Session 3: Teaching and Learning

Overview

This session is designed to explore how people learn, and to consider how to develop lessons that reflect a variety of learning styles. Participants 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. Participants 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. They also participate in a lesson 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 participants' experience with the stations and the sand lesson.

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 to 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 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 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.

Reflection on one's own learning, 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 deeper meaning-making to occur.

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 lessons 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;
— deepen their awareness 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 lessons 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)
Participants think 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 gives them a chance 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 more sophisticated science audience.*

Debriefing Ice Cube Investigation Stations (25 minutes)
The instructor leads a probing discussion of the Activity Station experiences and thoughts, helping the group compare and contrast the strengths of each kind of teaching approach. The instructor brings out the idea 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 in classrooms, since groups of learners working together on 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 participants and 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 (40 minutes)
Participants design a lesson for investigating sand that exemplifies the Learning Cycle. They consider how this activity may play out in a classroom setting. 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.

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.)*

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, and PowerPoint presentation (25 minutes)
- Introduce and Explain Learning Cycle (10 minutes)
- Designing a lesson based on Learning Cycle (25 minutes)
- Debrief learning cycle lesson (15 minutes)
- Homework (10 minutes)

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

1. The Content for the Station Rotations. While you may want 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 Lesson as Application of Learning Cycle. Choose whether you want to use the sand materials included in this session or would prefer to have participants design a different type of lesson based on the learning cycle.

Ideally, the lesson that 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

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 two 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 lesson set-up for each group of 4 participants:
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 Preparation of Materials section)
- crayons or colored markers or pencils
- microscope or scope on a rope (optional)

For each participant:

- 1 copy of *Sand on Stage* lesson from *On Sandy Shores* GEMS guide
- 1 copy of *Sand on Stage and the Learning Cycle*

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 may want to laminate the station signs because they are likely to get wet.

2. Make copies for each participant and set aside:

q one copy of “Structured Activity” sheet
q one copy of “Read and Answer” sheets
q one copy of “Teaching Approaches and Educator Goals”
q one copy of “The Learning Cycle and the Sand Activity”
q one copy of “The Learning Cycle Explained” sheet
q 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* lesson:

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 four 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 which 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 only need to present just a bit of background about sand in this session – if the participants will actually be presenting this lesson in the classroom, 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.)*

4. Duplicate one copy of *Sand on Stage* lesson from the *On Sandy Shores* GEMS guide and one copy of *Sand on Stage and the Learning Cycle* 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
Questions about the 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, 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 they are not meant to be announced to participants.

1. Initiate thinking about the topic. Ask participants to brainstorm different teaching approaches they have experienced themselves. For example: lecture, textbook, simulation, debate, exploration activity, etc. Have them 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. During 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, which 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. Add that they may know a little or a lot about this particular topic, but what's important here is that 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 which 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 educators' choices for different approaches can often depend on the goals of the lesson. Ask which 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.

Participants' experiences and ideas are integrated into research and pedagogy as science content about salinity and density is introduced and then later, as 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 about which participants may choose to develop activities (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 Rodger 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 participants just a few minutes to read it over.

5. Connect structure of this session with learning cycle model. Draw 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 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 lesson for the classroom. Tell them you will distribute the materials for doing a lesson 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 25 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 lesson. 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 lesson. Ask several groups to share how they incorporated the phases of the learning cycle into the lesson 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 form groups 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. Ask participants what the advantages are of presenting the lesson in a learning cycle way. [Without the opening invitation and free exploration, students have had no opportunity to become interested in and develop the concepts for themselves, before the conceptual content is introduced. It steals the fun of discovering the concept.]

3. Point out that it is very common for science to be presented in a non-learning cycle-based way. Typically a teacher introduces several concepts and some new vocabulary, and then instructs students to follow a procedure through which those concepts are demonstrated or verified. Share how easy it is to reformat "traditional" science lessons to follow a more effective learning cycle approach. If you have time, ask students to reformat a hypothetical lesson.

4. Explain how science is often presented in classrooms. Point out that it's very common for science topics to be presented to students 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 watch a demo 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 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. Distribute the *Sand on Stage* lesson. Distribute the *Sand on Stage* lesson and assign participants to read through it for homework and note the different aspects of the learning cycle.

7. 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 lessons, 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.**

Homework

READING
Sand on Stage lesson

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.

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.

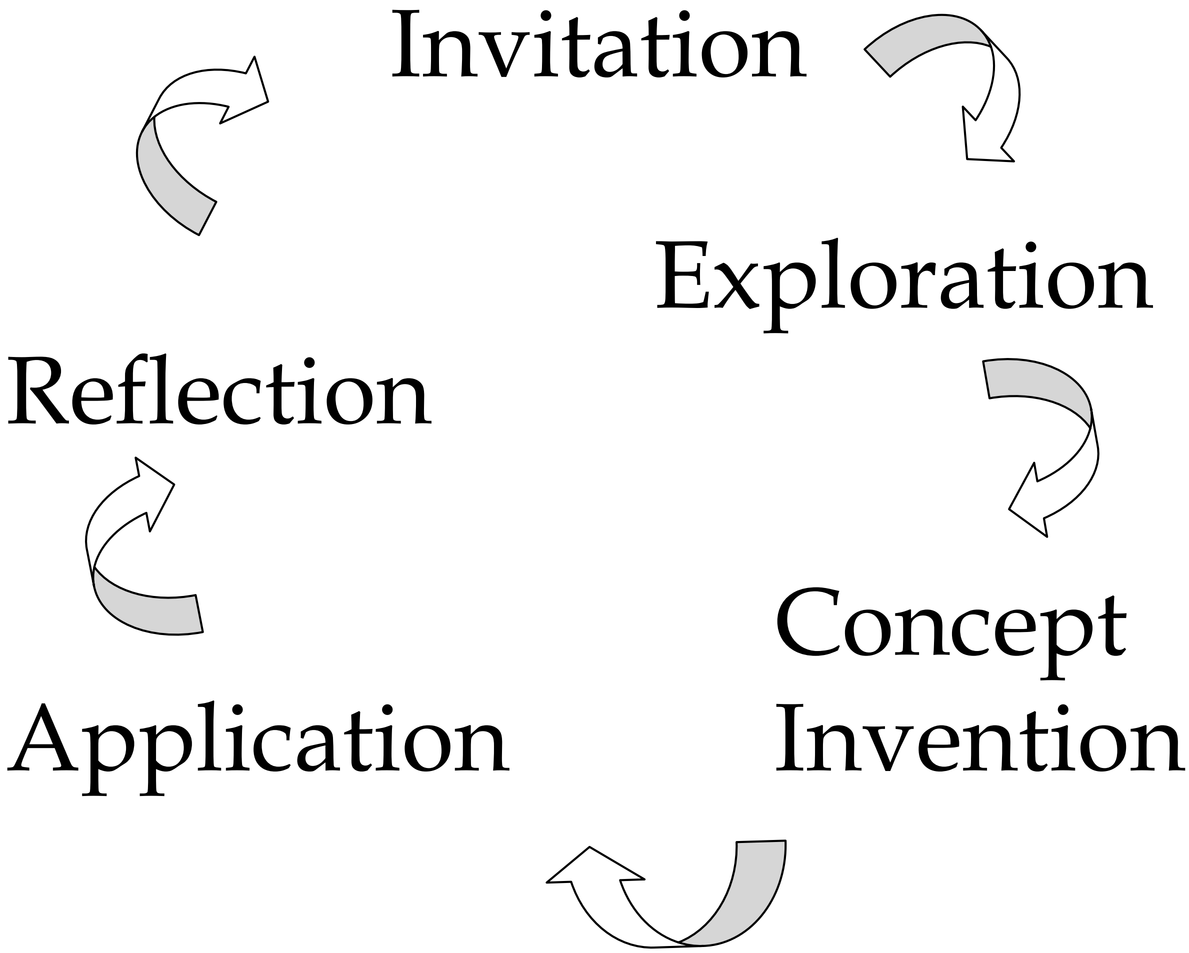
Problem-Solving Challenge/Application

- 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



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.

Teaching and Learning Session Handout

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 explanations 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.

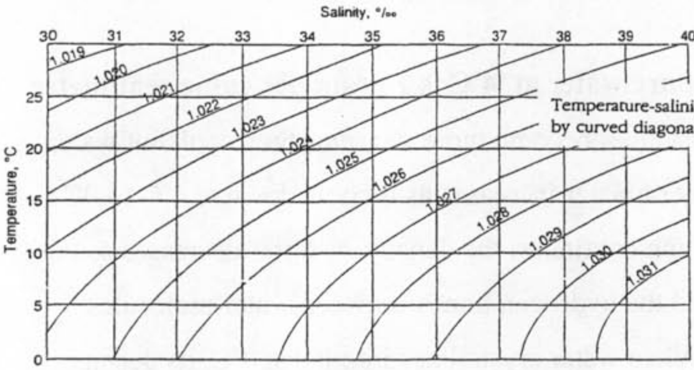
Pure water

By definition, the **density of pure water at 4^{o}C 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 4^{o}C (3.98^{o}C, to be exact), but then, as cooling continues, the density of water decreases as the molecules form a rigid framework and the hydrogen bonds between water molecules cause the liquid to expand slightly. When water crystallizes into ice at 0^{o}C, its density decreases abruptly. Ice is less dense than an equal volume of water. As ice cools below 0^{o}C its density increases, but no matter how cold ice becomes, its density never reaches the density of liquid water. Since ice is less dense than water, ice "freezes over" as a floating layer instead of "freezing under" or freezing from the bottom like almost all other liquids.

Seawater

Seawater is a solution of pure water and dissolved materials. A liter of seawater weighs between 2% and 3% more than a liter of pure water. Most of materials dissolved in seawater are ions (positively or negatively charged atoms and molecules), which combine into salts when the water is evaporated. **Salinity** is the total number of 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$^{o}/_{oo}$. (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 that is responsible for most of the vertical movement of water in the ocean and for the circulation of the world ocean as a whole.

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 (^oC)	Salinity ($^o/_{oo}$)	Density (g/cm^3)
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 (^oC)	Salinity ($^o/_{oo}$)	Density (g/cm^3)
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.

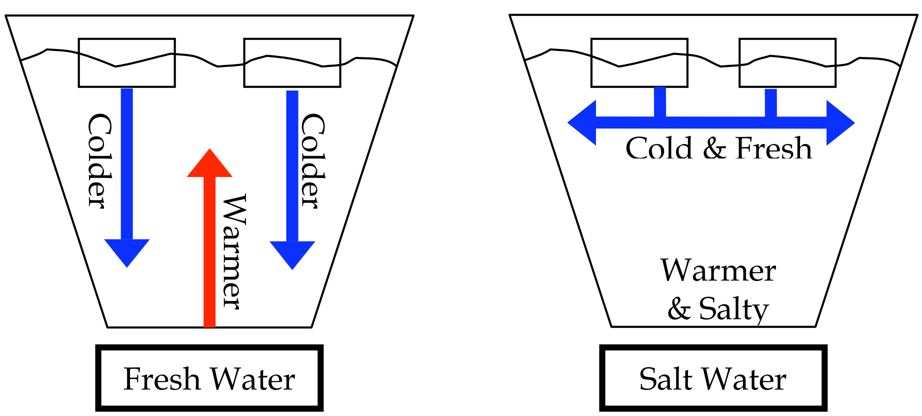
It's all about density!

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

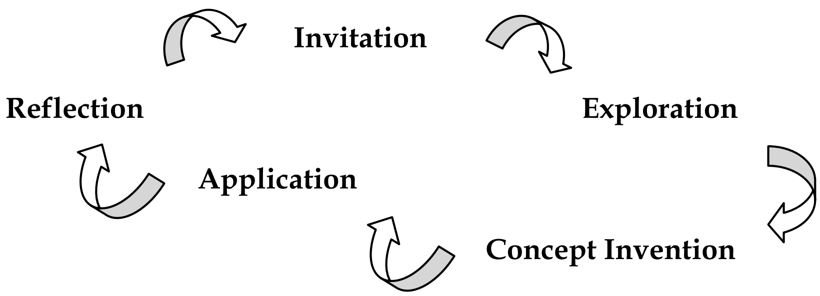
- Water from melting ice is cold and fresh. It is more dense than fresh water at room temperature. (REMEMBER: Water density decreases as *temperature* increases.)
- The denser cold water from the melting ice sinks to the bottom of the cup. That's why you saw the food coloring sink to the bottom of the 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.

Sand on Stage and the Learning Cycle

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 form groups 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?*

