Session 3: Teaching and Learning

Overview

This session is designed to explore how people learn, and to consider how to develop activities that reflect a variety of learning styles. Students access their prior knowledge about teaching and learning by thinking back on how different teaching approaches affected them as learners. They are challenged to think about a model for how people learn and how that model impacts how they teach and communicate. Students rotate through four activity stations focused on salinity and density that illustrate different teaching approaches. They discuss the four approaches and how each affected their interest and conceptual understanding. Students also participate in an activity about sand that is an exemplar of how teaching approaches can be used to increase conceptual understanding. The "learning cycle" is introduced and related to the students' experience with the stations and the sand activity.

Background Information for the Presenter

There has been much research, particularly in the past 10 years, seeking to uncover the processes involved in how people learn. An awareness of some of the main findings from this research is very useful to anyone involved in developing or presenting educational activities. This session is designed to open the door on the topic of how people learn, and how 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 taking place in specific phases—invitation, exploration, concept invention, application, and reflection—which eventually leads the learner to begin the cycle once again. This model for instruction also takes into account the learners' prior understandings and recognizes their need for firsthand experiences. Activities designed according to the Learning Cycle are learner-centered, provoke questions, and enable the learner to integrate and apply new ideas and information conceptually. In fact, all the adult learning activities in this 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 perspective on teaching and learning. Constructivism is a perspective on learning grounded on the premise that ***we construct (build, create) our own understanding of the world we live in through our experiences and interactions***. Constructivism has led educators to develop teaching strategies that can help make explicit the connections between new learning and previously learned knowledge; and 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 learners 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.

The Learning Cycle in Informal Environments

In informal environments, learning cycles occur on a very different time scale than in a typical classroom, and often include several "false-starts" or partial cycles. In the classroom, students are typically guided through a 60- or 90-minute long lesson. In informal environments, direct engagement at exhibits or with educators may last only a few minutes. However, many visitors report thinking about and applying information they learned in a museum weeks or months after their visit.

Many of the experiences (exhibits, activities, programs) in informal institutions are designed to attract visitors and are easy to approach and to initiate—this serves as the invitation step of a learning cycle and is very successful in engaging most groups. During the exploration phase, visitors can familiarize themselves with the experience and determine if it is something that interests them and if they will spend time with it. Due to the self-guided and free-choice nature of informal settings, visitors will start many learning cycles (***invitation*** and ***exploration***), but will only follow through to complete those with the most interest and relevance to them personally. If they are motivated to continue an experience, visitors may move to the ***concept invention*** phase: manipulating the exhibit, reading text panels, and hopefully talking to their group and thinking about their conceptual understanding.

The fourth step of the learning cycle, ***application of the concepts,*** can happen immediately following the experience and is ideally prompted by facilitators or signage. In many cases, application of concepts happens, or continues to happen, well after the visit, when relevant ideas are encountered in an everyday situation.

Reflection or metacognition involves the learner in considering his or her own learning path and taking note of experiences and ideas that have led to their personal understanding. This type of internal self-monitoring is what exemplifies the ***reflection*** phase of the Learning Cycle. As learners acquire scientific knowledge and understandings, it's critical that they spend time discussing *how* they arrived at these concepts and explaining their thinking. Through reflecting on their learning processes, learners develop the ability to think flexibly and acquire new understanding as needed. Reflection is important and can happen during any part of the learning cycle. Providing opportunities to discuss with friends, families, or educators how they arrived at ideas and how these ideas connect with their prior knowledge is critical for meaning-making to occur deeper.

Experiences in informal environments can be designed to accommodate visitor patterns by using a "learning spiral"— a sequence of interconnected, miniature learning cycles. Very short cycles (a minute or two each) maximize the number of groups that experience at least one complete cycle, while the spiral nature provides opportunity for interested visitors to engage with a concept for a longer period of time and potentially at increasingly sophisticated levels. There is much potential to create more coherent learning experiences in informal settings if they are crafted with the learning cycle model, especially miniature learning cycles, in mind.

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 is 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 depending on the person and the content being learned 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 activities that succeed in conveying concepts to learners meaningfully and effectively.

Session Objectives

In this session, participants:
— explore the advantages and limitations of different teaching approaches;
— understand that everyone learns differently;
— see the importance of incorporating a variety of teaching approaches and trying to achieve a balance among them;
— learn about an instructional model known as "the learning cycle" and gain the ability to analyze how an informal learning activity can be constructed to incorporate the learning cycle; and
— understand that effective teaching employs a sequence of different teaching approaches to achieve greater learning.

Session Activities at a Glance

Quick Write (10 minutes)

Introducing the Session (10 minutes)
This session begins with participants thinking back on how different teaching approaches have affected them as learners, as a way to invite them to begin thinking about the topic, and accessing any prior information they may have about teaching and learning.

Ice Cube Investigation Stations (40 minutes)
The participants take part in a modified version of the Ice Cubes activity from the GEMS/MARE unit entitled, *Ocean Currents.* They engage in four Activity Stations: Open-ended Exploration, Structured Investigation, Problem-Solving Challenge, and Read & Answer. This allows participants to experience how learning can be approached in different ways.

Note to Instructor: *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. There is a set of four* ***Ice Cube Investigation*** *stations written up in the session that are challenging enough and work well for most audiences. We are confident that this material will work equally well for undergraduate participants as well as for a sophisticated science audience.*

Debriefing Ice Cube Investigation Stations (25 minutes)
The instructor leads a probing discussion of participants' Activity Station experiences and thoughts, helping the group to compare and contrast the strengths of each kind of teaching approach. The instructor draws out the fact that different learners have different abilities and preferences for teaching approaches, highlighting the importance of an educator using a variety of approaches. This can

be particularly important at informal science education institutions, since groups of learners working together to do the activity will likely be composed of individuals with different learning styles.

Science Content (25 minutes)
Science content about currents is introduced through discussions, demonstrations and PowerPoint presentations to provide background information for the participants and to demonstrate how the learning cycle can be used in an interactive content presentation. The purpose of the science content presentation is threefold: (1) provide background about important concepts participants may choose to develop activities about; (2) show how to make content presentations interactive and discursive; and (3) model how to present science content using a learning cycle.

Note: *If you're interested in using this or other science content presentations, please see the Science Content Index on the website.*

Explaining the Learning Cycle (10 minutes)
The instructional model known as the learning cycle is then introduced, in the following sequence, as a helpful way to think about how people learn:

invitation
exploration
concept invention
application
reflection

Participants discover that different teaching approaches are more or less suited for each phase of the learning cycle and consider the logic of sequencing different teaching approaches.

Designing and Debriefing a Learning Cycle Lesson (25 minutes)
Participants design a lesson for investigating sand that exemplifies the Learning Cycle. They consider how this activity may play out on the museum floor. Participants are invited to point out the different phases of the cycle during the class session and reflect on the power of the order in which they were presented.

Share concept ideas and pair up (15 minutes)
Participants share the concepts they are potentially interested in developing activities about (assigned as homework) and partners form based on mutual interests.

Homework (5 minutes) *(Note – this homework is assigned as part of the UC Berkeley course; other institutions may decide to use these assignments or develop different assignments.)*

Optional: Activity Carousel (20 minutes or more—not included in the 2 hour 55 minute session)
Partners investigate one or two activity kits (materials and write-ups) for those activities they are interested in presenting on the floor next week. Instructors facilitate their investigations of the kits and answer any questions.

Time Frame

Total Workshop: 2 hours 55 minutes
- Quick Write (10 minutes)
- Introduce session & Ice Cube Investigation Activity Stations (10 minutes)
- Ice Cube Investigation Activity Stations (40 minutes)
- Debrief Stations (25 minutes)
- Break (10 minutes)
- Science Content: Debrief the Density and Currents with demos, discussion & PowerPoint presentation (25 minutes)
- Introduce Learning Cycle (10 minutes)
- Designing a lesson based on Learning Cycle (15 minutes)
- Debrief learning cycle lesson (10 minutes)
- Share concept ideas and pair up for activity development (15 minutes)
- Homework (10 minutes)
- Optional: Activity carousel (20 minutes or longer—not included in 2 hour 55 minutes session)

Important Note to Instructor: *You will need to consider two important points before proceeding:*

1. The Content for the Activity Stations. While you may wish to use another topic to model the learning cycle in the station rotations, we've found that the lesson is particularly effective if the activities employed are challenging enough to stretch the participants, but not so overly challenging that they become frustrated.

2. Choosing activity as application of Learning Cycle. Choose whether you want to use the sand materials included in this session or you would prefer to have participants design a different type of lesson based on the learning cycle.

Ideally, the activity participants design and then debrief should be about a topic you are very familiar with, that's appropriate for the level of your participants and the audience they work with, and is related to the content needs of your course. The specific lesson used is less important than having an activity that provides a good and relevant example of the learning cycle.

Materials Needed

For the class

- ❑ PowerPoint presentation
- ❑ Digital/data projector
- ❑ Whiteboard
- ❑ Flip-chart paper and pens

For each participant

- ❑ Copies of activity write-ups participants can choose to do on museum floor

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 Ice Cube Investigation 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 "Structured Activity" sheet for Station B
- one copy of "Read and Answer" sheets for Station D
- one copy of "Teaching Approaches and Educator Goals"
- 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 Exploration (materials needed to set up one station):

- ❑ 2 identical approximately 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
- a few miscellaneous "sink and float" objects, including two of each of the following: marbles, blocks, crayons, or paperclips

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

- 2 identical approximately 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 approximately 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
- a few miscellaneous "sink and float" objects, including 2 of each of the following: marbles, blocks, crayons, or 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

For the *Sand* activity:

Materials Needed:

For one activity set-up for each group of 4 participants: (also see page 37 for the "Sand" activity writeup)

1 large ziplock bag with the following:

- ❑ 4–6 small ziplock bags containing different sand samples
- ❑ 1 bottle of white glue
- ❑ small ziplock bag of index cards (1/2 white, 1/2 colored)
- ❑ small ziplock bag with hand lenses or "scope on a rope"
- ❑ 1 rock and mineral kit
- ❑ 2 sets of sand samples (see Getting Ready section below)
- ❑ crayons or colored markers or pencils
- ❑ microscope or scope on a rope (optional)

Preparation of Materials

Before the Day You Present the Session

For the Ice Cube Investigation 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 "Teaching Approaches and Educator Goals"
- ❑ one copy of "The Learning Cycle and the Sand Activity"
- ❑ one copy of "The Learning Cycle Explained" 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 parts per thousand (ppt). This salinity ensures that food coloring density isn't a factor in the saltwater part of the experiment and makes the visual impact more dramatic.

Very importantly, always test your saltwater solution to make sure it is the right salinity. Test as follows: (a) fill a cup with saltwater and gently float an ice cube in it for about 1 minute; (b) place 2 drops of food coloring in the cup; (c) if the food coloring stays at the surface of the cup, it is the correct solution, but if the food coloring starts sinking—add more salt!

For the *Sand* activity:

1. Assemble materials (rock and mineral kit, any picture of beaches or sand you might think would be helpful, glue, crayons or colored pencils, hand lenses, microscope or scope on a rope). Have one set of materials for each group of 4 participants to work with as they design a learning cycle-based lesson.

2. Gather at least four different types of sand for each group of four students. Place a small amount of one kind of sand in a baggie and then place the four separately bagged sands in a larger plastic bag.

Make Sand Samples for each small group as follows:
Make at least two samples of each type of sand for each small group by smearing white glue onto 3" x 5" cards and liberally spreading sand onto the glue. Allow to dry and then simply dump the remaining sand back into its container.

3. Determine what sand content you'd like to present to participants to provide them with the information they would need to develop and present an activity about sand. Refer to the Sand Activity for background.

Note: You really only need to present just a bit of background about sand in this session—if the participants will actually be presenting this activity, they will have access to the background included in the write-up. We've found it very effective to show about three PowerPoint slides (beaches covered in different colors of sand, close-up photos of diverse sand grains, and a photo of a beach covered in sand compared to one covered with rocks) with just a small amount of content for each. (See the session PowerPoint for examples.)

For *Sharing Concepts*

Determine how you would like participants to partner to develop an activity and present activities at the museum during the course. One efficient way to do this so partners are formed based on mutual interests is as follows: (a) The week before this session, assign homework to have students decide on just a few concepts they are interested in developing into an activity (b) have students send you their short lists before class meets (c) group together those ideas that seem similar and record one concept per sheet of chart paper (d) make one sheet titled "I'm interested in a concept not listed on the other posters" (e) place sheets on walls around the room.

Optional: For the *Activity Carousel*
Determine which activities you'd like your participants to do in the museum with visitors. Collect the kits and place in the classroom and also copy the activity write-ups for each participant.

The Day of the Session
For the *Ice Cube Investigation Activity Stations*:

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'll need to set up duplicate sets of these stations if you have more than 20 participants. The four stations are: Open-Ended Exploration; Structured Activity; Problem-Solving Challenge/Application; and Read and Answer.

Instructor's Guide–Session Details

Quick Write

Question about Hohenstein and King article assigned for homework:

1. Before the reading what were your personal ideas about how people learn?
2. What were your reactions to the different theories of learning presented in the reading? Please give one specific example from the reading.

Introducing the Topic of Teaching Approaches

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 Instructors: *As with all sessions in this guide, the presentation to 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 lesson, the participants actually experience a version of the learning cycle instructional model as they learn about it. It's important that the session and instructor 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 instructor 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.*

2. Introduce the overall goals of the Activity Stations. Point out that in this next part of the session, they will be rotating through four stations that represent different instructional approaches.

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 or small group to read the signs and follow the directions. There will be a signal given when time is almost up. They should expect to spend about eight minutes at each station.

b. **Clean up the station:** When they are finished, please use the dish tubs 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 Ice Cube Investigation Stations

1. **Monitor station activities.** Check in with 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 their structured exploration (after about eight minutes), announce to the whole group that it's 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, Station C moving to Station D, and Station D moving to Station A.

Debriefing Station Activities

***Note to Instructor**: In order for participants to feel comfortable sharing their own ideas in a discussion based on open-ended questions, it's important for the instructor to be accepting of all responses. The discussion may be much less effective if a hidden agenda emerges when the discussion leader responds in a positive fashion to some comments while negatively to others. Also, to encourage participation from everyone rather than just a few more assertive participants, after asking a question, allow 3–4 seconds ("wait time") before calling on anyone.*

Some background information for the instructor has been provided in the lesson as a guideline and framework, and should not be read to participants. Rather, the discussion leader should ask open-ended questions—many of which are suggested in the lesson—and "flow" with the participants' responses and comments, while keeping the discussion generally on track and within schedule. This may entail asking additional follow-up questions and inserting information *we have provided as appropriate, as well as sharing some personal experiences of your own related to the topic. All of this should take place with a focus on non-judgmental acceptance of the participant's comments and insights, while those of the instructor are judiciously sprinkled throughout the session—in non-lecture fashion. This kind of dynamic interchange cannot be fully scripted, and depends on the facilitation skills of the instructor. Like everything else, these presentation skills can take time and practice to develop.*

1. Ask participants to reflect on their responses to the activities and discuss the strengths and weaknesses of each approach. Draw their attention to Station A, the Open-ended Investigation, and ask for 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.

Point out that in this example, the Open-Ended Exploration station was intentionally unstructured in an *exaggerated* fashion, in order to provoke reaction and discussion. Exploration need not be completely unstructured, and more specific procedural directions, data recording charts and debriefing discussions can make it a more rewarding and educational experience for all learners.

Do the same debrief with Stations B, C, and D. Give ample time for discussion of each station.

2. Take 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. Prompt participants to recall their answers to the exercise at the beginning of class. This will help to deepen their ability to reflect on their *own* ideas (often referred to as ***metacognition***).

Tell them that different individuals often have different teaching approach preferences, and although each of them or their particular group may (or may not) have a shared collective preference, others may have a different one. Note that these preferences may have to do with individual learning styles or with what teaching approaches they've had most exposure to in the past. This holds true for informal learning activities and exhibits too.

3. Ask participants to suggest some possible goals related to different teaching approaches. Point out that educator's choices for different approaches can often depend on the goals of the lesson. Ask what goals each type of approach might serve.

4. Distribute Teaching Approaches handout. Without reading the lists item-by-item, use the following summary to supplement the discussion as needed.

Open-Ended Exploration

- Introduce learners to a new subject area
- Generate questions
- Generate learner interest and foster positive attitudes about science.
- Encourage learners to work together without direct educator intervention
- 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 learners 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 learners' 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 educator's 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 educator. 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 found it easiest to learn from an Open-Ended Exploration approach, they are more likely to teach using that approach. Remind participants to keep in mind that not all learners function best with whatever approach the educator prefers. Some groups (and individuals) need more guidance, and others need more time to explore. Because of different learner preferences, it's best to use a balanced diet of teaching approaches.

6. Discuss the sequence of stations. In the previous discussion, participants' preferences regarding the order of the stations may have already been mentioned. Point out that each group rotated through the stations in a different sequence. Ask if they liked the order they did the activities, or if there's a different order they think would suit them better or be more effective. Have each group suggest the order they think would be the most effective way to organize the stations as you record on the board. Encourage them to explain the reason underlying their ordering preference.

CONCEPT INVENTION
Participants' experiences and ideas are integrated into research and pedagogy as science content about salinity and density is introduced and then later, the learning cycle is described.

Science Content

We've chosen to introduce science content about density and salinity as a follow-up to the ice cube activity stations to model how science content can be presented through an interactive series of discussions, demonstrations, and PowerPoint slides. The purpose of the science content presentation is threefold: (1) provide background about important concepts participants may choose to develop activities about (2) show how to make content presentations interactive and discursive, and (3) model how to present science content using a learning cycle.

***Note:** if you're interested in using this or other science content presentations, please see the Science Content Index on the website. This presentation included three demonstrations—wind-driven currents, and then thermohaline currents, with cold and hot temperature layers and salty and fresh layering.*

Participants reflect on science presentation. Ask participants a question about the way the science content was presented to model reflection, then lead a short discussion about their ideas.

Think about yourself as a learner. What do you feel are the pros and cons about the way the science content on currents was presented?

Explaining the Learning Cycle

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

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 in how 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 researchers who study teaching and learning.

> ***Note to Instructor on the 5 E's****: Engagement, Exploration, Explanation, Elaboration and Evaluation. Also 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, and the chapter entitled Improving Instruction in* Achieving Scientific Literacy: From Purposes to Practices *by Roger Bybee (1997).*

3. Display *Learning Cycle* and describe phases. Use the following information to briefly 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 learners' 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.

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, learners should be free to invent and discuss their own understandings directly from their hands-on experiences, through discussion with their peers and with those with more knowledge.

Application: Armed with new ideas and concepts, the learner applies knowledge and abilities to different situations than 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, learners 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. Distribute the Learning Cycle Explained handout. Distribute the handout and give the participants just a few minutes to read it over.

5. Connect the structure of this session with the learning cycle model. Draw participants' attention to the elements of the Activity Stations lesson that fit with the learning cycle model. Ask participants to identify the parts of the learning cycle in the lesson that they just experienced with the Ice Cubes Stations.

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 and content discussion.
Application: The current and following activities. Further applications will occur in subsequent lessons in this course.

6. 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 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.

7. Describe drawbacks from focusing on only one phase of the cycle. 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 educators spend most of their time with concept invention, most likely because this is the way they were taught. It can be just as detrimental to focus solely on exploration, neglecting or rushing other important phases in the process.

Designing a Learning Cycle-Based Lesson

1. Provide science content about sand. Present a bit of science content about sand including: composition of sand, how it is formed, and how it gets to the beach.

2. Introduce task and materials. Explain to participants that they will now have a chance to apply what they've learned about the Learning Cycle to designing a specific learning activity for the audience they work with. Tell them you will distribute the materials for doing an activity involving exploring different types of sand. Show them the bags of sand samples, glue, cards, hand lenses, microscopes (optional), and the rock and mineral kit.

3. Challenge participants to design lesson together. Ask participants to work in pairs. Say they will now have about 10 minutes to decide how these materials could be used to engage visitors in an investigation of the sand samples. Ask them to try to incorporate the specific phases of the Learning Cycle in a logical sequence for the activity. They may decide to divide up the phases among themselves or work together to devise a plan.

4. Participants design activities. Pass out the sand materials and the Learning Cycle handout to each table and ask if there are any questions about the process. Have them begin working. Circulate among the groups to offer assistance as needed.

Debriefing the Learning Cycle-Based Lesson

1. Participants reflect on stages of learning cycle in their sand activity. Ask several groups to share how they incorporated the phases of the learning cycle into the activity they designed. Point out any differences in the way each group approached the task. Emphasize that there could be more than one way to address phases of learning for this particular content and set of materials.

Following is a suggested outline of the learning cycle stages of a Sand activity.

> ***Invitation**: Questions to elicit interest and curiosity: "What is sand?" "Have you ever looked at sand close up before?" "How might sand be made?"*
>
> ***Exploration**: Learners look at sand samples, notice similarities and differences, then group and answer specific questions based on observations and evidence.*
>
> ***Concept Invention**: The composition of sand and the process of erosion and transport are introduced.*
> ***Problem-Solving Challenge/Application**: Learners make their own sand samples using a "mystery sand," then make discoveries about their sand. Learners make inferences based on evidence to describe their sand's origin. They are also prompted to*

imagine the beach where their "mystery sand" came from. This promotes reflection on the concepts of sand composition and formation.

***Reflection**: Questions help learners to reflect on what they used to know about sand and how that connects with their new knowledge. Other questions include: what was your favorite part of the activity and why? What part/concept was most difficult/easiest for you to understand? Why?*

2. Lead discussion about how activities might play out with actual visitors. Tell participants to imagine how their presentation would be done on the floor with visitors. Ask if they think the visitors will complete an entire cycle. Ask: "Could the activity include "false-starts" or "incomplete cycles" that happen quickly in a spiral fashion?"

3. Discuss importance of personalizing lesson for visitor. Explain that it's inherently difficult to write a "script" for an interaction with learners in informal environments, because each interaction is different and each visitor brings a variety of experiences and ideas they (and you) can draw from when investigating sand. Another complicating factor is that the learner is in charge of his or her own time, unlike formal education, where the learner has an assigned amount of time for an activity. This puts a greater emphasis on keeping the learner engaged and the need for the facilitator to personalize the interaction. By asking guiding questions and listening carefully, the facilitator can incorporate the learner's ideas, observations, and questions to guide their investigation.

4. Explain how science is often presented in informal settings. Point out that it's very common for science topics to be presented to visitors without giving the learner a chance to really engage in discovery. Provide an example of how an educator might introduce concepts and new vocabulary at the start of an activity, and then ask learners to merely follow a procedure or view a display where those concepts are demonstrated and essentially nothing new is learned. Without the opening invitation and free exploration phases, learners have much less opportunity to become interested in and develop an understanding of the concepts. And merely delivering the information removes the fun (and educational impact) of discovering ideas for themselves. Share how it is often possible to reformat "traditional" science exhibits, activities, or lessons to follow a more effective learning cycle approach.

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

Sharing Concepts

1. **Place concept sheets prepared before class.** Place the concept sheets around the room that list one concept per sheet that participants are interested in creating activities about. Tell them that these are the concepts they submitted for homework.

2. Participants choose concept. Have participants walk around the room looking at the concept sheets and choose one they are most interested in. Have them pair up with one other person who chose the same concept so their partnership is based on mutual interests. Give participants a few minutes to discuss their ideas and schedules.

Optional: Activity Carousel

1. **Place Activity kits around room.** Disperse Activity kits and/or materials around the room that participants could present to visitors.

2. **Participants choose activity to investigate further.** Have participants browse through the kits and then choose one or two activities that they are interested in learning more about and presenting on the museum floor. Provide time for participants to investigate the kits with their partner as instructors circulate and answer questions. Distribute copies of the activities to participants after they have had a chance to browse through all of the kit materials.

3. **Participants sign up for time to present.** Circulate a signup sheet and have participants sign up for their first presentation on the floor coming up the following week.

Homework

ACTIVITY DEVELOPMENT

Identify one of the concepts that you are most interested in. Develop a three-question questionnaire with your partner, and each of you interviews three categories of people—college peers, other adults, friends and families under 18—to find out what they know about that concept. Record responses. Use this questionnaire as a reference when developing your activity.

Activity Proposal: 1–2 page proposal outlining the concepts, content, and activity that you would like to develop. (Each set of partners hands in one proposal.)

READING

Current reading from textbook pg. 40–55.

Bransford, J., Brown, A. L., Cocking, R. R. (2000). Chapter 3: Learning and transfer. In *How people learn: Brain, mind, experience, and school* (Expanded edition, pp. 51–78). Washington, D.C.: National Academy Press.

National Research Council. (2009). Chapter 3: Designing for science learning—Basic principles. In *Surrounded by science: Learning science in informal environments* (pp. 25–42). Washington, D.C.: National Academy Press.

Note: You may want to have your participants start presenting on the floor of the informal science education institution during the next week. This is a great opportunity for them to get a better feeling for the learners and the learning atmosphere of the informal environment.

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?**

Teaching Approaches and Educator Goals

Open-Ended Exploration

- Introduce learners to a new subject area
- Generate questions
- Generate learner interest and foster positive attitudes about science.
- Encourage learners to work together without direct educator intervention
- 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 learners toward specific discoveries.
- Provide a common base of experiences.
- Provide successful activities with predictable outcomes.

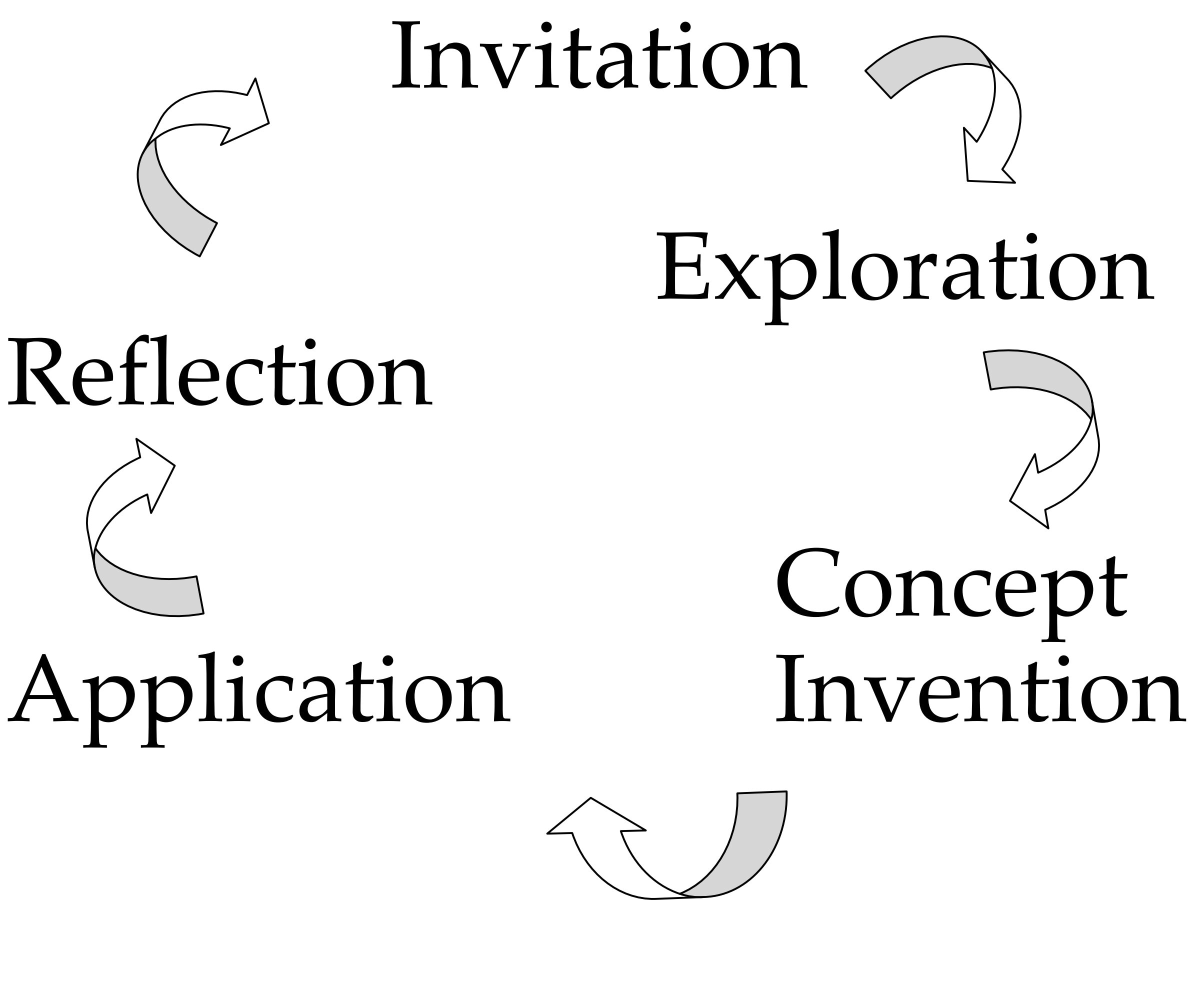
Problem-Solving Challenge/Application

- Model what scientists do.
- Provide a sense of accomplishment.
- Challenge learners' 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.

The Learning Cycle



Teaching and Learning Session Handout

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 2 minutes. 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 cups 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.

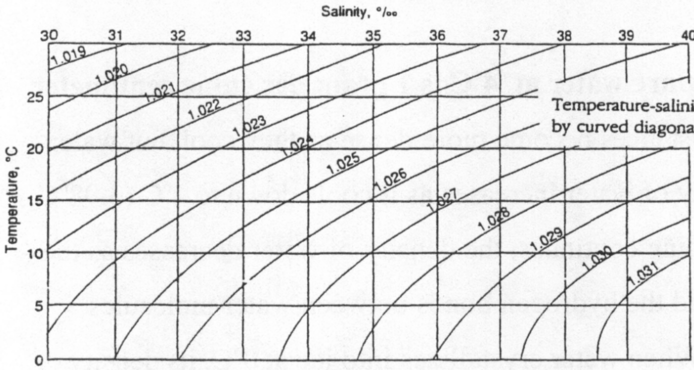
Pure water

By definition, the **density of pure water at 4ºC is 1 gram per cubic centimeter** (cm^3 ; note: 1 cm^3 = 1 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 4ºC (3.98ºC, 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 0ºC, its density decreases abruptly. Ice is less dense than an equal volume of water. As ice cools below 0ºC 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) which 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.)

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



Temperature-salinity-density (T-S-D) diagram. Density values (in g/cm³) are represented by curved diagonal lines.

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 which is responsible for most of the vertical movement of water in the ocean and for the circulation of the world ocean as a whole.

Worksheet for Station D
Questions to answer on "Water Density, Ocean Stratification, and Density-Driven Circulation"

Answer these questions:

1. What is density?

2. What factor(s) affect the density of pure water? How does the density of pure water vary with each factor you have listed?

3. What factor(s) affect the density of seawater? What is the relationship between seawater density and each factor you have listed?

4. What is density stratification in the ocean? How might density stratification affect organisms in the ocean?

5. What is thermohaline circulation? How might thermohaline circulation affect organisms in the ocean?

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

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

	Temperature (°C)	Salinity (°/₀₀)	Density (g/cm³)
Mediterranean Sea	18	39	______
Atlantic Ocean	20	36	______

a. Determine the densities of Mediterranean Sea water and Atlantic Ocean water.

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

7. DATA

	Temperature (°C)	Salinity (°/₀₀)	Density (g/cm³)
Yukon River (AK)	4	______	______
Bering Sea	9	33	______

a. Determine the densities of Yukon River water and Bering Sea water. What assumptions (if any) do you have to make?

b. 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.

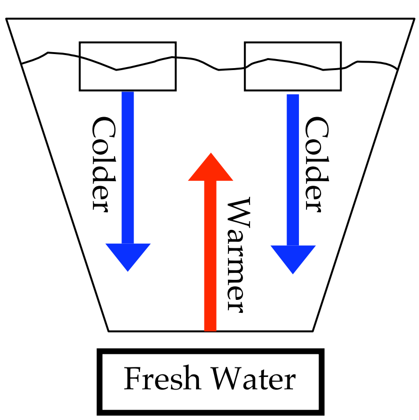
It's all about density!

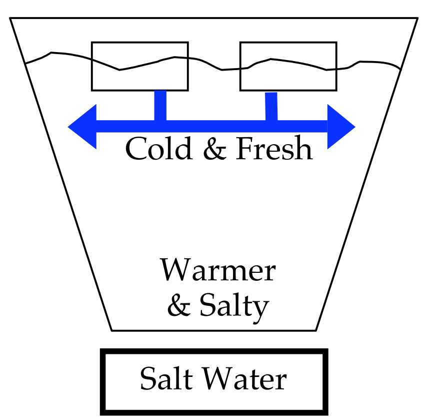
1. What happens when ice melts in fresh water at room temperature?

- 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.

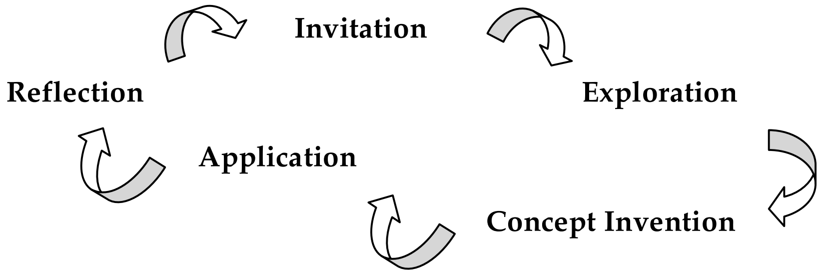
2. What happens when ice melts in salt water at room temperature?

- 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.





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.
Educator's Role:
Create interest and generate curiosity. Raise questions and problems to be explored. Elicit responses that uncover learners' 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.
Educator's Role:
Encourage learners to work together without direct instruction from the educator. Observe and listen to learners as they interact. Ask probing questions to redirect learners' investigations when necessary. Provide time for learners 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.
Educator's Role:
Encourage learners to explain concepts and definitions in their own words. Ask for evidence, results and clarification from learners, to help guide them to making sense of their experience. Provide formal definitions, explanations, and new vocabulary, as necessary. Use learners' 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.
Educator's Role:
Provide opportunities for learners to use vocabulary, definitions, and explanations in a new context. Encourage learners to apply concepts and skills in new situations/problems. Evaluate learner 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.
Educator's Role:
Encourage learners to confront their former ideas and evolve new ones, to solidify conceptual framework connections, and to help build metacognitive skills.

Teaching and Learning Session Handout

Sand Activity

Lawrence Hall of Science

This activity outline was developed for use in a variety of informal venues. By design, it provides the content, pedagogy and strategy necessary for implementation by both the novice and experienced informal educator. It is expected that this outline will be adapted and improved upon by the user. We welcome your feedback!

Synopsis of the Activity:
Learners observe a variety of sand samples with the naked eye and up close (with hand lenses and microscopes). They investigate what their sand is composed of and make inferences about the process and forces that made it.

Audience:
Ages 5 and up in groups of 1-10 for 2 facilitators. (The learner's ability to view through a magnifier or microscope is beneficial, although comparisons of color, size and shape differences with the naked eye is enough for this activity.)

Setting
Anywhere in the science center or aquarium where a table can be set up. Seating may be helpful if they are going to be using individual microscopes.

Activity Goals
Learners will become aware that sand can differ in size, shape, and color. They will then be more likely to develop an interest in investigating how those differences occur by asking questions such as what kind of material is it composed of and how do the characteristics of the local geology, weather and ocean affect the attributes of sand on a particular beach.

Concepts
• The world's beaches are composed of sand that is made from biotic and/or abiotic materials.
• Materials on a beach can come from local or distant places and from land or marine sources.
• The attributes of the sand in a particular location are affected by the local geology, weather and water action.
• Sand can also be found along ponds, rivers and lakes.

Ocean Literacy Principles
2c Erosion- the wearing away of rock, soil, and other biotic and abiotic materials occurs in the coastal areas as wind waves and currents in rivers and the ocean move sediments.
2d Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by the surf.

Materials
- ❑ 2 sets of 6 small resealable bags containing different sand samples labeled with their location
- ❑ 5 bottles of white glue
- ❑ a few packs of index cards (1/2 white, 1/2 colored)

- 5-10 hand lenses
- "scope on a rope" with monitor and/or individual microscopes
- 5 rock and mineral kits
- collections of small samples of marine animal "hard parts" -coral, shells, sand dollar test, exoskeletons of crabs, bones
- 2 sets of sand samples (see Procedure and Set up section below)
- crayons, colored markers and pencils
- sand shape sign, and sand size gradient sign
- pictures of the locations where your sand samples are from
- pictures of sand or sand poster
- copies of the Mystery Sand worksheet
- Optional, but helpful: Globe or world map, blank paper

Procedure and Set up

1. Assemble materials (worksheets, geology kit, pictures of sand and beaches especially beaches where your sand samples are from, glue, crayons or colored pencils, hand lenses, scope on a rope, microscopes).

2. Make Sand Samples:
   - Use 8 or more 4 x 4 pieces of heavy stock paper or poster board, or note cards.
   - You will need at least 4 very different types of sand to make at least 2 sets of sand samples.
   - Make at least 2 samples of each type of sand by smearing a tiny drop of white glue onto the paper and liberally spreading sand onto the glue. Dump the remaining sand back into its container. Allow the card to dry. Label the card with the location that the sand is from.

Guiding Questions

Have you ever been to a beach?
What did you see there?
What color was the sand?
What did the sand feel like?
What do you think sand is made of?
How could we find out what sand is made of?
How might natural and manmade materials be broken down into sand?
How do you think some of these items may have come to the beach?

Activity Description

***Note**: The activities below are suggestions for possible avenues to pursue. The number of activities and the order of them will be different for every group. Facilitators should "read" the learners and introduce new activities only if the learner is still interested and able (no time constraints, etc) to continue. We would not expect that all learners would do all of the described activities. See Attachment A for more information on the activity's flow.*

1. Greet the Learner. Invite visitors to your table by asking them if they want to look at sand up close. Introduce yourself and ask them if they have ever been to a beach or where they have seen sand before. Prompt them to tell you where they were and what they saw. (See Guiding Questions) Tell them that you have samples of sand from different places (perhaps from all around the world) for them to look at today.

2. Introduce the sand cards. Bring out the sand cards and give the learners a minute or two to explore with their naked eye and with a magnifying lens or a microscope. Ask them questions and observe their reactions to the sand cards to gauge if they have seen this diversity of types of sand.

Note: Expect that different learners will give you more or less of a response depending on many factors, including experience and interest. You may have to probe more or jump to the next phase.

Suggested questions/discussion threads:

a. Talk about what looks like "regular" sand that they have seen before and encourage them to describe other samples and how it surprised them.

Educator: What is it about this sand that makes you say it doesn't look like sand?
Learner: Oh, it's really big and white. I've only seen small brown sand before.
Educator: I see what you mean. What do you think it might be made out of?
Learner: I thought sand was tiny pieces of rock, but this doesn't look like that.
Educator: How do you think we could figure out what this sand is made of?
Learner: Maybe we could look at it a little more closely.
Educator: You could use this hand lens/microscope if you like to look more closely. What do you notice?
(In this case skip to Step 4.)

b. Encourage learners to describe the differences between the sand samples by having them group or order the samples. Depending on their level of interest and initiative you can have them focus on the samples in a number of ways. Here are two ideas:

1) Have them choose any criteria and sort their cards. Then have them explain (or have another learner guess) their criteria (size, color, sand and not sand). Have them resort if they have the interest.

2) If they have already noticed one attribute of the sand, e.g. size, have them order their samples smallest to largest. Have them tell you why they think sand may be different sizes in different places.

3. **Composition of sand.** Ask the learners if they have an idea of what these sands are made out of and how it might have been made into sand. Allow them to compare and contrast all samples or, especially for younger audiences, have them focus on one sample. Have them explain a few of their ideas and ask them how we might discover what the sand is made of.

4. Comparing Sand. Many learners will want to look at a few samples. Encourage them to do this and ask them to compare attributes of the different samples (color, shape, size). Suggest that they might want to take turns observing samples and sharing their descriptions with others at the table.

5. Introducing Rock and Mineral Kits. Have the rock and mineral kits and any animal hard parts (coral, shells, sand dollars) accessible so that they can note similarities to these materials. (They may have noticed and used them already.)

6. Refocus discussion on composition of sand. Refocus the discussion on what the sand is made from and how it is formed.

Educator: So what do you think this kind of sand is made from?
Learner: Shells and this pink rock here.
Educator: How did you figure that out? *or* Why do you think that? *or* What evidence did you have that it was shell and pink rock?
Learner: From here it just looks white, but when you look through the scope, you can see these clearish/pinkish bits that look just like this rock sample here.
Educator: Interesting. What did ***you*** notice under the scope? (Directed at another learner.)
Educator: So how do you think the rock and shell got to be this size?

7. **Discussion about how sand became sand-sized.** Encourage the learners to discuss their ideas about how materials came to be "sand sized" with each other in pairs or small groups. Then have the learners share out their ideas with the whole group.

Learner: I think that erosion made the rock or shell smaller
Educator: What is erosion? How does it work?
Learner: Erosion happens when things are worn away or made smaller by wind or water or other hard materials moving past or smashing into an object.

Take a poll to find out which factors (wind, water, smashing rocks) could be found at a beach. Ask learners how wind or water action would affect the different sizes and shapes of sand. "What would happen to the tiny grains or the big grains in waves or wind?" Have them think about how rock may have arrived at the beach and how it became so small.

Sample discussion:

Ask the learners to imagine they are a very tiny sand grain, about the size of the smallest grain in their group's samples.
Educator: 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?
Learner: If I was smaller I think I would move a lot, but if I was larger, I might stay put because I'm heavier.
Educator: What could the size of the sand grain tell you about the kind of place your sand sample was from?
Learner: These 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. Large waves or fast water would pick up small grains and carry them

away down the river or off the beach and out to the ocean. So if there were a lot of wave action the grains would probably be bigger.
Educator: Are there any sand samples that we know are from a place that has slow moving water?
Learner: Yes, the one from the Lake, the water doesn't move much there.
Educator: So how do those grains compare with the other beaches? What other factors might affect sand size?

8. **The Sand's location.** Have the learner look at the globe/world map and find the location of the place that their sand is from. Provide a beach picture from that location to perhaps confirm some of their findings or spark more conversation.
Learner The mountain behind that beach is completely black rock, just like the sand. Maybe the sand eroded from that mountain and made it's way to the beach.
Educator How would sand have gotten to the beach?

Applications:
Use one or more of the following activities as a reflection and take home piece for the visitor if they have an interest.

Imagine the Beach
After exploring the sand and discussing what sand is made of and what physical forces affect the size and shape of sand, have the learner pick their favorite sand sample and imagine the beach it came from. Have them incorporate their ideas about the make up of their sand and the physical forces on that beach into a picture of that beach. Example: a beach scene with large waves, and high wind with a volcano in the background.

Make a Sand Sample to Take Home
If the visitor is interested, show them how to make a sand sample to take home.

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.
d. Have them put their name and the location from where the sand was taken on the card. (You may also need to have a space set up for visitors to leave the samples while they dry.)

Mystery Sand Sample

1. Introducing the Mystery Sand. If the learner is still engaged, challenge him/her with a new "mystery" sample. Tell them that this is a mystery sample and they are going to use all the techniques and tools they used earlier to try and figure out (1) what this sand is made from (2) what the local conditions are at that beach (windy or not, how strong is the wave action) and (3) how this material got to the beach.

2. Learners make mystery sand card. See "Sand Sample to Take Home" directions and have the learners make a sand card with the mystery sand. (Omit labeling with the location of where the sand came from.)

3. **Introduce Mystery Sand Worksheet.** Introduce the learner to the worksheet. Be available to answer any questions they might have.

Note: *This may be a good time to allow them to investigate on their own while you engage new learners in the activity. But be sure to reengage the independent worker by asking what they have noticed/discovered, or what they think about this new sample.*

4. Investigate the Mystery Sand. Challenge learners to use the same observation skills they used to sort the sand samples. They can use these skills to help them match their "mystery sand" to one of the known samples. Remind them to use the worksheet to help them find out as much as they can about their "mystery sand".

5. Imagining the Beach. As they finish, ask them to imagine the beach where 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? Are there big waves or small waves?

6. **Draw a Picture.** If possible, have each learner draw a picture of what their beach looks like. Have them label their drawings with the name of where the sand came from. Remind learners they can take their "mystery sand" sample home with them.

Prep Section
Collect sand samples from a variety of locations. Put samples into small resealable bags and label with the location, or an identifying number mark if you prefer them to be mystery samples. The more diverse the collection is in material, size and shape the more interesting the experience will be for the visitor. Even "regular" sand looks very interesting under a microscope.

Related Activities/Extensions/Modifications
For younger audiences (ages 7 and below) they will need lessons on how to use a hand lens and will likely need you or another adult to focus the microscope for them. Have them describe what they see in the scope to insure they are actually able to see the sample in focus and that they are looking through it properly. Be prepared to instruct everyone on use of the microscopes.

For all ages it is recommended to have pens and paper available so that they can draw the location that their sand came from. This may be best stationed at a nearby table on busier days to clear the main table for sand viewing and discussion. Usually kids will be the most interested in doing the drawings, but adults enjoy this exercise as well.

Additional Resources
On Sandy Shores Teacher's Guide, LHS GEMS, ISBN 0-912511-98-2

Background (from *On Sandy Sho*res GEMS Teacher's Guide)

Note: *This is meant as background information for educators to give them a broader knowledge base with which to facilitate discussion and discovery by the learners. It is not meant to be read to the learners.*

Nearly all solid materials in the world, both living and non-living, will eventually be eroded into sand. Mountains, rocks, minerals, shells, corals, bones, metals and glass are all worn down over time by wind, waves, rivers, earthquakes and other forces into smaller and smaller particles.

Beaches can form wherever water moves loose material onto a shore. Rivers, lakes, ponds, and oceans can all have beaches. These beaches can be made of sand, gravel, or cobbles-these terms refer only to the size of the individual grains on the beach.

Some sand is produced right at the shore where waves crash on rocks, headlands and reefs. For example the red sand beaches on the Hawaiian and Galapagos islands are found directly next to or on top of lava flows of the same color. White sand beaches in Florida and in the Caribbean are primarily made of eroded coral reefs. Parrot fish, which eat the coral polyps, grind up the corals with their teeth and can excrete up to 100 pounds of coral sand per year. Pink sand might be full of coralline algae fragments. Other sands come from far away inland, when mountains are weathered by freezing, wind, rain, and running water and the fragments are carried down streams and rivers to the seashore. Once the pieces of rock reach the ocean, the strong, continuous force of the ocean waves sorts the particles by size. Quartz, a glass-like mineral, is the most common mineral on earth and is nearly insoluble in water. It is often the most common component of these transported sands. In fact most light colored sand beaches contain large amounts of quartz.

Sediments are classified by particle size, from mud to gravel. Particles are generally called sand when they are 0.06 -2 mm. Where particles are deposited depends on the speed of the water carrying them. In fast moving river or ocean water only the largest, heaviest sand grains settle out. On wave impacted outer coast beaches, only large sand grains or gravel will be found. The smaller the particle the slower the water must be moving for it to settle out. Mud grains are only found inside protected bays or far offshore on the deep ocean bottom where the water is barely moving.

On a normal coastal beach, no individual sand grain stays in the same place for long. Each wave picks up thousands of grains and deposits them somewhere else. If a prevailing wind causes the waves to always strike the coast from the same angle, sand can be slowly transported great distances along the coast. (Sand grains can be hit by as many as 8000 ocean waves a day!) The finest grains of sand can be carried in the wind and are often deposited high up on the beach in the dunes. Dune sand is usually noticeably finer and lighter than beach sand.

Vocabulary

<u>Sand</u>-small substrate particles between the size of silt and pebbles. (For your own reference between 0.0625 and 2 millimeters in diameter.)

<u>Erosion</u> – the wearing away of rock, soil and other biotic and abiotic material due to interaction with wind, water, ice and other forces.

<u>Abiotic</u>- nonbiological, not involving or produced by an organism, never-alive

<u>Biotic</u>- biological, living, produced by an organism, or once alive

MYSTERY SAND

1. What Is Your Sand Made From? What's In Your Sand?
Look carefully at your sand sample with your magnifier (or microscope if you have one). Which of the following things are in your sand (you can circle more than one).

• small rocks • pieces of shells • pieces of glass • pieces of wood

• pieces of plants • pieces of plastic • other things (name them):

2. Sand Shapes. Draw some sand grains. Draw them BIG!

3. Sand Shapes. When sand first breaks off from rocks, it's usually sharp and pointy. The longer sand moves around, the more rounded it gets. How old do you think your sand is?

not rounded–	a little rounded–	very rounded–
		
usually "young"	usually a little "old"	usually "old"

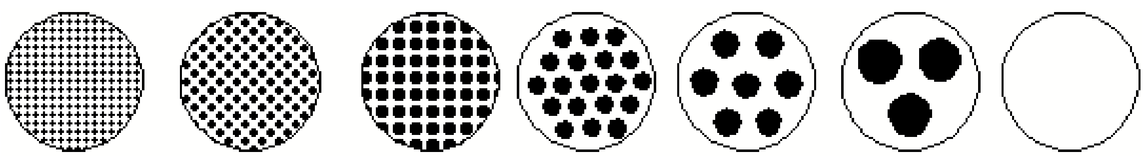
Hint: River sand is often young sand, and ocean sand is often old.

4. Sand Color. What color is your sand? Look closely at your sand with your magnifier. List the colors you see or use crayons to show all the different colors of your mystery sand.

5. Sand Origins. Where do you think your sand came from?

White rock sand is mostly quartz from mountains.
Colored rock sand is from other kinds of rocks from mountains.
Black sand is usually from lava from volcanoes.
Reddish orange sand is usually from lava from volcanoes.
White coral/shell sand is usually from coral and shellfish in the ocean.
Colored coral/shell sand is usually from colored coral and shellfish.
Colored glass or plastic is broken glass and plastic from human garbage.
Wood is from plants.

6. Sand Size. **Compare your sand sample to the size chart below**. Imagine the black dots are grains of sand. Which group of dots are about the size of your sand grains? If your sand is not like any of these, use the empty circle to draw yours.



tiny grains (no waves) — small grains (small waves) — big grains (big waves)

7. Sand Size – Big Waves, Small Waves, or No Waves?

Do you think your sand came from a beach with big waves, small waves or no waves?

Big grains of sand are usually from a beach with bigger waves (big waves wash away small grains).
Small grains of sand are usually from a beach with small waves.
Tiny grains are from protected bays where there are no waves.

8. Imagine the beach.

What do you think the beach where your sand came from looks 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?
Are there big waves or small waves?

Now draw a picture of the beach your sand might have come from.

The Learning Cycle and the Sand Activity

INVITATION

Welcome: "Hi my name is ________.
I have some sand samples here from around the world.
Where have you seen sand before? What did the sand (or place) look like?
What do you think sand is made of?
Go ahead and take a look at these samples. They are from Belize and the Mediterranean...here, this one is really neat. Take a look under the microscope."

FREE EXPLORATION

Observing Samples: "What do you notice?"
Visitor Notices: Color, Shape, and Size

GUIDED EXPLORATION

Communicating observations
"What colors did you notice?"
"What shapes are the grains?"
"Are all the grains the same size?"

Noticing Different Attributes
"How do you think this other sample will look under the microscope?"
"Do you think it will look the same or different?"

Comparing Samples: Have learners group or order cards by color, shape, or size.
"Which ones are light colored? Which are dark?"
"Did you notice the shape of the grains in that sample?"
"What do you think the different sands are made of?"

CONCEPT INVENTION

Considering composition (what the sand is made of):
"Why do you think the sand samples are different colors?" sizes?" shapes?"
"Would sand made from shells be the same color as the sand made from rocks?"

Considering erosion and the forces that make sand:
How can all these different things become grains of sand?
"Why do you think one beach has tiny grains of sand and another beach has larger grains?"
"How would wave action affect the size of the grains of sand on the beach?"
"How did all the rocks/shells get to the beach?"

APPLICATION

Completing Mystery Sand Worksheet:
Imagine and draw a beach where your sand came from.

Attachment A

The difficulty in writing guidelines for an informal interaction with learners is that each interaction is different and each visitor brings a variety of experiences and ideas that they (and you) can draw from when investigating sand. An additional complicating factor is that the informal learner is in charge of their own time, unlike a formal education situation where the learner has a dedicated amount of time for an activity, which puts a greater emphasis on keeping the learner engaged. Keeping the learner interested in the activity often involves a great deal of interaction on the part of the facilitator to personalize the lesson for the visitor. Due to the fluid nature of these interactions it is often difficult to "script" a lesson. What we have done for the Sand activity is to break the interaction down into layers and demonstrate how the facilitator can use the learner's ideas, observations, and questions to guide their investigation of a subject.

The following is a guide map to the activity. Graphically, it represents the fluid nature of the interaction. In it, the activity is broken down into three layers. In the first layer, the visitor observes the sand samples (one or more) with the naked eye, or with microscopes/hand lenses. The second layer has visitors focusing on details by having them describe the attributes (size, color, shape) that they observe and make comparisons within and between samples. In the third layer, the visitor considers the causes of the traits found in their sand sample, using the similarities and differences between samples, as well as new information to refine their ideas about how sand forms and what factors affect the sand at a certain location.

Facilitators should allow the visitors time to explore the sand, encourage them to share their observations and ideas and play off their observations to delve further into the question "what is sand and how does it form?" Another major role of the facilitator is to gauge when it is advantageous to go more deeply into the subject, by following one attribute through the layers, or to direct the visitor's attention to another attribute, at any layer.

Welcome: "Hi my name is _________. I have some sand samples here from around the world. Where have you seen sand before? What did the sand (or place) look like? What do you think sand is made of? Go ahead and take a look at these samples. They are from Belize and The Mediterranean...here this one is really neat. Take a look in the microscope."

Layer 1:
Observation of Samples
"What do you notice?

Visitor Notices

Color ↔ Shape ↔ Size

Layer 2: ***Communicating observations.***

"What colors did you notice?" "What shapes are the grains?" "Are all the grains the same size?"

Encourage learner to compare samples and notice different attributes
"How do you think this other sample will look under the microscope? Do you think it will look the same or different?"

Have the learner group or order sand samples by color, shape or size.
"Which ones are light in color? Which are dark?" "Did you notice the shape of the grains in that sample?" What about the size?
"What do you think sand is made of?"

More observations compare/contrast *More observations compare/contrast*

Layer 3: ***Considering Causal Factors***
"Why do you think they are different colors?" "Why the different shapes?" "Why do you think they are different sizes?"

Visitor Response: *What sand is made of.* *What sand is made of &/or forces of water/wind.* *What sand is made of &/or forces of water/wind*

Depending on visitor's responses/interest, ask some of the following questions to help visitor think about causal factors:
"How could being made of rock cause the differences (variation) in color and/or shapes?"
"Would sand made from shells have the same shape/color as the sand made from rocks?"
"Would the stuff that sand is made from affect the size of the grains? How?"
"Why do you think one beach has tiny grains of sand and another beach has larger grains?"
"How do you think wave action might affect the size of the grains of sand on the beach?"

