**Teacher:** What about this one, is it a solid, liquid or gas? (Initiate)

**Student:** It's a liquid too. (Respond)

**Teacher:** No, this one is a solid. (Evaluate)

The student responses may be short answers, while the teacher's evaluations of the responses may be long and elaborate. In another variation, often called I-R-F the teacher initiates the conversation with a question or comment, the student responds, the teacher seeks follow-up ideas and comments from the students, then the pattern repeats with response and follow up (Sinclair & Coulthard, 1975).

#### **IRF example:**

**Teacher:** Is this a solid, liquid or gas? (Initiate)

**Student:** It's a solid (Respond)

**Teacher:** What makes you say that it's a solid? (Follow-up)

**Student:** Because it holds its shape. (Respond)

**Teacher:** You're right, it is a solid. (Evaluate)

In both cases, the turn-taking switches back and forth between teacher and student regularly, and the teacher directs the conversation and makes knowledge public. Again, these patterns often fail to provide students with opportunities to articulate their own understanding and express themselves in the language of the discipline (Alexander, 2005 ; Wellington & Osborne, 2001). On the other hand, such interactions can be a way to extend the student's answer, to draw on its significance, or to make connections with other parts of the student's total learning experience (Wells, 1999)

### **Peer-to-Peer Discourse**

Peer talk occurs in pairs or groups of students where adults are either not present or are refraining from full participation in the discussion. Researchers believe that having a more equal structure for participation in a discussion (i.e. when the teacher acquiesces control to the students) promotes more active cognitive involvement, as students may

## **Session 7: Classroom Conversations**

not be as intimidated from freely expressing their ideas. (Rogoff 1990, Piaget 1977) Recent studies on discourse patterns have found that talk with other children can help provide the opportunity for the kinds of social interactions that help support student learning (Blum-Kulka & Snow, 2004).

These various patterns of talk are neither intrinsically good nor bad; their merits and demerits come from the reason and ways they are used to support and achieve intended goals. In teaching science, there is often tension between the teacher imparting information and directing the conversation to communicate the views of science and “holding themselves back” in the conversation in order to encourage children to develop their own ideas, and for everyone to voice their views.

A single science lesson may incorporate a variety of different dialogue approaches based upon the needs at each stage of the lesson. For instance, a teacher may begin with reflective discourse in order to give students a chance to express their everyday views in order to motivate and encourage students to be engaged, to legitimize students’ ways of thinking, and to probe students’ prior knowledge. The teacher may then shift to IRF to draw out more of students’ thinking and guide the expressions of their understanding towards the scientific views. The teacher may transition into an IRE pattern in order to model how to connect students’ everyday ideas to scientific language, and then finish with more open-ended reflective discourse to give students the opportunity to practice using this academic language.

### **Teachers’ Role in Science Discussions**

Learning science adds increased complexity to the practice of facilitating discourse, because it involves acquiring the language and tools of science and the accepted methods of reasoning in science (Anderson, Holland, & Palincsar, 1997; Kuhn, 1962) This process of acculturation is not possible without guidance and assistance from a more expert mentor (Scott, et al., 2006).

“Learning science, therefore, is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the ‘ways of seeing’ which have been established and found to be fruitful by the scientific community. Such ‘ways of seeing’ cannot be ‘discovered’ by the student—and if a student happens upon the consensual viewpoint of the scientific community he or she would be unaware of the status of the idea” (Driver, 1989, p. 482).

Thus it is necessary for science teachers to engage students in dialogue about their everyday views of phenomena, **and** to introduce the perspective and conceptual understandings adopted by the scientific community (Scott, et al., 2006).

It is important that students have the opportunity both to make explicit their everyday ideas and to apply and explore newly learned scientific ideas through talk and other actions for themselves (Scott, et al., 2006). The fundamental point here is that “meaningful learning involves making connections between ways of thinking and talking...between everyday and scientific views” (Scott, et al., 2006, p. 622). This type of discussion offers the student the opportunity to voice her or his everyday views of the world in common language, but requires the assistance and guidance from more knowledgeable individuals to make connections between everyday views and scientific views (Scott, et al., 2006). Analyzing the patterns of talk and insights from student conversations provides participants with information about the benefits of talking with students and allowing them to articulate their own thinking.

## Session 7: Classroom Conversations

Research clearly shows that giving students an opportunity to discuss their ideas in the context of analyzing the arguments of others significantly helps with the development of scientific knowledge (Osborne, Erduran, & Simon, 2004). So why do so many teachers rely mainly on monologic instruction and I-R-E if there is substantial and widespread research supporting the idea of creating classroom situations in which students actively discuss ideas? It may be due to the following concerns and questions teachers often raise:

- How to ensure enough time for students to fully explore topics, in addition to covering the concepts required by state and district standards
- Concern that students bringing up inaccurate ideas in discussion it may be a distraction or an impediment to learning the correct scientific information ( i.e., reinforcing misconceptions)
- How to keep students on-task and focused on discussing the assigned topic
- What to do if the students bring up questions that the teacher cannot answer or topics that are unfamiliar
- Being reluctant to “lose control” of the classroom discussion if it is not teacher directed.

It can be challenging for teachers to create situations in the classroom in which students consider and talk about their everyday views, connect those views with scientific explanations, and, in the process, encourage concept and skill development as dictated by standards and other state or district learning goals. By modeling dialogic reflective discourse strategies in this and other sessions, we hope to engage participants in seeing both the incredible value of discourse for their own learning, and also how scientific discourse can successfully be put into practice in the classroom.

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## Session 7: Classroom Conversations

### Materials and Preparation

#### Materials Needed

##### For the Session:

- LCD projector and screen, or overhead projector.
- PowerPoint slides or overhead transparencies
- **Windows on the Classroom Series: Growing Science Inquiry, DVD** from National Gardening Association, 1998

##### For the Jigsaw Activity:

##### For each team of four:

- 1 set of the following research cards:
  - #1 Zone of Proximal Development (ZPD) - Vygotsky
  - #2 IRE (Initiate, Respond, Evaluate)
  - #3 Dialogic Classrooms - Nystrand
  - #4 The Role of Dialogue in Learning
  - #5 Peer-to-Peer Discourse
  - #6 Value of Guidance in Learning Science
  - #7 Science as a Sociocultural Process - Lemke

##### For Watching and Coding Potato Video:

- 1 copy of the Potato video
- DVD and projector for Potato video
- 1 copy of the *Coding Teacher Moves* sheet for each participant

##### For the Dry Ice Investigations Exemplar:

##### For the class:

- 1 electric water heater/hot water dispenser (coffee pot)
- 1 cold water dispenser (use a dish tub, pitcher, unplugged hot water dispenser or water cooler, if you have no running water in your classroom)
- 1 plastic dish tub
- 1 box of ziplock sandwich bags
- 1 8-10 lb. slab (or pellets) of dry ice
- 1 hammer to break up dry ice
- 2 dish cloths or towels
- 1 insulated container to store dry ice

##### For each team of 4–6 participants:

- 4-6 plastic spoons
- 1 tray or small tub
- 5 clear plastic cups
- 2 metal tweezers
- 2 balloons
- 2 cups that will not melt with hot water in them (such as heavy plastic or Styrofoam)
- 2 droppers
- 2 small plastic flasks or vials (*without* lids)
- 1 or 2 pennies, or other metal objects
- 1 copy of the *Dry Ice Challenges* sheet

**Warning:** *If dry ice is placed in an airtight container, pressure from the gas released from the dry ice may burst the container. If the container is glass, this can be particularly dangerous.*

## Session 7: Classroom Conversations

### For the Conclusion and Quick Write:

- 1 copy of the handout, *Classroom Discussion Activities* for each participant
- 1 sheet of blank paper for each participant

### Preparation of Materials

1. Set up the PowerPoints, computer, LCD projector and screen, or overhead projector and transparencies.

2. Set up DVD player with Potato video

3. Prepare the Jigsaw Research Cards

Groups will need one copy of each:

- #1 Zone of Proximal Development (ZPD) - Vygotsky
- #2 IRE (Initiate, Respond, Evaluate)
- #3 Dialogic Classrooms - Nystrand
- #4 The Value of Dialogue
- #5 Peer-to-Peer Discourse
- #6 Value of Guidance in Learning Science

- Make copies of the cards, cut up the cards, put one of each card in an envelope, or paper clip them together to make a set for each group of six participants.

4. Prepare the Dry Ice Challenges Cards

- Copy *Dry Ice Challenges* sheets. For each team copy one sheet of *Dry Ice Challenges*.

5. Make copies of take-home handouts:

For each participant:

Make one copy of the following handouts:

- Coding Teacher Moves
- Classroom Discussion Activities

### For the Dry Ice Investigations Exemplar

#### Before the Day of the Activity

1. Obtain the materials for the session.

Dry ice: Obtain one 12" square slab of dry ice. These usually come about two inches thick. Dry ice can also be ordered in 1/2" diameter pellets, but these will dissipate (or "sublimate") more quickly than a slab. Wrap the dry ice with towels, blankets, rags or newspaper, and pack it in a well-insulated container. The more you insulate it, the longer it will keep. **Do not store dry ice in a freezer or refrigerator** (they are not cold enough to preserve dry ice).

**Note:** If you are unable to obtain dry ice, you may substitute an investigation of some other interesting materials or organisms you have access to. What is important is that it be an activity they can implement in their teaching situations, and that it provide excellent opportunities for peer-to-peer discussion, as well as an excellent opportunity for a teacher-led discussion about their discoveries.

2. **Prepare for Dry Ice discussion.** Read through the Dry Ice discussion suggestions for ideas about how to encourage open-ended discourse.

## Session 7: Classroom Conversations

### The Day of the Activity

#### For the Dry Ice Activity:

1. **Set aside *Dry Ice Challenges* sheets.** Set near your presentation area the *Dry Ice Challenges* sheets you prepared.

2. **Set up Dry Ice materials.** Prepare one tray for each table of 4 or 6 students containing:

2 plastic cups, 2 metal tweezers, 2 balloons, 2 cups that can hold hot water, 2 medicine droppers, 1 spoon for each student, 2 small plastic flasks/vials (*without* lids), 2 pennies or metal washers.

*Note:* When dry ice is placed in a container sealed with a lid, the container may “explode.” (see also Note on page 7.)

3. **Set out *Dry Ice Challenges* sheets.** In a central location, place the following materials:

- 1 *Dry Ice Challenges* sheet for each team.

#### Just before class:

1. **Fill and plug in the electric water heater.**

2. **Break dry ice into tiny pieces.** Lay a slab of dry ice on a towel, T-shirt, or other rag. Place another towel or dishcloth on top of it. Use the side of a hammer to pulverize the dry ice through the rag. Break the dry ice into powder and tiny pieces, and put them in a small, insulated container.

## Session 7: Classroom Conversations

### Instructor's Guide

#### Session Objectives

- Read short excerpts of writing and research to become aware of such ideas as the zone of proximal development, I-R-E (Initiate, Respond, Evaluate), characteristics of dialogic classrooms, value of dialogue in learning, and the value of guidance in learning science.
- Code transcripts of a teacher leading a science discussion, watch video footage of it, and become more aware of patterns of classroom discourse, and their effects.
- Experience a variety of strategies (Partner Share, Jigsaw, Think-Pair-Share) that can be used to encourage discourse in their own teaching situations.
- Become aware of *Dry Ice Investigations* GEMS (Great Explorations in Math and Science) guide exemplar activities.
- Practice using questions to encourage observations, investigations, and explanations.
- Take part in a discussion of their discoveries with dry ice led by the instructor, while witnessing discussion-leading strategies modeled by the instructor.

#### Session Activities at a Glance

##### Partner Share: Why Is Talking Important for Learning?

The session begins with participants discussing in pairs the following questions:

- Why is talking important for learning?
- What strategies might be used in a classroom to encourage discussion between students?

This serves as an invitation, stimulating interest in the topic, encouraging participants to think about and access their prior knowledge and experience of the topic. It also serves as a model of the Partner Share activity, which they can use with their own students to encourage student-to-student discussion in their classrooms.

##### Jigsaw: Research Cards on Talking and Learning

In groups of four, each person is responsible for quickly reading and taking turns presenting to their group the information from one research card on the topic of classroom discourse. They include their own reactions to the information and questions they have about it, leading a discussion on the topic within their group.

##### Watching a Discussion Video and Coding Transcripts

Participants watch a short video in which a teacher is leading a discussion about a classroom investigation about potatoes. They receive transcripts of the discussion and classify the teacher "moves" in the transcript, based on codes for specific types of teacher responses. They conduct a Think-Pair-Share activity, discussing what the teacher did or did not do to encourage discussion, and how the students reacted.

##### Dry Ice Investigations Exemplar

The instructor leads the participants through an activity in which they design and conduct their own investigations with dry ice. During this portion of the activity, one member of each small group plays the role of "teacher," asking questions to encourage observations, investigations, and explanations from their fellow group-members. After their investigations, the instructor leads a large group discussion about their explanations for some of the interesting things they noticed. This serves as an example of model-teaching on the part of the instructor, using the discussion map strategy to model how to lead a discussion.

## Session 7: Classroom Conversations

### Conclusion and Quick Write

The leader explains that the Partner Share, Jigsaw, and Think-Pair-Share activities they took part in can also be used to encourage discussion with children in classrooms.

Participants receive a handout describing these and a few other activities. Participants do a Quick Write on how to promote discussion in their own teaching situations.

### Time Frame

Partner Share: Why is Talking Important for Learning? (5 minutes)

Jigsaw: Research Cards on Talking and Learning (30 minutes)

Watching and Discussing the Potato Video and transcript (35 minutes)

Dry Ice Investigations Exemplar (40 minutes)

Conclusion and Quick Write (10 minutes)

Total Workshop: 2 hours

### Partner Share: Why is Talking Important for Learning? (5 minutes)

*Note: Since one of the purposes of this session is to encourage teachers to foster cross-discussion, or student-to-student discourse in their classrooms, the instructor should encourage and model this during the session as often as possible. For example, when a participant makes a comment, the instructor can invite other participants to comment on that comment (e.g.: "What do you think of that comment?" or "Does anybody have a different opinion or different idea?") During these exchanges, the instructor can also encourage the participants to address one another rather than the instructor.*

**1. Introduce Partner Share.** Tell participants they will be discussing two questions to get them thinking about the session's topic—Classroom Conversations. Have participants find a partner near them. Tell anyone without a partner to raise their hand, and make adjustments as necessary. If you have an odd number of students, you may choose to partner with a student, or have a group of three.

**2. Begin the Partner Share.** Display the slide of the two questions for participants to discuss:

- Why is talking important for learning?
  
- What strategies might be used in a classroom to encourage discussion between students?

**3. Seat participants in small groups.** After about five minutes, ask participants to form groups of approximately six people.

## Session 7: Classroom Conversations

### Jigsaw: Research Cards on Talking and Learning (30 Minutes)

**1. Introduce Jigsaw activity.** Tell participants each small group will receive a few research cards. Each card features a piece of information from research about the connection between talking and learning. Each group member is responsible for carefully reading one of the cards and explaining the information to their small group. Like a jigsaw puzzle, each member of the team is in charge of one of the “pieces.”

The Research Cards are:

- #1 Zone of Proximal Development (ZPD) - Vygotsky
- #2 I-R-E (Initiate, Respond, Evaluate)
- #3 Dialogic Classrooms - Nystrand
- #4 The Role of Dialogue in Learning
- #5 Peer-to-Peer Discourse
- #6 Value of Guidance in Learning Science
- #7 Science as a Sociocultural Process - Lemke

*Note: Each member of a group six people is responsible for one card, since there are seven cards. If there are less than seven in a group, each member should take responsibility for one of the cards, and if they have extra time they may look at the other cards.*

**2. Each member leads a brief discussion about one research card.** Display *Jigsaw Activity* slide. Tell them that after each group member reads and shares the information from their research card, they should tell the group their own thoughts about the topic. Then they will invite group members to discuss the topic on the card, including:

- anything they find confusing
- questions or issues they have
- how this information might influence classroom teaching.

During this discussion, each member should hold on to, and be in charge of, their research card. If they have less than six people in their group, they can discuss additional research cards. They should take turns sharing and discussing each research card until you tell them to stop.

**3. Large group share.** After about 15–20 minutes of discussion, ask each group to share out any issues, ideas, or questions that came up during their small group discussion. Specifically ask how the information from research could inform their teaching.

**4. Explain rationale behind jigsaw activity.** Tell participants that this type of jigsaw activity is often used with children in classrooms, and is meant to encourage collaboration and discussion in small groups. Having each member responsible for the information on their card and leading the discussion about that information, can help keep everyone involved in the discussion, and prevents any one person from dominating the group.

## Session 7: Classroom Conversations

**Watching and Discussing a Video Transcript (35 Minutes)**

- 1. Introduce video.** Explain that they will now watch a video from the *Windows on the Classroom* series in which a teacher is leading kindergarten and first grade students in their investigation of how potatoes grow. Explain that although the investigation included activities, the video is primarily focused on discussions in the K–1 classroom led by the teacher.
- 2. Set expectations for viewing video.** Ask participants to observe and think about how the teacher encourages discussion among the students. How does what she does influence student participation in sharing their ideas and questions about potatoes? Start the six-minute video.
- 3. Explain how the transcript has been coded.** When the video has ended, pass out a copy of the transcript to each participant. Pass out the *Coding Transcripts* handout, and explain that the transcript has been “coded” in order to identify different types of moves a teacher can make during a discussion. Explain the various codes listed on the handout.
- 4. Think: Participants think about questions.** Display the following questions on the next slide, and ask participants to look at their coded transcripts as they quietly think about each one:
  - What moves did the teacher make and what were the results?
  - To what degree did the teacher generate student involvement?
  - Were there any instances of students talking directly to each other?
- 5. Pair: Partners discuss questions.** After a few minutes, tell the participants to now discuss these questions with a partner. Encourage them to cite evidence from their coded transcripts during their discussions.
- 6. Share: Large group discussion.** Get the entire groups’ attention, and ask participants to share some of their thoughts with the class. Make sure to provide accepting responses and encourage participants to elaborate on and clarify their ideas. When you’re ready to conclude the discussion, point out that examining the pattern of teacher moves can help us understand their positive and negative effects on student discourse.
- 7. Explain purpose of Think, Pair, Share activity.** Point out that the activity they just conducted is often called, Think-Pair-Share, and it is very effectively used in classrooms with children. Explain that the *Think* portion of the activity is meant to encourage students to access their own knowledge or to formulate their ideas about a topic or question. The *Pair* portion gives students the opportunity to express and compare their ideas in a safe one-on-one setting. The *Share* portion then allows the whole class to benefit from hearing what others have thought about the topic.

## Session 7: Classroom Conversations

**Exemplar Activity: Dry Ice Investigations (40 minutes)****Introducing the Dry Ice Investigation**

*Note: If obtaining or using dry ice is problematic given your situation, you can substitute a different open investigation of interesting materials or organisms.*

**1. Introduce dry ice lesson.** Explain that they will now experience an exemplar activity and discussion, which is appropriate for grades 5–8, from the GEMS guide, *Dry Ice Investigations*. Tell them that this lesson is intended to demonstrate how a discussion can help support student meaning-making.

**2. Observe dry ice.** Explain that they will be investigating the dry ice as if they have never seen it before. During this activity, they will be finding out all they can about dry ice. They will be conducting their own *safe* investigations of dry ice. Hold up a piece of dry ice, and ask them to describe it as if they have never seen it before. Tell them to call out, and not raise hands for these observations.

**3. Use scientist’s perspective.** Urge them to continue with this same perspective as they conduct their dry ice investigations—as if they’ve never seen or heard of dry ice before. They should try to come up with explanations for anything interesting they observe during their investigations. No explanation will be considered too crazy or silly. This is meant to be an exercise in making observations, conducting tests, and coming up with tentative explanations for what they observe, not an exercise in repeating information they’ve heard before. Tell them that if anyone has prior knowledge about dry ice, to refrain from sharing that information until after the exemplar.

**4. Explain “teacher” role for each group.** Tell them they will start off with everyone investigating, but after a little while you’ll tell them to choose one person in their group to play the part of a teacher. The “teacher’s” role will be to ask questions of other members of the group—to encourage the “students” to make observations, conduct investigations, and try to explain what they are observing.

**5. Introduce materials they will use.** Briefly describe each of the materials they will have available for their investigations:

**a. Dry ice supply:** Tell participants that a limited supply of dry ice is available, and that they need to use it sparingly. Tell them that it’s much more interesting to use small amounts of dry ice in a variety of different investigations than to dump it all into one large investigation. Instruct them not to simply keep dumping more dry ice into an investigation just to make it bigger.

**b. Warn about touching dry ice:** Tell participants that dry ice is very cold and can produce “frostbite” if touched by their bare hands. Ask them to be careful with the dry ice at their tables—trying to contain it on their trays, so that they don’t touch it accidentally. Explain that if they touch it accidentally for just a second or two, it’s not harmful, but if they touch it for longer than that, it can be harmful.

## Session 7: Classroom Conversations

**NOTE:** Be sure **NOT** to model unsafe behaviors with dry ice yourself, such as tossing it back and forth in your bare hands, or putting it in your mouth. These behaviors are not only examples of bad role modeling for young people, and might inspire them to be unsafe with the dry ice, but they are also forbidden in many schools, since they can result in injury.

**c. Tweezers and spoons:** Let participants know that anything besides the dry ice itself is safe to touch with their bare hands. Point out the tweezers and spoons for safe handling of dry ice.

**d. Water:** Show participants where they can get cold and hot water. Demonstrate how to carry the hot water *with two hands* back to their tables, as a reminder to themselves that they are carrying something very hot that could hurt someone. Warn them not to touch the hot water or the sides of the coffee pot.

**e. Cups:** Show participants which cups they may and may not use for hot water.

**f. Flasks/vials, balloons and sealable plastic bags:** Warn participants that they are not to put dry ice in airtight containers, unless they are sealable plastic bags, or if they are sealed with a balloon (such as a plastic vial with a balloon over its mouth). **Also warn them that they are not to use glass containers with dry ice.**

**Warning:** As noted previously, If dry ice is placed in an airtight container, pressure from the gas released from the dry ice may burst the container. If the container is glass, this can be particularly dangerous.

## Conducting the Dry Ice Investigation

**1. Distribute materials.** Ask a volunteer from each team to get a tray of equipment for their team.

**2. Distribute dry ice.** Distribute a small amount of dry ice powder and tiny pieces to each team (~1 teaspoon). As they use it up, periodically distribute more dry ice as needed, giving each table the same amounts to be fair. The less you give them at first, the better they tend to be about making more detailed observations and not wasting it. Give each team about 2 teaspoons full the second time you distribute, and keep giving about twice as much as the time before each time you come by.

**3. Assist groups as they investigate; pass out *Dry Ice Challenges* after about 10 minutes.** Circulate to all groups, **ask questions**, lend a hand, make suggestions, and enforce safety rules. After about 10 minutes of investigation, distribute the *Dry Ice Challenges* sheet to one of the course participants at each table. Explain that these are some challenges for them to try.

**4. One participant in each group begins playing “teacher” role.** After about five more minutes, tell each group to choose one person to play the “teacher” role, and ask questions of their fellow participants to encourage observations, investigations, explanations, and thinking.

## Session 7: Classroom Conversations

**Discussing Dry Ice Investigations (10 minutes)**

**1. Conclude dry ice investigations.** At the designated stopping time, use a signal to get their attention (you could tell them to “freeze.”) You may also want to give instructions for cleaning up materials.

**2. Gather participants for discussion.** Have participants either remove the materials from their tables or move to a discussion area.

*Note: Even with adults, it's very challenging to conduct a discussion when dry ice is within reach!*

**3. Lead discussion on discoveries and explanations.** Using the **Discussion Map** (as introduced in the Questioning Strategies session) as a general format, invite participants to share discoveries. Also ask them to share possible explanations and reasoning for observations, accepting all ideas, and encouraging participation.

Of course, discussions are unpredictable and never actually fit neatly into a “map.” You will need to listen to ideas and improvise as you go, following participants’ interest and lines of reasoning, while providing focus to the discussion as necessary. What’s most important is that the topic be interesting (it is!), and that the instructor sets a tone in which participants feel that their ideas are desired and valued. It’s also important that they feel that the question is truly broad, and that the teacher is not trying to get them to give particular answers. **See the sample discussion map in the box on the next page for an idea about how this discussion might proceed.**

*Note: Since every participant is likely to have an enthusiastic response to the question, “what is something interesting you saw during your investigations,” this provides an excellent opportunity to ask this of a participant who has not participated much in discussion — without waiting for them to raise their hand. Doing this also models the use of a strategy participants can use with reluctant-to-speak children in their classrooms.*

**4. Lead a discussion about what influenced the dry ice investigation and discussion.** Ask the following questions to promote discussion about factors and teacher moves that may encourage or inhibit exploration and discussion:

- How would you describe the investigation and discussion we just had?
- What factors encouraged exploration and discussion in this activity?
- How did specific moves made by instructors influence participation and the discussion?
- Can you think of any teacher moves – beyond what we did today - that could potentially inhibit exploration and discussion?
- In what ways did these discussions illustrate how learners can build meaning or understanding through discussion?

*Note: Depending on the amount of time you have, and the patience of participants, you'll likely need to cut off portions of the dry ice discussions before reaching full resolution.*

## Using a Discussion Map to Discuss Dry Ice Discoveries and Explanations

### Ask a broad question:

- Ask participants to share something interesting they saw during their investigations.

*Example:*

Instructor: What is something interesting you saw during your investigations?

Participant: Some pieces of dry ice floated, and some sank.

### Ask for evidence or explanation:

- Ask follow-up questions to clarify, as necessary.

*Example:*

Instructor: Was there anything different about the pieces of dry ice you observed floating or sinking?

Participant: They were different shapes and different sizes.

Instructor: Did you notice that any particular shapes or sizes tended to float or sink?

Participant: Yeah, the small ones floated and the big ones sank.

Instructor: You noticed the small ones floated and the big ones sank?

Participant: Yeah.

Instructor: Did the shape seem to make a difference?

Participant: I don't think so.

Instructor: What do you think might be causing the small ones to float and the big ones to sink?

Participant: I think they're just lighter, so they float.

### Ask for alternative opinions or ideas:

- Ask other participants what they think of this explanation.

*Example:*

Instructor: Does anyone want to say anything about this explanation, or offer a different explanation?

Participant: I agree, I think they're lighter, but I think they float because gas from the dry ice makes like a bubble that pushes the lighter pieces of dry ice up. I think the bigger pieces are just too heavy for the bubble to lift.

Instructor: Does anyone want to say what they think of this explanation?

### Bring the discussion back to the main topic:

- Ask for other interesting things they noticed during investigations, while keeping them focused on what has been discussed so far.

*Example:*

Instructor: Did anybody else do any other interesting investigations with dry ice, particularly any that had to do with dry ice floating or sinking, or dry ice and bubbles?

## Conclusion and Quick Write (10 minutes)

1. Describe different discussion activities modeled during the session. Tell participants that there have been many different discussion strategies modeled during this session, all of which can be used with the students they teach. Point out that most of the discussion that they've been involved in during this session has been student-to-student discussion. Point out the following activities or strategies you modeled:

- Partner Share
- Jigsaw
- Think, Pair, Share

## Session 7: Classroom Conversations

- Large group discussion using a Discussion Map

**2. Introduce Classroom Discussion Activities handout.** Display the *Classroom Discussion Activities* slide and distribute the handout. Explain that in addition to paying attention to teacher moves, it's helpful to structure classroom activities in ways that can encourage and enhance discussion. Briefly describe the activities on the handout that were not modeled during the session.

**3. Quick Write on applying what they have learned to their teaching.** Ask participants to gather their thoughts from this session in writing using the following prompt to help them personalize what they learned about conversations and to think about how they might apply it to their practice.

Describe changes you could make in your teaching to promote conversation. Cite specific strategies you would use and detail possible responses you would expect from your students.

### Optional Homework Assignments:

- Read and discuss. Scott, et al., 2006. p. 608–613. The tension between authoritative and dialogic discourse: a fundamental characteristic of meaning making interactions in high school science lessons:
  - What makes questions so important in learning and teaching?
  - When, how and why do you use questions in your practice? (What is your purpose for asking questions?)
- If you have the time and equipment, have participants video each other while teaching, type out transcripts of what was said, then code them.

**Session 7: Classroom Conversations**

## **Handouts**

- Research Cards**
- Video Transcript**
- Coding Transcripts**
- Classroom Discussion Activities**

Session 7: Classroom Conversations

**Research Card #1:**

**Zone of Proximal Development (ZPD) - Vygotsky**

Constructing knowledge requires intellectual support. Without guidance, a learner, and children in particular, may not be able to make sense of concepts and potentially leave an interaction with an incomplete or incorrect understanding of an idea (Grandy, 1997; King, 2009; Klahr & Nigam, 2004). **A learner's potential—with such guidance—has been called the “zone of proximal development” or zpd (Vygotsky, 1978). The zpd concept addresses how experienced individuals can help less experienced learners extend their learning beyond where they are able to go on their own based on their physical or developmental level.** “The zpd is the area between what a person can accomplish on their own, to that which they could achieve with the help of someone more experienced” (Hohenstein & King, 2007).

**Research Card#2:**

**IRE (Initiate, Respond, Evaluate)**

In what Mehan (1979b) calls an IRE pattern, the teacher initiates the conversation with a question or comment, the student responds, the teacher evaluates the response, and then repeats the pattern with another question.

IRE example:

**Teacher:** Is this a solid, liquid or gas? (Initiate)

**Student:** It's a liquid. (Respond)

**Teacher:** Yes, it is a liquid. It takes the shape of its' container. (Evaluate)

**Teacher:** What about this one, is it a solid, liquid or gas? (Initiate)

**Student:** It's a liquid too. (Respond)

**Teacher:** No, this one is a solid. (Evaluate)

The turn-taking switches back and forth between teacher and student regularly, though the teacher is directing the conversation because they are asking the questions and determining the correctness of the response. Also, student's response may be short answers, while teacher's evaluation may be long and elaborate on the student's response. The teacher controls the conversation by the topics they allow to be formulated and the “off-topics” they ignore (Eder, 1982).

**Research Card #3:**

**Dialogic Classrooms - Nystrand**

“In these classrooms, the teacher validates particular students' ideas by incorporating their responses into subsequent questions, a process Collins (1982) calls “**uptake.**” In the give-and-take of such talk, students' responses and not just teacher questions shape the course of talk. The discourse in these classrooms is therefore less predictable and repeatable because it is “negotiated” and jointly determined – in character, scope, and direction –by both teachers and students as teachers pick up on, elaborate and question what students say (Nystrand, 1990a, 1991a). Such interactions often are characterized by “**authentic**” questions, which are asked to get information, not to see what students know and do not know; that is, authentic questions are questions without “pre-specified” answers (Nystrand & Gamoran, 1991a). These questions convey the teachers' interest in students' opinions and thoughts. Hence, in contrast to the “test questions” of recitation, or what Mehan (1979a) calls “known

## **Session 7: Classroom Conversations**

information questions,” they indicate the priority the teacher places on thinking and not just remembering. These ‘instructional conversations,’ as Tharp & Gallimore (1988) call them, or ‘substantive conversations,’ as Newmann (1990) calls them, engage students because they validate the importance of students’ contribution to learning and instruction. The purpose of such instruction is not so much the transmission of information as the interpretation and collaborative co-construction of understandings. In this kind of classroom talk, teachers take their students seriously (Gamoran & Nystrand, 1992).”

Opening Dialogue, Martin Nystrand 1997, page 6-7

### **Research Card #4:**

#### **The Role of Dialogue in Learning**

Vygotsky (1978) detailed the importance of discourse by arguing that higher mental functions have social origins that are first expressed between individuals before they are internalized within the individual. In other words meanings are rehearsed and made explicit as a result of conversations and interactions between people before becoming internalized by the individual. In the sociocultural viewpoint, learning relies on conversation. For learners, engaging in conversations can foster more generative thinking and enable them to practice dialogic skills, such as asking questions and communicating ideas in an effective manner. It can be a way for them to process information and make social connections. These thinking and dialogue skills form the basis of active, analytic, individual thought, and allows individuals to develop their ability to communicate their ideas. For educators, conversation can be a window into their learners’ prior knowledge, skill-level, personality, previous experience, and ability to articulate ideas.

**Session 7: Classroom Conversations**

**Research Card #5:**

**Peer-to-Peer Discourse**

Peer talk unfolds in pairs or groups of children unhindered by the inherent asymmetry of adult–child interaction. The more equal participant structure of peer groups may be conducive to both cognitive and pragmatic development. Rogoff (1990) highlights Piaget’s (1977) argument that children’s discussions with adults are less conducive to cognitive development than their discussions with equals – while the superiority of adults might intimidate children from freely expressing their ideas, other children can provide the opportunity for discussion and reciprocal exchanges, thus promoting the types of social interaction conducive to cognitive development.

**Research Card #6:**

**Value of Guidance in Learning Science**

Learning science adds increased complexity to the practice of facilitating discourse. Learning science involves acquiring the language and tools of science and the canonical ways of reasoning in science (Anderson, Holland, & Palincsar, 1997; Kuhn, 1962), and is not possible without guidance and assistance (Scott, et al., 2006). “Learning science, therefore, is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the 'ways of seeing' which have been established and found to be fruitful by the scientific community. Such 'ways of seeing' cannot be 'discovered' by the learner—and if a learner happens upon the consensual viewpoint of the scientific community he or she would be unaware of the status of the idea” (Driver, 1989, p. 482). Thus it is necessary for science teachers and informal science educators to engage learners in dialogue about their everyday views of phenomena, **and** introduce the science perspective (science content) (Scott, et al., 2006).

**Research Card #7:**

**Science as a Socio-cultural Process - Lemke**

...”science is a social process. This is true even when a scientist is physically alone. Whenever we do science, we take ways of talking, reasoning, observing, analyzing, and writing that we have learned from our community and use them to construct findings and arguments that become part of science only when they become shared in that community. Teaching science is teaching students how to do science. Teaching, learning and doing science are all social processes: taught, learned, and done as members of social communities, small (like classrooms) and large. We make those communities by communication, and we communicate complex meanings primarily through language. Ultimately, doing science is always guided and informed by talking science, to ourselves and with others.

Page XI From Talking Science, Jay L. Lemke

## Session 7: Classroom Conversations

### Coding Transcripts

The following codes were used to mark teacher statements in the transcript:

- Focused question (FQ)
- Broad question (BQ)
- Evaluation (E)
- Follow-up (F)
- Invitation (I)
- Repeat or Rephrase (RR)

**Note:** Some teacher statements (e.g., rhetorical questions) don't fall under any of the above categories. This list doesn't represent all the possible conversational moves that can occur, and there are others that can provide for a rich discussion. It can also be helpful to record when the teacher chooses to remain silent and waits for the students to answer a question or follow-up on a statement.

#### **Student statements can also be coded**

When students actively participate in a dialogue, their statements and questions can serve the same functions as those of the teacher. It can also be useful to note on the transcript when open-discussion between students takes place.

#### **Focused questions (FQ)**

A focused question (also known as a *test*, *narrow* or *closed* question) is one in which the speaker already has an idea in mind about the answer or range of answers that are acceptable. It serves to confirm student understanding or to resolve a discussion. Teachers often give evaluative responses after an answer to a focused question, to inform the student whether their response was correct or incorrect.

Example: What causes volcanoes to erupt?

#### **Broad questions (BQ)**

Broad questions (also known as open-ended questions) have no pre-specified answer the speaker is looking for. In order for a question to work as a broad question, the student must perceive that the speaker is not expecting a particular response and is really curious about their answer. Sometimes a teacher asks a question as if it is broad, but it then becomes clear that the teacher is actually seeking a specific answer to a focused question when the teacher evaluates the responses.

Example: What did you notice?

## Session 7: Classroom Conversations

### Evaluation (E)

Evaluations are when the person indicates that an answer is either correct or incorrect. Evaluations can also be non-verbal and often are communicated by the tone of voice.

Examples:

Hmmm...not exactly  
Yes, that's right!  
No, that's not correct.

### Follow-up (F)

Follow-up questions or statements (also known as *uptake*) are when the teacher (or students) "follows-up" on something someone has said, by either asking them to elaborate and explore an idea they have brought up or asking how they arrived at their understanding. It functions by taking up an idea that has been put on the table and encouraging students to further explore what it may mean or where it possibly came from. Often, another student will respond by following up on the comment thus extending the discussion.

Examples:

So you said that spoons float...what makes you think that?  
You noticed it's smoother than before...what do you think made it so smooth?  
Tell us more about that

### Invitation (I)

When a teacher asks other students to respond to or take up an idea that has been presented. This kind of question is best asked after an idea has been more fully fleshed out, and serves to invite others to participate and think about what has been said. It can also serve to *initiate* a conversation sequence, as described by IRE.

Example:

Student: So the rocks crunch together, break into smaller pieces and turn into sand.

Teacher: What do the rest of you think about that idea?

### Repeat or Rephrase (RR)

This response takes place when a teacher either repeats something a student has said verbatim or rephrases it to determine whether they have understood correctly. It can either serve to encourage students to elaborate further or to merely confirm that the comment was understood. If the response is used to summarize or synthesize what the students have been discussing, then it could also be properly coded as Follow-up.

Example:

Student There were no bubbles when it was mixed.

Teacher: There were no bubbles when the solutions were mixed?

**Session 7: Classroom Conversations**

**Transcript for Potato Video**

NOTE: Teacher statements and responses appear in italics, and are indicated by the letter "T." Coding appears in parentheses. Student names are listed when they are specifically addressed by the teacher. Students whose names are not used in discussion are indicated as S1, S2...etc.

*T: When we start new areas of study, we usually write down what we already know. And we are going to spend some time talking about potatoes. And I wanna know what you know about potatoes! Adrian, what do you know about potatoes? (BQ)*

Adrian: Mmmmm...cook it?

S1: You can eat it.

*T: You can cook potatoes...(writes on the board) alright. (RR) Anyone else have something they know about potatoes? (I) Haley...*

H: Um, they grow underground.

*T: Oh, Haley! You say they grow underground. (writes on the board) (RR)*

S1: Yeah!

Haley: (nods her head) You have to dig 'em up.

S2: And they look like dirt...

*T: OK, Jessica...*

Jessica: You can plant 'em in a cup with water.

*T: You can plant them in a cup with water... (RR) when you say that, do you mean just the cup? (F)*

S2: And where's the seeds go?

*T: Tell me how, tell me what your plan would be. (F)*

Jessica: You put water and then, um, put it in a cup and, and, put it next to the window so it can get some sun.

*T: OK, so you say plant...them in a cup with water. (RR) (writes on the board)*

S1: Yeah, but you put soil, soil.

S2: Planting...Where's the seeds in 'em?

S3: And then you have to plant soil.

S1: Dirt!

*T: Here we have a couple things, though, about planting...They grow underground. They have to dig them, you have to dig them up. And that you can plant them in a cup with water. (RR) Nobody has said where they get potatoes. OK where do you get them, Ryan? (BQ)*

Ryan: Uh, you get 'em at the store.

*T: At the store. (RR) (writes on the board) Martin?*

Martin: You can grow potatoes.

*T: Oh, so you can just get them from your garden...(RR)*

New segment:

*T: I want you to look at this potato... like you have never seen a potato before. Now what do I mean by that? (FQ)*

Student: That looks like a rock.

**Session 7: Classroom Conversations**

T: *That's what I...I want you to really look at it very carefully, and see what you notice about it.* (BQ)

S1: And that one looks like...that one look like a...cocoon.

T: *Now, I'm gonna give one potato to every two people. So Cary and Kia can share a potato, Germaine & Martin, and really look at it carefully. You can talk about it a minute or two and then we're gonna write a list of what you noticed about it.*  
(Students talking....)

T: *If you can tell me something you can see about this potato...something you observe about this potato.* (BQ) *That's my word...observation. Jeremy...*

Jeremy: Oh, they grow uh...

T: *Someth..No...(begins to E, but then stops)*

Jeremy: ...little things all over.

T: *Oh, they grow little things...(RR)*

Jeremy: ...with holes you can see 'em. You can see holes.

T: *You can see little holes on the outside of it?(F)*

S: Those things...that's where you put the toothpicks.

T: *Now, when I give you the other potato, I want you to observe it also. Look at it carefully, but see if you can see anything different about the potato I give you this time, from the potato you already have.* (BQ) *(Oops, Sean you're right)*

S1: What are those?

S2: I don't know.

Jeremy: I know! That's what I was talking about. These are what those things are with the holes in them!

Jessica: I know - they're planting stuff on 'em!

T: *OK raise your hand if you have a comment. Jessica...(I)*

Jessica: That these things are planting...

T: *What do you mean? (F)*

Jessica: Um, I had potatoes that looked like one of these and they're growing...

S: They're sprouts!

Jessica: The potato wasn't in the water, but it still grewed in the bag.

T: *So you think that potato's growing... Or when you said some...(F)*

S: It is...it's growing some.

T: *OK. You think that, you think that's coming out of the potato or did you think something was put on the potato? (F) I guess I couldn't quite understand.*

Jessica: I think it's coming out of the potato.

T: *You think it's, you think it's coming from inside and coming out of the potato. (RR)*

Jessica: nodding.

T: *OK. What do you want to call that? (FQ?)*

Many students answer at once: growing, buds, growing potato

T: *What do you want to call it? (I) You think it's a little grow...a little...a little thing growing on the potato. (RR) But just...*

Martin: Nu-uh it's called sprouts.

**Session 7: Classroom Conversations**

*T: Martin, when you raise your hand you can add to this...So Jessica you said "a little thing grows out of the potato." (RR) (writes on the board)*

Martin: These are sprouts, that are growing out of these potatoes. Sprouts grow on these potatoes when they come...when they come out of the grounds, they get' em and um...sprouts, sprouts, um, grow.

*T: OK. So you wanna, you wanna call these things...are you saying spouts? (F)*

Many students at once: Sprouts!!

*T: Sprouts, sprouts, sprouts. (RR) (writes on the board)*

S: We have a hard time with that word.

*T: OK. I just didn't get that "r" in there did I? Sprouts are coming out of it. (RR)*

Haley: The little seeds on the potatoes...they're, I think they're these...only, um, they're, um, tinier 'cause they haven't grown as much.

*T: So even on the first potato, the ones that you could see a little bit, you're saying are just smaller ones of these. (RR)*

Haley: Yeah.

*T: Now you, you called them something, though. What'd you say that you thought they were? (F)*

Haley: I think, um, seed.

*T: So you think maybe those are like a seed. (RR) (writes on the board)*

## Session 7: Classroom Conversations

### Classroom Discussion Activities

An important part of the process of learning is having opportunities to talk with others about the topic. These are some activity structures that provide opportunities for students to discuss during classroom time, and that can be used with any topic.

- **Partner Share**

**Pairs of students discuss one or more questions.** This very simple strategy can be done with planned questions, or can also be improvised at any point in a lesson. “Turn to a partner and discuss, [insert question here].” It helps keep everyone engaged in large groups, and gives opportunities for everyone to talk about what they are thinking, as well as hear the ideas of others.

- **Jigsaw**

**1. Each member of a small group is responsible for reading a piece of information.** Each piece of information is relevant to the topic they are to discuss. Each member of a group is responsible for carefully reading one of the cards. Then they take turns explaining the information from their card to their small group. Like a jigsaw puzzle, each member of the team is in charge of one of the “pieces.”

**2. Each member leads discussion about information on his/her card.**

One group member shares the information from his/her research card, and tells the group their thoughts about it. They may include:

- anything they find confusing about it.
- any questions or issues they have about the topic on the card.

They should also invite group members to discuss the topic on the card.

- **Think-Pair-Share**

**1. Think:** Give students an interesting broad question to think or write about briefly.

**2. Pair:** Pair students, and ask them to discuss the question(s) with their partner.

**3. Share:** Lead a large group discussion about the topic.

- **Thought Swap**

**1. Choose a series of broad questions on a topic that will be interesting to discuss.**

**2. Line up participants and establish partners.** Have participants stand shoulder to shoulder to form two parallel lines, so each person is facing a partner. Participants standing side by side should be at least 6” apart.

**2. Explain procedure for discussing questions.** You will be providing a question for them to talk about with their partner across from them. They will have about a minute to talk. You will signal them to be quiet to prepare for the next question or statement by gently tapping on the shoulder the first two participants at the end of the lines (the “tap of silence”). These two will then pass the tap on down the line, till the entire group is quiet.

**3. Begin the thought swap.** Pose the first question for participants to discuss

**4. Share responses with group.** After about a minute, tap the first two participants at the ends of the lines and wait for the entire group to become silent. Repeat the question. Ask a few participants to share with the large group what their partner told them.

**5. Change partners for discussion.** Tell participants which one of the lines will shift with each question, while the other remains in place. Tell the person at the end of one line to walk down and rejoin the line at the opposite end. Have this line now shift one position to the left so everyone is facing a new person. Everyone now should have a new partner.

**6. Do the same with the other questions.**

## **Session 7: Classroom Conversations**

- **Tape recorders**

1. **Pair up students.** Assign partners, with one student as “talker,” the other as “tape recorder.”

2. **Explain roles.** The “talkers” role will be to say all they can think of about the topic you give them, until you say, “stop.” The “tape recorders” job will be to listen to everything she says until you announce, “stop,” then try to repeat as much of it back as possible, like a tape recorder.

3. **Begin talking and recording.** Provide a prompt or a question and tell students to begin discussing. After a couple of minutes, get the group’s attention and instruct them to switch roles.

4. **Discuss process.** Now tell them to briefly discuss in their teams how it felt to be a “talker” and “tape recorder.” After a few minutes, ask for a few comments to be shared with the whole class.

**Session 7: Classroom Conversations**

## **Presentation Slides**

- Discuss with a Partner**
- Jigsaw Activity**
- Transcript Observations**
- Classroom Discussion Activities**
- Quick Write**

## **Discuss with a Partner:**

- Why do you think talking is important for learning?
- What strategies might be used in a classroom to encourage discussion between students?

## **Jigsaw Activity**

- Silently read your card
- Explain to the group what it says and your thoughts about it
- Ask group for comments about:
  - things they found confusing
  - questions they have
  - how this information could influence teaching

## **Transcript Observations**

- To what degree did the teacher generate student engagement and, if so, how do you think she did this?
- What types of teacher “moves” preceded a series of responses made by students?
- What evidence did you observe of student meaning-making during the discussion?
- When and how does the teacher’s facilitation open up opportunities for students sense-making?

## **Classroom Discussion Activities**

Partner Share

Jigsaw

Think, Pair, Share

Thought Swap

Tape Recorder

**Session 7: Classroom Conversations**

**Quick Write**

Describe changes you could make in your teaching to promote conversation. Cite specific strategies you would use and detail possible responses you would expect from your students.

**Session 7: Classroom Conversations**

## **Additional Activity**

### **Floating Bubbles Demonstration**

If your visiting students are at high school or university level, you may want to demonstrate a phenomenon that is more challenging to explain. Pass out bubble solution, tubs and straws, and demonstrate how to place a large amount of dry ice in the tub. Dip a straw in the solution and gently blow a bubble in the air above the tub, so the bubble floats down into the tub. This will probably take a few tries. The first bubble might sink quickly, as it often has a drop of bubble solution on it that makes it heavier. Try blowing a second bubble without re-dipping your straw. Be sure not to blow into the tub, or else the dry ice gas will be blown out of the tub.

Participants should observe that the bubbles float on the layer of carbon dioxide gas, created by the subliming dry ice. If they observe carefully and long enough, they may notice that over time the bubbles slowly sink and get bigger.

Note: Do not explain to the participants what is going on. That's the mystery for them to solve! If the bubbles are very small, they are less likely to float. Hint for making larger bubbles: If you are using a straw to blow bubbles, blow more slowly, then flick them off the straw.

If you have trouble observing the floating bubbles phenomenon, it may be because the invisible layer of carbon dioxide gas has not accumulated in the tub. Try one or more of the following: Add more dry ice to the bottom of the tub or break up the dry ice into smaller pieces.

If you do this demonstration, see the "Floating Bubble" discussion questions below in the "Wrapping Up" section.

**Session 8: Designing a Lesson**

# **Session 8: Designing a Lesson**

## *Contents*

<b>Session Overview</b>	<b>2</b>
<b>Background Information for the Presenter</b>	<b>3</b>
<b>Materials and Preparation</b>	<b>6</b>
<b>Instructor's Guide</b>	<b>7</b>
<b>Session Handouts</b>	<b>13</b>
<b>Presentation Slides (also in separate PowerPoint)</b>	<b>19</b>

## Session 8: Designing a Lesson

### Session Overview

In this session of the course, participants focus on applying some of the insights and understandings they've gained as they plan lessons for students. The lessons they design are focused on addressing a common alternative conception regarding photosynthesis. During the first part of the session, participants observe a video that shows students grappling with the concept of photosynthesis in individual interviews and classroom activities. They look at a few common alternative conceptions, and discuss the possible origins of these ideas. Then participants are given a handout to guide their development of a lesson to address a specific photosynthesis-related alternative conception while keeping the framework of the learning cycle in mind.

Designing instructional materials is challenging and requires different skills than teaching. The goal of this session is not to create curriculum developers or even great lessons, but to engage participants in considering the important elements that good instructional materials embody. While few educators will engage in full-scale materials design in their careers, most educators will need to adapt and modify their instruction according to feedback about students' level of understanding, and experiences like these can help to inform this process.

That leads to the final message of the session—a reminder that one experience, no matter how compelling and memorable, is not necessarily sufficient to enable students to transform deep-seated alternative conceptions. As they witness in the video, students often come up with quite ingenious and clever ways to retain their older ideas at the same time as they adapt some aspects of more accurate conceptions. Monitoring students' changing ideas and engagement through repeated experience, over time, are part of the path to building more accurate understanding.

It should be noted that in designing the "Communicating Science" course as a whole—we have tried to "practice what we preach." The course seeks to exemplify a flexible model of how people learn. In that sense, this session can be seen as the *application* phase for the entire course, as students apply what they have learned about learning and teaching to the task of designing a lesson.

## Session 8: Designing a Lesson

## Background Information for the Presenter

### Importance of Accessing Students' Ideas in Science

As discussed in previous sessions, taking students' prior ideas into account is very important for teaching science effectively. By incorporating a constructivist approach to teaching, we acknowledge that students have already assembled their own personal schemas for understanding the natural world. We also recognize that to help students learn science in a lasting and meaningful way, we must create situations so they confront their inaccurate or incomplete ideas and have the opportunity to adjust their thinking to a more scientific view. For this reason, having students' alternative conceptions firmly in mind when designing lessons can help teachers achieve their goals for student learning in science.

### Why do we develop and hold onto inaccurate ideas?

The tenacious structures of thought that students create about science are quite unique to the individuals who produce them, however, they also share some common features. Research studies have shown that children (and adults) all over the world may share the same alternative conceptions in science, even though their school experiences can be very different. This may be because alternative conceptions and naïve ideas have as their source a characteristically human approach to trying to understand the world.

We primarily use our physical perception of events to make sense of the phenomena we encounter. What we see, hear, taste and feel counts for a lot in the ways that we understand the world around us. In science however, we must rely on constructing mental models for things that can't be perceived directly. Often these models contradict what can be directly observed – i.e., the Earth does seem flat from our viewpoint, and we usually can't see gases or feel their mass. This is one reason that scientific ways of understanding may not seem to “make sense” to learners and why they sometimes have a difficult time believing the more accurate explanations.

It can also be a struggle to understand the world from a systems perspective. We tend to explain what we see by attributing particular properties to specific objects, rather than thinking of the interactions between groups of objects. For example, we may think that a metal container will help to keep ice cold, because metals generally feel cold to the touch. We don't necessarily think about the way the air surrounding the container will interact with the metal by rapidly transferring heat and the metal will efficiently transfer this heat to the ice, thus causing it to melt. Obviously, this argues for providing students with ample experiences in analyzing how systems work and how small changes to system components can result in large overall effects.

Another common pattern found in young children's thinking (and in many adults!) is to focus on explaining *changes* rather than on things that occur in a steady state. Changes are what seem to require an explanation, and things that don't change seem to merely exist without necessarily having a cause. This kind of thinking makes it hard to recognize, for example, that all particles in matter are constantly moving, even when the substance is in a solid state and not only

## **Session 8: Designing a Lesson**

when it is changing phase. Similarly, the prominent alternative conception that a force can only be present when objects are in motion, is likely as a result of this kind of error in causal reasoning. Again, we have a tendency to reduce complex causes or systems of interactions into being the result of a single action or event that occurs in a linear fashion to produce whatever is observed.

Another impediment to understanding science is that learning is often very context dependent. We may experience a scientific phenomenon or process in one context and not be able to make generalizations or extend it to another. For example when performing investigations, students may be unaware of the transferable aspects of the activity, and only relate their understanding to the particular situation they have witnessed first hand. In order to learn how to transfer or generalize scientific understanding, students need to be explicitly asked to think about concepts and explanations as applied to a variety of settings.

### **Some Common Alternative Conceptions Explained**

#### **Concentration in Solutions**

When a solid is completely dissolved in a liquid, the resulting solution has the same concentration from top to bottom. We call the dissolved substance the solute and the liquid into which the solid dissolved the solvent. Once a solute is completely dissolved, the solute particles can freely move around between the solvent particles and therefore spread out evenly. As a result, the amount of solute per volume of solvent is the same at any location within a solution. Of course this is only true when the solution has not gone beyond the saturation point, i.e., the amount of solute added can be completely dissolved.

#### **Temperature and Heat Transfer**

When you expose any two materials – whether metallic material or non-metallic – to the same conditions, both will reach the same temperature. For example, after being in a car on a hot summer day for a while, the metal buckle and the seatbelt strap will both be at the same temperature as they come in contact with the hot air. As the air in the car heats up from the sun, the heat transfers to all the objects in the car until they reach the same temperature. In other words, the temperature of all the objects is equilibrated. While the metal buckle may “feel” hotter when we touch it, our experience is caused by the metal transferring heat more quickly to our finger than the seatbelt strap, not by a difference in temperature.

#### **Insulation Properties of Materials**

If you want to keep something either hot or cold, you must insulate it. Insulation is achieved by materials that slow down the rate of heat transfer. Therefore, insulation is any barrier that slows down the rate at which heat is transferred between an object and its surroundings. Metals transfer heat quickly, non-metallic materials like wool or Styrofoam transfer heat more slowly. So tightly packed wool can keep a can of soda cold, but aluminum foil will actually cause the can of soda to warm up more quickly as the heat from surrounding air transfers to the can.

## **Session 8: Designing a Lesson**

### **Phase Change and Mass**

When you freeze any liquid, including water, a change in physical state occurs. The liquid neither gains nor loses particles upon freezing, so the mass of the solid formed must be the same as the mass of the original liquid. While the number of particles does not change, the solid formed contains stronger forces holding the particles together than the original liquid. This explains why solids hold their shape while liquids can be poured.

### **Size and Density**

Density is a property of substances related to the amount of mass in a fixed volume. Solid objects will float or sink in a liquid depending on their density and the density of the liquid. When the average density of the object is less than the density of the liquid, the object will float. When the average density of the object is greater than the density of the liquid, the object will sink. While big objects can weigh more than little objects, it is the density (mass per unit volume), not the mass alone, which determines whether the object floats or sinks. Objects with low density have more “empty space” within their structure (i.e., the particles are more spread out). So a big piece of plastic can float (low density) while a small piece of stone will sink (high density).

### **Gases and Mass**

Because gases are made of matter and all matter has mass, gases therefore have mass. Like liquids and solids, gases are composed of particles that have mass. While it is true that gases are much less dense than liquids and solids, this is because the particles in the gas are spaced very far apart. A helium balloon floats in air because the helium gas is less dense than the air surrounding it. While the helium gas has less mass per volume than air (which is composed of mostly nitrogen, oxygen and carbon dioxide gases), nonetheless, it still has mass.

## Session 8: Designing a Lesson

# Materials and Preparation

## Materials Needed

### For the class:

- Part one of the video *Lessons From Thin Air*
- DVD player & projector (or VCR and monitor)
- Slides or overhead transparencies of the following pages:
  - Learning Cycle
  - Common Alternative Conceptions Slides (6)
  - Designing a Lesson
  - Addressing a Specific Alternative Conception

### For each participant:

- 1 copy of each of the *Common Alternative Conceptions Explained* handout
- 1 copy of *Designing a Lesson to Address an Alternative Conception* handout
- 1 copy of the *Photosynthesis* handout

## Preparation of Materials

### Before the day of the activity

Obtain a copy of the video, *Lessons From Thin Air*, part of the Annenberg Foundation video series, *Minds of Their Own*. Video Series: *Minds of Our Own*, 1997 Producer: Annenberg Corporation for Public Broadcasting, 1-800-965-7373, <http://www.learner.org>

### On the day of the activity

1. Make one copy for each participant of the following pages:
  - *Common Alternative Conceptions Explained* handout
  - *Designing a Lesson to Address an Alternative Conception* handout
  - *Photosynthesis* handout
  
2. Make slides or overhead transparencies of the pages:
  - Learning Cycle
  - Common Alternative conceptions slides
  - An impediment to fully understanding photosynthesis
  - Designing a Lesson
  
3. Set up a DVD player or VCR and monitor in the classroom. Cue the video to the beginning.

## Session 8: Designing a Lesson

# Instructor's Guide

## Session Objectives

In this session, participants:

- learn that alternative conceptions in science are common and can be hard to change;
- gain an understanding of effective strategies for uncovering and addressing students' alternative conceptions in science;
- apply what they've learned in the course thus far, to the task of designing a lesson to address a specific alternative conception; and
- reflect on their own understanding of designing lessons.

## Session Activities at a Glance

### Strategies for Uncovering and Addressing Students' Ideas

Participants are shown the first part of the video, *Lessons From Thin Air*, which is about photosynthesis. In the video, Harvard graduates and middle school students display a commonly-held alternative conception that the mass of a plant comes primarily from water and minerals, rather than from CO<sub>2</sub> gas in the air. The interviewer in the video asks questions to find out why the student holds these ideas, and provides some clues to encourage them to re-examine their thinking. During the video the participants are challenged to note strategies used both to uncover alternative conceptions, and to challenge them.

### Discussing Alternative Conceptions in Science

After a class discussion on the strategies used in the video, the class is presented with a number of other widely-held alternative conceptions. Small groups are assigned one of these alternative conceptions and told to discuss what they think might be the source of this idea.

### Designing a Lesson to Address an Alternative Conception

The whole class then focuses on an alternative conception related to the understanding photosynthesis. In small groups, they are challenged to come up with an activity designed to encourage students to question this alternative conception. Each group is assigned to outline an activity that is designed specifically to address problems with understanding photosynthesis. The large group then discusses the challenges involved in meeting this lesson design task.

### Reflecting on Designing Lessons

The session ends with a reflection prompt about what they've learned about designing lessons in science. They begin by brainstorming and writing down how their ideas about designing lessons have changed through the experiences in the session. They share these with a partner, then discuss in the large group.

## Session 8: Designing a Lesson

### Time Frame

Total Workshop: 2 hours

Strategies for Uncovering and Addressing Students' Ideas (30 minutes)

Discussing Alternative Conceptions in Science (20 minutes)

Designing a Lesson to Address an Alternative Conception (60 minutes)

Reflecting on Designing Lessons (10 minutes)

### Strategies for Uncovering and Addressing Students' Ideas (30 minutes)

**1. Project the "Learning Cycle" slide.** Reflect on how there have been learning cycles used throughout the course to structure individual sessions and in the overall design of the course.

**2. Explain Use of Learning Cycle in the course.** Tell participants that in the *overall* learning cycle design of the course, the beginning sessions of the course provided opportunities for Invitation, Exploration, and Concept Invention. Tell them that today's session is part of the overall Application stage of the course—as they begin trying to put some of ideas and strategies they've gained from the course into practice.

**3. Explain that they will incorporate strategies to design lessons that address alternative conceptions.** In this session they'll be practicing designing lessons in small groups and seeking to incorporate the strategies taught in the course into their lesson design. In their lessons they'll be focusing on addressing a specific set of student alternative conceptions.

**4. Introduce Lessons from Thin Air video.** Tell them that first you're going to show them a short video dealing with alternative conceptions. The video is part of a series called *Minds of their Own* that was made by the same group that made the *Private Universe* video they saw in the *Constructing Knowledge* session.

**5. Focus on alternative conception strategies as they watch video.** Tell participants that, as they watch the video, they should try to identify strategies the interviewer uses:

- to uncover alternative conceptions
- to address alternative conceptions

**6. Show Part 1 of Lessons from Thin Air.** Participants watch the segment of the video that relates to photosynthesis (the first ~17 minutes). Stop the tape right after you hear: "Parents have to be asking their child all the time, 'Are you really learning to understand or are you just learning to pass the test?'"

**Session 8: Designing a Lesson**

**7. Discuss strategies for uncovering alternative conceptions.** Ask the participants what strategies they identified that the interviewer used to *uncover* alternative conceptions. If your participants don't raise them, consider mentioning the following examples:

**Asked questions to find out what the student already knew before instruction.**

- How much do you think that (log) weighs?
- What did it need to grow?

**Asked questions to find out what the student remembered after instruction, one month later.**

- Can you remember what you said about air?
- What is it (the plant) using from the air?
- What do you remember about the photosynthesis equation you drew a month ago?
- What would you say now about the percentages?

**Asked questions to find out what the student was thinking.**

- What would you say about air not weighing anything?
- Why would you say that sometimes that statement is right, and sometimes wrong?

**8. Discuss strategies for addressing alternative conceptions.** Ask what strategies the interviewer used to *address* the alternative conceptions, and again, consider mentioning the following examples, if they don't come up:

- **Identified a foundational idea that the student did not understand** (that gas has mass) which may be a stumbling block for the student to be able to comprehend that the mass of the wood came primarily from CO<sub>2</sub>.

- **"Adapted the curriculum,"** and presented new materials to address the specific needs of the student.

- **Asked questions to prod the student into thinking more deeply about the subject matter.**

"You mentioned carbon dioxide and you mentioned oxygen. Any idea what these things are?"

"Do they have any kind of weight, do you think?"

- **Brought in information and evidence that conflicted with the student's ideas,** through the use of more focused questions, forcing the student to rethink ideas.

"Ready, OK, I want you to hold that." (piece of dry ice)

"Do you know what dry ice is? Does it have weight?"

"What if I told you this is carbon dioxide? It's frozen carbon dioxide."

"What do you think is happening to it? What do you think will be left?"

"It's not made of water, it's made of CO<sub>2</sub>. Any clues about what might be left when it's gone?"

Session 8: Designing a Lesson

**Discussing Alternative Conceptions in Science (20 minutes)**

**1. Introduce additional alternative conceptions.** Tell participants that you're now going to introduce some commonly held alternative conceptions in science.

**2. Display and briefly explain the first slide.** Show the *Concentration in Solutions* slide and briefly explain the ideas students sometimes express about this concept and why it is generally considered incorrect. Be careful not to mention the possible sources of this erroneous idea.

**(1) Concentration in Solutions**

Some students think that the concentration is greater at the bottom of the container in a solution.

**3. Briefly introduce other alternative conception slides.** Do the same with the other slides: *Phase Change and Mass*, *Temperature and Heat Transfer*, *Insulation Properties of Materials*, *Size and Density*, and *Gases and Mass*. Again, be careful not to discuss the possible reasons for these ideas.

**(2) Temperature and Heat Transfer**

Some students think the fabric and metal buckle of a seat belt in a hot car are at different temperatures, because one feels hotter than the other.

**(3) Insulation Properties of Materials**

Some students think that wool generates heat and/or that aluminum foil can be used to insulate heat and cold.

**(4) Phase Change and Mass**

Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of liquid water.

**(5) Size and Density**

Some students think that only big things sink and little things float.

**(6) Gases and Mass**

Some students think the reason gases float and are invisible is because they have no mass.

*Note: There are many other common alternative conceptions that could serve well in this activity other than the above list. Feel free to substitute others if they seem more appropriate for your participants' needs.*

**4. Explain that small groups will discuss possible sources of one alternative conception.** Each small group will now discuss what they think are some possible sources for one of these alternative conceptions—what observations of real world phenomena or other factors might foster such a widely held misunderstanding.

## Session 8: Designing a Lesson

**5. Groups discuss possible sources of alternative conceptions.** Assign one alternative conception per group, and distribute the *Alternative Conceptions Explained* handout. They can refer to the handout for a simple scientific explanation of each of the ideas.

**6. Class discusses possible sources of conceptions.** After about 10 minutes, regain the full groups' attention, and lead a discussion of what they think might be sources of each of the alternative conceptions. Point out that understanding the possible sources of these ideas can be the first step in designing instruction that can help students achieve more accurate scientific understandings.

### Designing a Lesson to Address an Alternative Conception (60 minutes)

**1. Introduce photosynthesis focus for lesson.** Display the slide, "An impediment to fully understanding Photosynthesis." The entire class will now focus on addressing the alternative conception that the student (and others) in the video expressed regarding where trees get their mass:

Many people think that the mass of a tree primarily comes from soil, water, and nutrients.

**2. Describe design task.** Explain that, working in the same small groups, they will now design a lesson aimed at helping students recognize their alternative conceptions related to photosynthesis and help them build a more scientifically accurate understanding. This lesson should be appropriate for the age of the students they are working with. Say that participants will plan the activity for the lesson on paper, but they can include the use of hands-on materials in their description.

**3. Introduce planning sheet and goals.** Display the *Designing a Lesson* slide. Distribute the handout with the same title to each participant and say that they will first begin by deciding on a specific goal for the lesson and then proceed with planning the other parts of the lesson. Point out that it can be helpful to have assessment in mind as they design their lesson—how they will know whether students have achieved this goal .

**4. Photosynthesis is a complex topic—they will focus on one aspect.** Distribute the handout on photosynthesis and point out that fully understanding the entire process is far beyond what can be realistically accomplished in one lesson. They will need to focus in on an age-appropriate aspect of the concept that they think students must confront in order to reach a more accurate (if not complete) understanding of the concept.

**5. Participants design lessons.** Let participants know they will have about 30 minutes to work on their lesson and fill out their planning sheet. Circulate among the groups, answering any questions and providing assistance as needed.

**6. Each small group shares lessons with another small group.** After ~30 minutes, tell participants that they will now present their ideas for a lesson to another small group, who will give feedback. Display the Lesson Feedback slide. Encourage them to be frank when providing feedback, including the pros and cons and whether they think the lesson is feasible for the students they are teaching. They will have about 10 minutes for one group to present their ideas and the other group to respond, then 10 more minutes to switch roles, and do the same.

## Session 8: Designing a Lesson

**7. Discuss grade level expectations for understanding photosynthesis.** After both groups have had a chance to hear and respond to lesson ideas, focus their attention. Explain that even very young students in elementary school can become aware that photosynthesis is the process by which plants use water, carbon dioxide, and energy from the Sun to produce food. It is also important for everyone to understand that the Sun is the ultimate source of energy for all living things. However, because we can't actually experience the chemical processes involved in photosynthesis directly, fully understanding the complex system of carbon cycling and energy transformations that occur as a result of photosynthesis requires thinking in rather abstract terms that are quite difficult for young children, as well as for many adults.

### Reflecting on Designing a Lesson (10 minutes)

**1. Introduce topic for reflection.** As a conclusion to the session tell participants that you would like to have them reflect on the process of designing a lesson. They will do this using the structure known as “**Think, Pair, Share.**”

**2. Participants think and write about prompts.** Ask participants to first “**Think**” about the following questions, and write down their own ideas on a piece of paper.

- What was challenging about this assignment?
- What caused you to think?
- What did you need more information about?
- How will this experience help you to prepare a science activity specifically to address an alternative conception?

**3. Partners discuss prompts.** After a few minutes tell each student to “**Pair**” up with another student, to discuss and compare ideas.

**4. Large group discussion.** Lead a class discussion allowing a few partners to share some highlights of their discussion.

**5. Explain that it takes more than one experience to address deep-seated ideas.**

Remind participants that one experience, no matter how compelling and memorable, is not necessarily sufficient to enable students to transform deep-seated alternative conceptions. As they saw in the videos, students often come up with quite ingenious and clever ways to retain their older ideas at the same time as they adapt some aspects of more accurate conceptions. Monitoring students' changing ideas through repeated experience, over time, are part of the path to building more accurate understanding.

**Session 8: Designing a Lesson**

## **Session Handouts**

- **Common Alternative Conceptions Explained**
- **Designing a Lesson to Address an Alternative Conception**
- **Photosynthesis**

**Session 8: Designing a Lesson****Common Alternative Conceptions Explained...****(1) Concentration in Solutions**

Some students think that the concentration is greater at the bottom of the container in a solution.

**Explanation:** When a solid is completely dissolved in a liquid, the solution you get has the same concentration from top to bottom. We call the dissolved substance the *solute* and the liquid into which the solid dissolved the *solvent*. Once a solute is completely dissolved, the solute particles can move around freely between the solvent particles and therefore spread out evenly. As a result, the amount of solute per volume of solvent is the same at any location within a solution. Of course, this is only true when the solution has not gone beyond the saturation point, i.e., when the amount of solute added can be completely dissolved.

**(2) Temperature and Heat Transfer**

Some students think the fabric and metal buckle of a seat belt in a hot car are at different temperatures, because one feels hotter than the other.

**Explanation:** When you have a metallic material and a non-metallic material under the same conditions, both will reach the same temperature. For example, in a car on a hot summer day, the metal buckle and the seatbelt strap will both be at the same temperature as they equilibrate in the car. While the metal buckle may “feel” hotter when we touch it, our experience is caused by the metal transferring heat more quickly to our finger than the seatbelt strap, not by a difference in temperature.

**(3) Insulation Properties of Materials**

Some students think that wool generates heat and/or that aluminum foil can be used to insulate heat and cold.

**Explanation:** If you want to keep something either hot or cold, you must insulate it. Insulation is achieved by materials that slow down the rate of heat transfer. Therefore, insulation is any barrier that slows down the rate at which heat is transferred between an object and its surroundings. Metals transfer heat quickly, non-metallic materials like wool or Styrofoam transfer heat more slowly. So tightly packed wool can keep a can of soda cold, but aluminum foil will actually cause the can of soda to warm up more quickly as the heat from surrounding air transfers to the can.

**(4) Phase Change and Mass**

Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of liquid water.

**Explanation:** When you freeze any liquid, including water, only a change in physical state occurs. The liquid neither gains nor loses particles upon freezing so the mass of the solid formed must be the same as the mass of the original liquid. While the number of particles does not change, the solid formed contains stronger forces holding the particles together than the original liquid. This explains why solids hold their shape while liquids can be poured.

## **Session 8: Designing a Lesson**

### **(5) Size and Density**

Some students think that only big things sink and little things float.

**Explanation:** Density is a property related to the amount of mass in a fixed volume. Solid objects will float or sink in a liquid depending on their density. When the average density of the object is less than the density of the liquid, the object will float. When the density of the object is greater than the density of the liquid, the object will sink. While big objects can weigh more than little objects, it is the density (mass per unit volume), not the mass alone, which determines whether the object floats or sinks. Objects with low density have more empty space within their structure (i.e., the particles are more spread out). So a big piece of plastic can float (low density) while a small piece of stone can sink (high density).

### **(6) Gases and Mass**

Some students think the reason gases float and are invisible is because they have no mass.

**Explanation:** Because gases are made of matter and all matter has mass, gases therefore have mass. Like liquids and solids, gases are composed of particles that have mass. While it is true that gases are much less dense than liquids and solids, this is because the particles in the gas are spaced very far apart and the gas is mostly empty space. A helium balloon floats in air because the helium gas is less dense than the air surrounding it. While the helium gas has less mass per volume, nonetheless, it still has mass.

**Session 8: Designing a Lesson**

**Designing a Lesson to Address an Alternative Conception**

**Goal:** What is the main learning goal of the lesson?

**(1) Invitation:** What would you do or ask to get students interested?

**(2) Discussion of initial ideas:** What questions would you ask to draw out their ideas?

**(3) Exploration:** How would you use materials to get students to explore and think further?

**(4) Discussion of concepts:** How would you guide students to making sense of their explorations and new ideas?

**(5) Application:** What challenge or application would you use to give another opportunity to apply their new ideas?

**(6) Assessment:** How will you know if students have adopted new ideas or understandings as their own? How will they demonstrate their understanding?

**Session 8: Designing a Lesson**

## **Photosynthesis**

Photosynthesis is a challenging concept for children to learn. A strong understanding of photosynthesis requires having mental models for understanding energy and how it can be transformed. It also requires an understanding of how organisms transform matter into different molecules through chemical processes, in order to store and use energy. This level of understanding is beyond most elementary school students. But there are simpler aspects of photosynthesis that are accessible for younger children.

### **Photosynthesis-related concepts taught in elementary school (from simple to more complex)**

- Plants need air, water, nutrients, and light.
- The Sun is the major source of energy for the growth of plants.
- Plants use energy from light to make sugars from carbon dioxide and water.
- Plants remove carbon dioxide from the air, and give off oxygen as a waste product.
- The mass of plants is primarily made from carbon dioxide and water.
- Plants transform light energy from sunlight into chemical energy contained in the carbohydrates they produce.
- Plants take inorganic materials from the environment and, utilizing energy from sunlight, transform them into organic matter, which can be used by plants and, ultimately, animals.
- Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment.

**Session 8: Designing a Lesson****Photosynthesis explained at a high school level:**

Through photosynthesis, plants convert energy from the light of the sun to energy-storing molecules. These molecules serve as the energy source, not just for plants, but for every other living thing.

Molecules of chlorophyll, found in the chloroplasts of plant cells, absorb photons from the sun. The photons' energy is converted into chemical energy that the plant can use to grow and reproduce. In the course of some rather complicated chemical processes, carbon dioxide and water from the plant cell's surroundings are converted into glucose (or other carbohydrates) plus oxygen. The net effect of photosynthesis is to remove carbon dioxide from the air, produce energy for the plant cell, and give off oxygen as a waste product.

The overall chemical reaction involved in photosynthesis is:



There are two parts to photosynthesis; the light reaction and the dark reaction. In the light reaction, light energy is converted to chemical energy. For this reason the reaction must take place in the light. Chlorophyll and other plant pigments absorb specific colors of light and pass this energy to a chlorophyll molecule where ATP is formed. Cells use ATP to store energy. In the dark reaction,  $\text{CO}_2$  is converted to sugar. The dark reaction involves the Calvin cycle where  $\text{CO}_2$  and energy from ATP are used to form sugar and subsequently other carbohydrates.

**Common Student Ideas About Photosynthesis****Accurate ideas about photosynthesis:**

- In their study of 33 eighth and ninth grade students, Stavey et al. (1987) found that 83.3% of the eighth graders and 40% of the ninth graders knew plants absorbed carbon dioxide from the air and over half of all the students identified carbon dioxide as one of the gases included in photosynthesis and respiration of plants.

**Inaccurate or incomplete ideas about photosynthesis:**

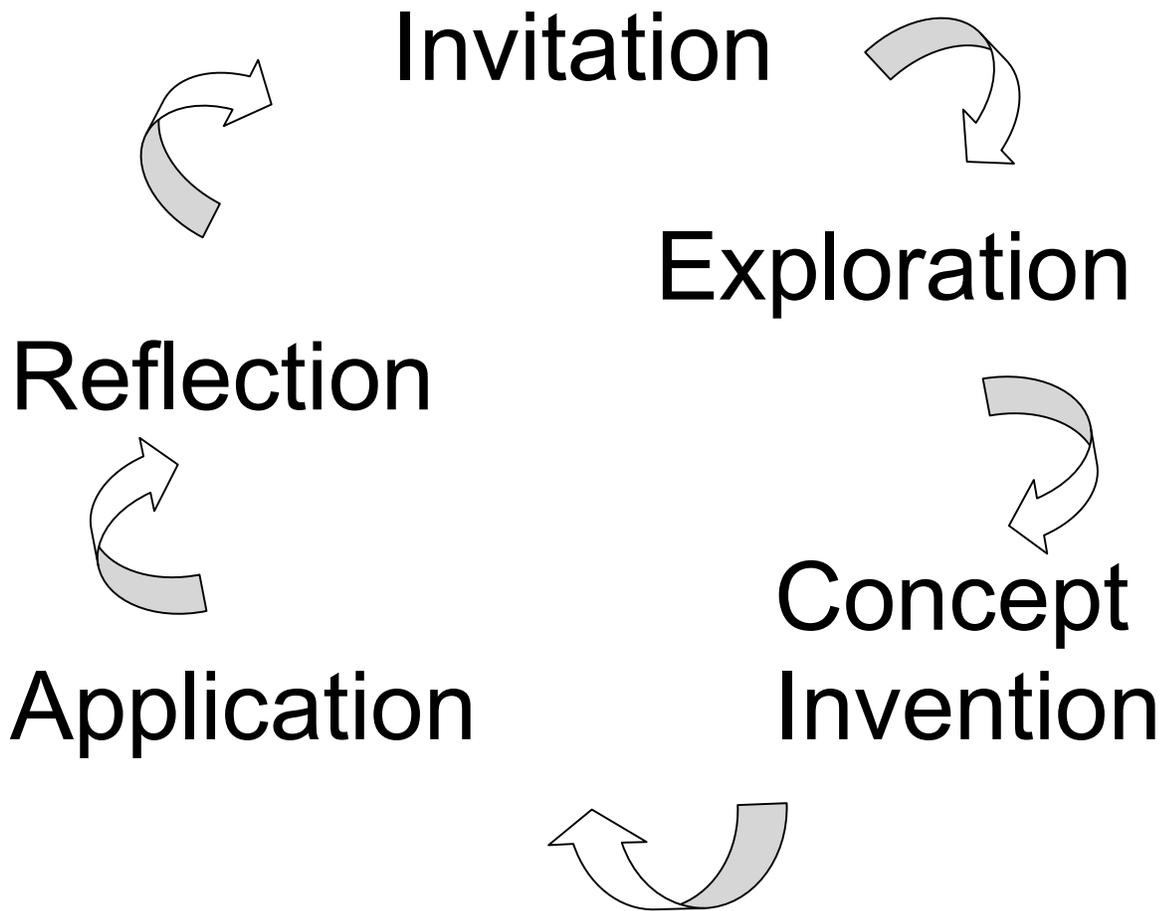
- students think the mass in plants comes from soil nutrients and water.
- students do not associate carbon dioxide with the development of biomass in plants.
- students are not aware that plants respire as they utilize some of the carbohydrates they produce.
- students cannot identify plants as producers or explain what plants produce.
- students think of photosynthesis as a form of breathing in plants.
- students think plants photosynthesize but do not breathe (respire), and only animals breathe.
- students think plants breathe in carbon dioxide and breathe out oxygen during the day and reverse this process at night.

**Session 8: Designing a Lesson**

**Presentation Slides**

- Learning Cycle
- **Some Common Alternative Conceptions in Science:**
  - Concentration in Solutions**
  - Temperature and Heat Transfer**
  - Insulation Properties of Materials**
  - Phase Change and Mass**
  - Size and Density**
  - Gases and Mass**
- **An Impediment to Fully Understanding Photosynthesis**
- **Designing a Lesson**

# The Learning Cycle



# **Some Common Alternative Conceptions in Science...**

## **Concentration in Solutions**

If everything is dissolved, is the concentration the same at the top and the bottom?

Some students think that the concentration of a solution is greater at the bottom of the container compared with the top.

## **Temperature and Heat Transfer**

Are they at the same temperature?

- seatbelt strap vs. metal buckle
- wooden object vs. metal object

Some students think that metals are generally at a higher or lower temperature than other materials in the same location.

## **Insulation Properties of Materials**

Can wool be used to keep things cold?  
Does aluminum foil insulate?

Some students think that wool generates heat.

Many also think that aluminum foil can be used to keep a soda cold.

## **Phase Change and Mass**

When you freeze a cup of water, does it still have the same mass as when it was a liquid?

Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of water.

## **Size and Density**

Can little things sink?

Can big things float?

Some students think that the size of an object alone can be used to predict whether it will float or sink.

**Session 8: Designing a Lesson**

# **Gases and Mass**

## Do gases have mass?

Some students think that gases have no mass.

# **An Impediment to Fully Understanding Photosynthesis**

Many people think that the mass of a tree primarily comes from soil, water, and nutrients.

## **Designing a Lesson**

(1) What is the main goal of the lesson?

(2) How will you address the following aspects of the lesson?

- Invitation
- Discussion of initial ideas
- Exploration
- Discussion of concepts
- Application
- Assessment

# **Lesson Feedback**

- **Share your lesson with another group**
- **Group provides feedback**
- **Switch roles**

**Session 9: Assessing for Learning**

# **Session 9: Assessing for Learning**

## *Contents*

<b>Session Overview</b>	<b>2</b>
<b>Background Information for the Presenter</b>	<b>3</b>
<b>Materials and Preparation</b>	<b>6</b>
<b>Instructor's Guide</b>	<b>9</b>
<b>Presentation Slides (also in separate PowerPoint)</b>	<b>17</b>
<b>Session Handouts</b>	<b>28</b>

## **Session 9: Assessing for Learning**

### **Session Overview**

This session provides participants with background on and experiences with the important topic of assessment. The session begins with a group assessment activity in which participants review and discuss the topics covered thus far in the course. They examine a real-world example of being assessed and think about some of the reasons for using particular assessment methods.

Participants learn the advantages of using different types of assessment measures and how they can reveal a broader range of understanding and skills. They also examine student work samples to evaluate how well they reveal student ideas in science.

Throughout the session participants gain a sense of the importance of formative classroom assessment and how it can best be used to support student learning.

## **Session 9: Assessing for Learning**

### **Background Information for the Presenter**

Assessment of student learning is a complex and sometimes controversial topic, especially in an era of increased emphasis on standardized testing and school accountability. Yet assessment is an essential part of education—both to gain insight into student learning progress and—as is sometimes forgotten—into whether or not teaching strategies and curricula are appropriate and effective.

Grant Wiggins, a leading commentator on issues in educational assessment, notes that the root of the word “assessment” derives from “to sit with.” In its original sense, it speaks to connecting with the person being “assessed” in such a way as to gain a close understanding of what they know and understand. From this perspective, teachers are constantly assessing students as they assign tasks and pose questions designed to uncover their understanding. However, educators do need support in developing the knowledge and skills required to effectively plan for assessment, observe learning, analyze and interpret evidence of learning, provide feedback to students, and support them in self-assessment.

The purpose of assessment is to gather **evidence of learning**—whether it is provided to teacher, student, parent, district, state, or nation. It’s important that learning be recognized for the complex process it is. Assessment should probe for depth of learning, apply appropriate measurement techniques, and understand that the full range of learning includes critical thinking, conceptual understanding, basic skills, and factual information.

### **Using Multiple Measures**

Educators use a variety of ways to assess what students know. Some of these methods resemble traditional tests; others aren’t always recognizable as such. One of the current “best practices” in education is to try to use a balance of different kinds of assessments in order to test for a broad range of student knowledge and ability. The idea is that multiple assessment measures are needed to attain a more complete and accurate assessment of student learning.

Using multiple measures may include: (a) administering a test comprised of various components or different types of assessment items, i.e., open-ended response, enhanced multiple choice, constructed response, performance task, etc. (b) using different types of measures within the classroom across the school year, or (c) looking at different levels of assessment across the larger education system, i.e., the classroom, district, state, and nation). Wiggins and many other educators believe, for example, that “tests” should be administered in settings that enable the student to explain or clarify answers. More than this, they argue strongly for assessments that allow students to demonstrate the full range of their abilities in the performance of a real-world related task.

## Session 9: Assessing for Learning

Wiggins notes, “There is room for the quiet techie and the show-off prima donna in plays; there is room for the slow, heavy lineman and for the small, fleet pass receiver in football. Why must all students be tested in the same way and at the same time? Why should speed of recall be so well rewarded and slow answering be so heavily penalized in conventional testing?”

This practice is also supported by the research related to developing expertise in a subject or a field. Experts are defined as those who can “transform” important knowledge and facts into usable conceptual understandings that allow one to solve new problems. This process is also referred to as *transfer* and supports the trend in using *authentic* assessments—where the learner is asked to apply what they’ve learned to a task they have not yet encountered.

Using a balance of different kinds of measures allows educators to gather multiple forms of evidence about student learning and allows students to demonstrate understanding through a variety of different formats, modalities, and testing situations.

### Assessments Should be Valid for Their Intended Purpose

A related idea in assessment is that a teacher should select assessment tasks and prompts based on their intended purpose. Each kind of assessment has advantages and limitations. Different types of assessments are best suited to different realms and kinds of knowledge, therefore, the type of assessment that is used depends on what information is desired.

For instance, it’s important to find out that children know their math facts; it’s also important to find out that children know how to think critically and solve complex problems. Carefully designed multiple-choice and short answer questions can be helpful for assessing factual and some conceptual knowledge. Open-ended prompts can be useful for uncovering students’ initial ideas and possible misunderstandings. Many standardized tests are designed to help make comparisons between different groups of students. Performance tasks, portfolios of work over time, and presentations of individual or group projects are useful for assessing complex reasoning and the ability to apply one’s understanding of concepts. Thus the kind of test or assessment method that is most appropriate depends on the kind of learning a teacher wants to assess and the goals for the use of the assessment information.

### Current Emphasis on Formative Assessment

Best practices in teaching recommend that formative assessment should be woven into *all* stages of learning: **before** new material is presented (to assess current knowledge), **during** the learning process (to monitor how well a student is grasping a concept), and **after** the lesson has been taught (to see how well the student understands the new material, and to assess the effectiveness of the teaching). This lets a teacher evaluate and modify the learning experience in time to make a difference—rather than discover a problem just as it’s time to move on to another subject.

## Session 9: Assessing for Learning

Curriculum-embedded, formative assessment practices create a continuous flow of information between teacher and student in order to guide the next steps in learning. For this reason, it's also important to actively involve students in the assessment process. Scoring guides and rubrics, as well as direct teacher feedback, are shared with students to help them envision performance goals and understand what is needed for improvement. In this way, students understand the work standards that are expected of them, and formative assessment information can be an important guide for instructional improvement for both the teacher and the student. By allowing students to be more in charge of their learning, their motivation to learn is greatly increased.

Assessment *for* learning is when students have:

- understanding of instructional goals
- opportunity to develop skills and knowledge necessary to achieve goals
- ownership of their learning
- motivation to learn

In fact research has shown that, when carried out effectively, formative classroom assessment that includes constructive feedback to students significantly raises the levels of student achievement. In this sense, quality formative assessment is indistinguishable from good teaching practices.

Teachers using formative assessment to support learning must:

- Develop clear learning goals for students
- Provide opportunities to learn content in a deep way
- Align assessment tasks with curriculum (what is taught) and instruction (how it is taught)
- Embed assessments at key points throughout instruction
- Make changes to curriculum, instruction, and assessments based on feedback from students

Teachers may also use *summative* assessments to measure student progress at the end of a unit of instruction. These kinds of assessments are more typically included in curriculum programs and textbooks, and are designed to help determine what students have learned from the instructional materials. Because they occur after instruction, when students are preparing to move on to other topics, they have a distinctly different purpose than formative assessments. They do provide feedback to the teacher about the success of the lessons, but this information can only guide instruction for the next time the materials are used, which is often not until the following school year. In this case, summative assessment can be referred to as assessment *of* learning, in direct contrast to formative assessments that are used throughout instruction as assessment *in support of* learning.

## Session 9: Assessing for Learning

# Materials and Preparation

## Materials Needed

### For the Class:

- an LCD projector (or overhead projector)

### For the Assessment Carousel:

- 10–15 large sheets of butcher paper—one for each question or topic and some extra sheets in case students run out of room.
- felt-tip marking pens—a different color for each group of 4–6 students
- masking tape for posting butcher paper

### The following slides (or transparencies): 1 each of the following:

- Goals for the Assessment Carousel
- Defining Assessment
- Purpose of Assessment
- Two Kinds of Tests
- Full Range of Learning
- Different Kinds of Assessments
- Formative Assessment
- Looking Student Work
- Research about Assessment
- Examples of Assessment Strategies

### For the Looking at Student Work activity:

(Samples of student work from a variety of assessments)

For each group of 4–6 participants:

2 manila folders

2 sets of student work from an assessment task

2 copies of the sheet describing the assessment task

## Preparation

### Before the Day of the Workshop:

**1. Make handouts.** For each participant, duplicate one copy of the following handouts:

- “Looking at Student Work” sheet
- “Examples of Assessment Strategies”

**2. Prepare slides or overhead transparencies.**

## **Session 9: Assessing for Learning**

- 3. Assemble student work folders.** Obtain and/or select six to eight samples of student work, either from the sample assessments included here, or from a representative classroom source. Duplicate two sets of identical student work for each group of four to six participants and place them in labeled manila folders. Make two copies of each sheet describing the assessment task and context (see the “Looking at Student Work” handouts) and place them into the corresponding folders.

### **For the Assessment Carousel:**

1. Decide how many “response sheets” you would like to use. The number will depend on the number of participants in the class (teams of no fewer than three and no more than five will rotate around the room—your minimum number of response sheets should equal the number of teams you have—each team needs to be at a response sheet). The number you decide on also will depend on the number of topics you want the teams to respond to. (See list of possible topics below.) Somewhere between 6 and 10 is probably a good range.
2. Label each piece of butcher paper with the topic or questions you would like your students to respond to. Number each sheet so that you can easily assign groups to a starting point. Post these charts along the walls, spreading them out around the room as much as possible.

### **Possible Pedagogical Content Topics:**

- Nature and Practices of Science
- Teaching Approaches
- The Learning Cycle Model
- Constructing Understanding - Constructivism
- Questioning Strategies
- Promoting Discussion
- Teacher Response Strategies
- Planning and Classroom Management Strategies
- What makes a good science lesson?
- Assessing for Learning

## Session 9: Assessing for Learning

### Pedagogical Content Not Explicitly Addressed in the course:

- Equity Issues in Education
- Multiple Intelligences
- Developmental Theory
- Inquiry

### Possible Science Content Questions:

- What concepts should be taught in Chemistry K-5 (or whatever grades are appropriate for your audience)?
- What concepts should be taught in Physics K-5?
- What concepts should be taught in Astronomy K-5?
- What concepts should be taught in Life Sciences K-5?
- What are general science concepts that should be taught in K-5?

*Note: We've included a listing of possible topics and questions, but be sure to choose topics and questions that reflect what you've taught in your course, and what you'd like them to be thinking about for the rest of the course. You'll need to eliminate some of these or add some of your own.*

### Immediately Before the Workshop: (20–30 minutes)

1. Set up LCD (or overhead) projector at the front of the room near where you will stand.
2. Assemble student work sample folders and instruction sheets.
3. Have the handouts easily accessible at the front of the room.

## Session 9: Assessing for Learning

### Instructor's Guide

#### Session Objectives

*In this session, participants:*

- have the experience of being assessed themselves as part of their exploration of the topic of assessment
- have the opportunity to teach each other
- review the course topics before applying them in designing their own lessons
- gain information about assessment and how this arena of education is changing
- learn how they can use some of these principles and practices in assessment to support student learning

*In this session, the instructors:*

- become aware of what the class has learned about the topics addressed in the course, as well as those that have *not* yet been addressed
- use this information to inform how to adjust instruction in the remainder of the course

#### Session Activities at a Glance

##### Assessment Carousel and Discussion

First, participants take part in an *Assessment Carousel* activity, designed to gain information on what they have learned in the course thus far. They then discuss the experience, and the goals behind it.

##### Introduction to Assessment

After a brief definition of assessment, participants begin a discussion about the value of the two kinds of driving tests given at the Department of Motor Vehicles—a multiple choice test about the laws related to driving and the performance test in which a person must actually drive. This leads to the general conclusion that different kinds of tests test for different kinds of knowledge—and both kinds are important.

At this point we offer a definition of assessment and its purpose to gather evidence of student learning. The presenter then introduces important assessment approaches that exemplify sound instructional practices—the importance of assessing the full range of learning, the value of using the right assessment for the right purpose and the benefit of using continuous formative assessment in order to inform instruction.

##### Looking at Student work

To gain some firsthand experience with assessment, the group is given a collection of actual student work from various assessments devised by previous course participants. By examining and discussing the student work in small groups, they learn what they reveal about students' knowledge and also reflect on the effectiveness of the assessments to reveal evidence of student understanding.

## Session 9: Assessing for Learning

### Assessment in Context

The class discusses what was learned from examining the student work and evaluating the assessments.

### Conclusion

The presenter concludes the session by presenting research findings about the value of formative assessment—assessment *for* learning as opposed to assessment *of* learning. Students receive a handout listing several examples of different kinds of authentic assessment techniques that can be adapted for use in a wide variety of situations.

### Time Frame

Total Workshop: 2 hours

Assessment Carousel and Discussion (50 minutes)

Introducing Assessment (20 minutes)

Looking at Student Work (40 minutes)

Assessment in Context (10 minutes)

Conclusion (5 minutes)

## Introduce Session

### Assessment Carousel

- 1. Introduce group assessment activity.** Tell participants they'll be taking part in a group assessment activity. Point out that this assessment will not be testing their individual knowledge, but the knowledge of the class, and they will work in teams to respond to a series of prompts about some topics that are important to teaching.
- 2. Display paper charts and prompts.** Show them the large sheets of paper with topics and questions posted around the room. Read each one out loud. Point out that most of the sheets deal with topics that have been addressed in the course (e.g., "Learning Cycle"), but that some will be challenging them to stretch their knowledge (e.g.: "What are concepts to teach in Astronomy in grades K–5?").
- 3. Assign teams for rotation and explain task.** Assign teams or have the students count off, up to the number of response sheets you have posted. Let them know that their group will be assigned to begin at one of these sheets. Explain that each group will have a specific color of marking pen to share, and they will use it to record their groups' responses to each of the questions or topics listed. When they arrive at each sheet of paper, the group will brainstorm and record everything they can remember about the topic.
- 4. How to indicate agreement/disagreement.** When they arrive at a station where others have already recorded their responses, their first task will be to read all the previously recorded statements on the sheet. If their group generally agrees with a statement, they should make a "+" (plus) sign next to it. They may

## Session 9: Assessing for Learning

also add to the statement. If they disagree with a previously recorded statement, their group should make a “-” (minus) sign.

**5. Explain timing.** They will have only a few minutes to respond to each prompt and you’ll make an announcement when it’s time for the groups to rotate to the next question or topic. Indicate the direction in which they will be rotating. They will have approximately five minutes at their first station, but as the activity progresses, it will become more difficult to come up with new statements, so you will give them slightly less time to write.

**6. Ask if there are any questions and begin rotation.** Tell them they may begin brainstorming and writing. Announce the rotation time approximately every 3–5 minutes, reminding them in which direction to rotate.

**7. Read comments at final station.** When every group has had the chance to respond to each topic, and has returned to their original sheet of paper, give them some time to read what the other groups have written. After a few minutes, have them return to their seats for a discussion of the activity.

## Discussing the Assessment Carousel

**1. Large group discussion.** Ask the class what they got out of doing the assessment activity. Invite them to comment on the process and how they responded when told this was an assessment.

*Note: If you or your students have questions about any of the statements, the group that wrote them can be identified by the color of pen they were written with.*

**2. Discuss Goals.** Ask what they think the goals of the assessment might have been. After accepting several responses, display the slide, *Goals of the Assessment Carousel*, and read each point aloud:

- Allows participants to:
- experience being assessed
  - learn from each other
  - notice interconnections between topics
  - review the course topics to prepare for teaching
- Helps instructors:
- find out what the class has learned
  - uncover knowledge about the topics *not* yet addressed
  - evaluate and adjust instruction in the course

## Introduction to Assessment

**1. Importance of Assessment.** Point out that assessing student learning in the context of teaching is crucial to teaching in a constructivist learning environment.

## Session 9: Assessing for Learning

As we've discussed, it's necessary to be aware of students' thinking and ideas to help them to better understand science.

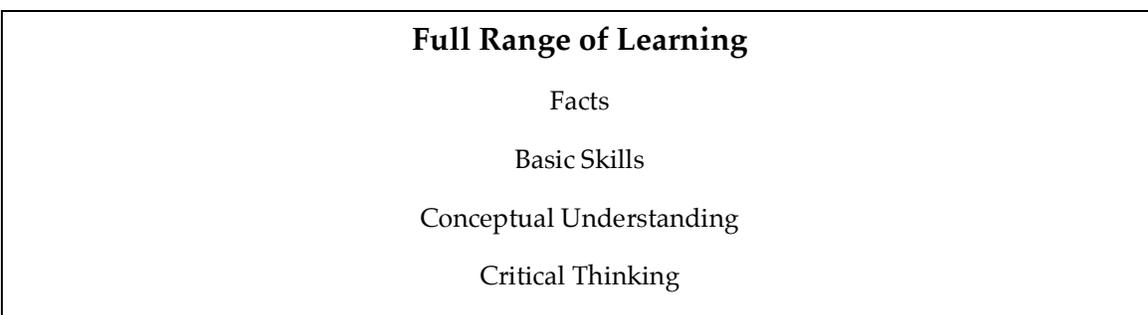
**2. Define assessment.** Display the slide *What Do We Mean by Assessment?* and explain that anything a teacher does to reveal student understanding can be considered an assessment. Emphasize that traditional assessments, such as tests, are not the only way teachers can find out about what students know. In this session they'll be exploring some different types of assessment methods and trying to evaluate what kind of information they provide about students' knowledge and progress.

**3. Point out purpose for classroom assessment.** Display the *Purpose of Assessment* slide. Emphasize that the purpose of the types of assessments we will be examining today is to provide evidence of student learning and progress. It will be helpful to think of the student work they examine as pieces of evidence from which we try to draw conclusions about their understanding.

**4. Display DMV testing example.** Project the slide *Two Kinds of Tests*, and ask participants to spend just a few minutes, in groups of four to six, discussing the two questions at the bottom. After several minutes, regain attention. Ask for several volunteers to share some of what was discussed in their group.

**5. Different kinds of tests assess different kinds of knowledge.** Summarize by saying that each kind of test is appropriate—depending on the kind of knowledge involved. In the case of driving, it is hard to imagine not testing in both ways, for both kinds of knowledge.

**6. Introduce notion of full range of learning.** Display the *Full Range of Learning* slide.



Point out that all kinds of learning are important, from mastery of factual information to the understanding of complex concepts and thinking skills. To develop competence in an area of learning, students must have both a deep foundation of factual knowledge, and a strong conceptual framework.

The key to expertise in a subject is developing a rich conceptual understanding of important information, transforming it from a set of facts into usable knowledge. And unlike pure acquisition of factual knowledge, the mastery of concepts improves the learner's ability to transfer their learning to solving new problems.

## Session 9: Assessing for Learning

**7. Different assessments have specific advantages and limitations.** The kind of test or assessment method that's most appropriate depends on the kind of learning a teacher wants to assess. Display the *Each kind of Test...* slide and point out that multiple-choice and short answer questions are quite adequate for assessing learning related to factual information and basic skills. However, performance tasks, like driving a car, are better for assessing the kinds of complex reasoning and thinking that ensure that students understand and can apply their knowledge.

**8. Balance of testing methods.** Say that one of the current practices in education is to create a balance of different kinds of assessments so we can test for a broader range of student knowledge. For instance, it's important to find out that children know their math facts (like driving laws); it's equally important to find out that children know how to think critically and solve complex problems (like driving itself).

**9. Introduce Formative Assessment.** Display the *Formative Assessment* slide. Another current practice is an emphasis on formative classroom assessment. This means that assessment should occur continuously in small ways throughout a unit, rather than only through a long test at the end of a unit. This ensures that information learned through assessment informs the teacher of how best to modify the learning experiences to address areas students are not grasping, and provides a more complete picture of each child's abilities and needs. Students also need input and feedback along the way in order to learn how to progress. When teachers take the time to do this, formative assessment can also provide important information for students to be more successful.

*Note: You may want to contrast formative with summative assessment here to help participants understand that summative assessments have the purpose of assessing achievement at the end of a unit or semester. As such, this type of assessment information cannot be used to modify instruction or provide feedback to students.*

## Looking At Student Work

**1. Introduce purpose for next activity.** Explain that in order to provide some experience with evaluating evidence from assessments, the next activity will involve them in analyzing and trying to draw conclusions from some samples of student responses to assessment tasks.

**2. Describe a process for looking at student work.** Display the *Looking at Student Work* slide. Tell participants that you will give them two identical folders with student work for their table. Inside they'll find a sheet describing the grade-level of the students and the context in which the assessment was given. Have them work in groups of four to six to look at and discuss the student work.

**Session 9: Assessing for Learning****Looking at Student Work**

1. Read, sort and discuss the student work.
2. Use the handout to guide your discussion.
- 3 Rotate through other assessment samples.

**3. Review instructions on handout and explain each step.** Distribute the *Looking at Student Work* handout and go over each of the steps described. They will first read through the samples and try to sort them into high, medium, and low responses. This will help them to begin discussing evidence of student learning. Next they'll look at the responses more closely and try to also evaluate the assessment itself based on the criteria listed. Tell them they'll also have a chance to briefly look at some other assessment samples if there is time. Ask if there are any questions about what they will be doing.

**4. Small groups begin discussing student work.** Distribute the two student work folders to each group. Let them know they will have about 25 minutes to discuss the student work at their table.

**5. Provide assistance as needed.** Circulate to each group and clarify the task or answer any questions as they come up. Check in to see how each team is progressing with their analysis.

**6. Have groups rotate through tables.** As small group discussions are winding down or when there are about 10 minutes left for this part of the session, tell participants they may move to other tables and briefly examine the other samples of student work. Ask them to try to get a sense of the different types of assessments and the kind of information they each provide.

**Assessment in Context**

**1. Lead a whole group discussion about the student work.** Get the whole groups' attention and have them sit at their tables with their small group. Ask:

- What issues came up as you were looking at the student work?
- Were you able to see evidence of student learning?
- What kinds of things made the assessment effective or not so effective?

**2. Student work was selected to provide for rich conversations.** Make sure participants realize that these assessments are not perfect nor were they selected to be examples of how to write good assessments. The purpose was to become aware of the analytical processes that go into thoughtfully examining the results from student assessments. Emphasize that it takes quite a bit of practice to make valid inferences about student understanding and what this may mean about both the instruction and the assessment of the concepts addressed.

**Session 9: Assessing for Learning****Concluding the Session**

**1. Mention current research about formative assessment.** Display *Research about Assessment* slide. Explain that formative classroom assessment can be very effective for helping students learn, when it includes providing feedback to students. In this way, students understand the work standards that are expected of them. For these students, the formula for high-quality work is not a mystery. When students are actively involved in assessing their own performance they have a better sense of what is expected and how it can be achieved. And by allowing students to be in more charge of their own learning, their motivation to learn is greatly increased. This is what is meant by assessment *for* learning as opposed to assessment *of* learning.

**2. Describe assessment strategy examples.** Reiterate that the best assessment activities are integral parts of the curriculum, rather than tests administered externally and out of context to students. Point out that with activity-based science, traditional short-answer paper and pencil tests are even more distant at being able to assess what we hope students will gain from these experiences. Display the list of different types of assessment strategies from the “Assessment Strategies” handout. Explain that these are some examples of authentic assessment tasks that can provide the teacher with the kind of information she needs to adjust her instruction. What makes them “authentic” is that they directly relate to the curriculum that has been taught and they emphasize skills needed to be successful both in school and in life.

*Note: If you are assigning the assessment development task and the related paper (see “Going Further” on the next page), then you can mention that these are examples of strategies they might want to use with their students. Also emphasize that they will use the same process of analysis when looking at their own student work and discussing the implications.*

**3. Participants reflect on learning about assessment.** Ask participants to do a “Quick Write” about any new or reinforced understandings regarding assessment that they have gained as a result of this session. Allow about five minutes for participants to record their thoughts.

## Session 9: Assessing for Learning

### Going Further

#### Design an Assessment Task

As an optional assignment, you could have participants develop and administer an assessment task related to whatever unit they are currently teaching, or may be teaching in the future. They should collect the student work and try evaluate the responses just as they did in this session. If you want a more in-depth assignment, we have included the requirements for writing a reflective paper about their assessment in the *Course Resources* section. In a three to five page paper they are asked to describe:

- Goal(s) for the Assessment
- Evidence of Student Understanding
- Modifications or improvements to the assessment, and
- Possible changes in teaching or instructional goals

#### Critiquing Assessments

Obtain sample questions from actual tests that are in use in your local district or state, and ask the participants to critique and evaluate them according to the criteria described in the “Looking at Student Work” handout. You may also want to have participants try to revise the assessments so that they would provide more formative information about student learning.

**Session 9: Assessing for Learning**

## **Presentation Slides**

- Goals for Assessment Carousel
- What do we mean by assessment?
- What is the purpose of assessment?
- Two Kinds of Tests
- Learning is a complex process...
- Different Kinds of Assessments
- Formative Assessment
- Looking at Student Work
- Research about Assessment
- Examples of Assessment Strategies

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## **Goals for Assessment Carousel**

Allows participants to:

- experience being assessed
- learn from each other
- notice interconnections between topics
- review the course topics to prepare for teaching

Helps instructors:

- find out what the class has learned
- uncover knowledge about the topics *not* yet addressed
- evaluate and adjust instruction in the course

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## **What do we mean by assessment?**

- Anything designed to reveal student understanding
- Could be formal ... (tests, quizzes, portfolios, projects, etc.)
- Or informal ... (listening to students, questioning strategies, etc.)

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**What is the purpose of assessment?**

... to gather evidence of student learning

## **Two Kinds of Tests**

After a person learns to drive, he or she goes to the Department of Motor Vehicles to be tested. There, the person takes two different tests to demonstrate his or her capability to be a licensed driver.

One test is a multiple-choice test. The person must correctly answer questions about the laws related to driving.

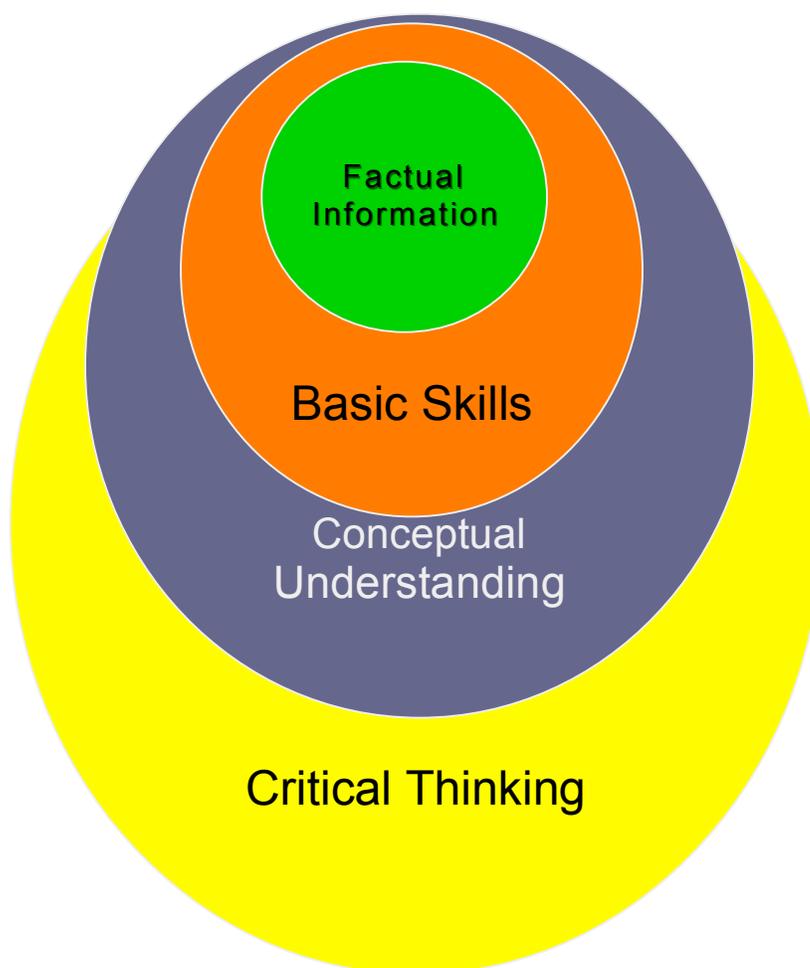
The other test is a performance test. The person must skillfully drive a car in a variety of road situations.

- Which test do you think is most important?
- Would you feel confident in knowing that a new driver had been tested in only **one** of these ways?

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Learning is a complex process...

The full range of learning includes:



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**Different kinds of assessments have advantages and limitations:**

**Multiple-choice/short answer tests** are good for measuring factual information and some basic skills, but not so good at measuring other things, like complex thinking.

**Performance tasks** are good for measuring conceptual understanding and complex thinking, but are not an efficient way to measure other things, like factual information.

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## **Formative Assessment**

- Occurs before, during, and after learning
- Serves as a guide for modifying instruction
- Provides feedback to students

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## **Looking at Student Work**

- Read, sort, and discuss the student work.
- Use the handout to guide your discussion.
- Rotate through other assessment samples.

## **Research about Assessment**

- When carried out effectively, formative classroom assessment that includes constructive feedback to students raises the levels of student achievement.
- Assessment **for** learning is when students have:
  - understanding of instructional goals
  - opportunity to develop skills and knowledge
  - ownership of learning
  - motivation to learn

## **Examples of Assessment Strategies**

Journal Writing

Letter Writing

Advertisements

Reflection Prompts

Game Playing

Prior Knowledge

Model Making

Explorations

Experiments

Investigations

Conventions Conferences Debates

Applications

Teacher Observations

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## **Session Handouts**

### **– Looking at Student Work**

- Magnets
- Dissolving and Evaporation
- Air Worksheet
- Cause and Effect
- Phase Change
- Phases of the Moon
- Liquid Explorations
- Chemical Reactions and Atoms

### **– Instructions for Looking At Student Work**

### **– Examples of Assessment Strategies**

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# Looking at Student Work

1. Read the information provided about the assessment and the context in which it was given.
2. Sort the papers. Look through the student work and see if you can group them into high, medium and low performance on the task.
3. Examine the student responses in greater detail according to the criteria listed below:
  - Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
  - Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
  - Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
  - Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
  - Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
  - Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work samples and see if you can group them into high, medium, and low performance on the task. Then look at the student responses in greater detail.

Assessment #1: Magnets

Grade level – 3rd

GEMS Activities – *Sifting Through Science*

Context: Assessment was given in two stages—first they were told to invent, draw, and label a new tool using magnets, later they were asked to label the north and south poles of magnets and to draw the magnetic field on a “planet.”

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #2: Dissolving and Evaporation  
Grade level – 1st  
GEMS Activities – *Involving Dissolving*

Prompt: Give your ideas about dissolving and evaporation.

Context: Assessment was given after students experienced several lessons about dissolving and evaporation.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #3: Air Worksheet

Grade level – 4/5th

GEMS Activities – *Matter: Solids, Liquids and Gases*

Context: Students had explored the *Matter* unit (designed for grades 1–3) as well as *Crime Lab Chemistry*. The teacher asked them to add in standards-based concepts about atoms and molecules, as related to states of matter.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #4: Cause and Effect

Grade level – 1st

GEMS Activities – *Secret Formulas*

Prompt: Write or draw a cause and an effect that you noticed over the weekend.

Context: Students had experienced several lessons where they predicted the effects of adding various ingredients to their mixtures. The instructors emphasized the principle of cause and effect through leading several discussions about how the ingredient (sugar) was the cause of the perceived effect (sweetness). This assessment was given to see if they could generalize the idea of cause and effect.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #5: Phase Change

Grade level – 4th

GEMS Activities – *Secret Formulas*: Ice Cream

Context: The assessment was given after the class witnessed a demonstration of condensation using: a cup of water at room temperature, a cup of water with ice, and a cup of water with ice and salt.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## **Session 9: Assessing for Learning**

### **Instructions for Looking at Student Work**

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #6: Phases of the Moon

Grade level – 3rd grade

GEMS Activities – *Space Science Sequence*

Context: The assessment was given after students' verbal responses in class seemed to show an understanding the various aspects of the phases of the moon.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
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6. Problems – Were there any issues or problems with the assessment? How could the task be improved?

## **Session 9: Assessing for Learning**

### **Instructions for Looking at Student Work**

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #7: Liquid Explorations

Grade level – 1st

GEMS Activities –Swirling Colors, Rain Drops & Oil Drops

Context: The following prompts were read out loud to the class, one at a time.

- 1) Name and/or draw a solid and a liquid.
- 2) Draw a leveled spoon.
- 3) Draw the Swirling Colors Plain water cup.
- 4) Draw the Swirling Colors Salt water cup.
- 5) Draw the Swirling Colors Bubble water cup.
- 6) What was the shape of the water drop looking at table level?
- 7) What was the shape of the oil drop looking at table level?
- 8) What did you observe when the cup of oil and water were poured together?
- 9) Draw a dissolved solution of Tang.
- 10) Draw a solution of Tang not dissolved.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Instructions for Looking at Student Work

Read the information provided about the assessment and the context in which it was given. Look through the student work and see if you can group them into high, medium and low performance on the task. Then look at the student responses in greater detail according to the criteria listed below.

Assessment #8: Chemical Reactions and Atoms

Grade Level – 4th

GEMS Activities – *Chemical Reactions, Of Cabbages and Chemistry*

Context: The assessment was given after these two units were taught. The concept of atoms was inserted and emphasized as an important aspect of these lessons.

Some criteria for evaluating and discussing the assessment:

1. Prompt stated clearly—Did it seem like the students understood the assessment task and knew what to do?
2. Appropriate for Grade Level—Does the concept or skill seem like something students should be able to understand or do at this grade level?
3. Important to Assess—Is the concept or skill central to understanding or doing the science addressed in the unit they have been experiencing?
4. Elicits Understanding—Do the student responses provide information about their understanding? Can you identify any patterns in the range of student responses? Are there different aspects of understanding that are expressed in groups of responses?
5. Informs Instruction—Is there information in the student responses that informs the teacher about how the lesson went and possibly how to improve it?
6. Problems—Were there any issues or problems with the assessment? How could the task be improved?

## Session 9: Assessing for Learning

### Examples of Assessment Strategies:

*Effective assessments are indistinguishable from good teaching and serve as learning activities for students.*

**Accessing Prior Knowledge**—Sharing ideas with a partner can be a safe, low anxiety place to tell what you know. Sharing what a partner said is also low stress because it's someone else's words. Informs curriculum planning, reveals misconceptions, allows for measuring growth of student knowledge.

**Example:** Conduct a Thought Swap. Tell your partner everything you know (or wonder) about... and listen to them tell you what they know.

**\*Science Journal Writing**—Allows students to use communication skills to relate knowledge about science and what they've discovered and helps them make sense of their investigations. Provides insights into students' thinking and thought processes. Good writers are not necessarily good "test" takers.

**Example:** Describe an investigation or experiment that you did: questions asked, planning for the investigation, data collection, results and/or conclusions.

**\*Letter Writing**—Can allow students to articulate steps in doing an activity, an experiment, or solving a problem. Students can raise issues and describe reasoning. Letters and persuasive writing have been central to the communication process of math and science.

**Example:** Write a letter to a forensic scientist explaining your technique for taking fingerprints.

**\*Advertisements**—Using scientific results to convince others, and other types of persuasive writing, are authentic to science. Incorporates societal aspect of doing science. Requires stating clear expectations for students.

**Example:** Create an advertisement comparing products after doing consumer-testing experiments.

**\*Reflection Prompts**—Using open-ended questions with many possible solutions can provide insights into students' thinking and thought processes. Reflection may help students recognize processes of investigation and critical thinking. Requires observation and analysis of experiment, then organization of thoughts, to be clear to others. Can emphasize applying knowledge to new situations.

**Example:** Compare two chromatography tests and try to explain why they have different patterns.

**Game Playing**—Can be very engaging, and often involves peer teaching. Analogous to "game" of science, i.e., quest for solutions, teams, rules.

**Example:** Guess My Rule game. Sort objects by their properties or attributes and have partner guess the rule used to group them.

*\* Strategies that involve a written product*

## Session 9: Assessing for Learning

**\*Model Making**—Can allow for different modalities of expression, Includes application of knowledge, creating a simplified representation of the world, illustrating how things work or might work. Modeling is a process used in science to both explain and predict phenomena.

**Example:** Create a paper animal with protective defenses and describe how the defenses work.

**\*Explorations**—Can be student-directed, and follow the learning cycle. Often begin with open-ended challenge and rich environment for exploration and can lead to new discoveries and interesting questions.

**Example:** Students asked to explore a cup of sand and describe/explain/draw how it behaves like a liquid and a solid.

**\*Experiments**—Experiments always include comparisons, controlling variables, measurable outcome. Opportunity for students to design comparison situations, conduct controlled experiments, and analyze their outcomes to draw conclusions.

**Example:** Observe a heat-producing chemical reaction in a baggie. Design an experiment to determine where the heat came from.

**\*Investigations**—Begin with a question followed by conducting the investigation, often designed by the student. Many types of resources can be used, previous student experimentation, research, observations, collecting data, etc. Can be more project-oriented, and students can produce reports, tailored to individual's interests.

**Example:** "What do you want to find out about bubbles?" Create an investigation to answer your question.

**Conventions, Conferences, Debates**—Students with different perspectives share their views, report and evaluate scientific findings. Ability to clearly communicate ideas, evaluate them with respect to larger field of knowledge, and convince others is essential in science. Allows students to deal with real world issues.

**Example:** Hold a town meeting at the end of a unit about *Acid Rain*.

**Applications**—Fit well with this phase of the learning cycle. By applying what they know to new situations, students use problem solving skills, and understanding of concepts to show what they've learned.

**Example:** Students use cabbage juice to test acidity of new or unknown substances.

**Teacher Observations**—Can consist of anecdotal reporting, behavior checklists, notes about students' comments, and other informal observations made by the teacher. Provides an opportunity to assess group behavior, and observe individual contributions and attitudes during science instruction.

**Example:** Teacher keeps a tally of productive questions students ask during a discussion about an investigation.

*\* Strategies that involve a written product*