beetles
Science and Teaching for Field Instructors

Professional Learning Materials

Constructing Understanding

There is a large amount of research on how people learn, and many aspects of learning that should influence how we teach are now quite clear. This session breaks this information down, provides experiences for field instructors to help make sense of it, and shows them how they can apply it to their teaching. Although all BEETLES sessions combine theory with practice, this session is heavier on theory than most.

There are different ways to view learners: as vessels to be filled with information that their teachers transmit to them; or as having clever minds already full of a life's worth of well-reasoned ideas and private explanations that influence how the learner understands new information. In this session, participants are presented with evidence from research to support the latter view—that learners come to education settings with prior knowledge, beliefs, capabilities, and skills, and that understanding and building on their mental frameworks is critical to teaching and learning. This session provides information about the persistence of individually held views about particular science concepts and what instructors can do to help learners adjust those frameworks by providing new experiences and information to deepen their understanding.

The goals for this session are:

- **gain a working knowledge of what the research tells us about how people learn.**
- **learn a variety of strategies that research has shown to be effective in helping learners become aware of, build on and modify their understandings.**
- **provide an opportunity to reflect on ideas about teaching, learning, and scientific conceptual understanding.**
- **experience a variety of instructional strategies through a model lesson, then reflect upon those strategies and their impact.**
- **gain awareness of how students can hold onto inaccurate ideas despite instruction on the topic.**

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

www.beetlesproject.org

The Lawrence Hall of Science is the public science center of the University of California, Berkeley. *www.lawrencehallofscience.org*

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The following programs have contributed to the development of these materials by field testing and providing invaluable feedback to the development team. For a complete list of contributors and additional partners, please see our website at beetlesproject.org/about/partners/

California: YMCA Camp Campbell, Rancho El Chorro Outdoor School, Blue Sky Meadow of Los Angeles County Outdoor Science School, YMCA Point Bonita, Walker Creek Ranch, Santa Cruz County Outdoor Science School, Foothill Horizons Outdoor School, Exploring New Horizons Outdoor Schools, Sierra Nevada Journey's School, San Joaquin Outdoor Education, YMCA Camp Arroyo, Shady Creek Outdoor School, San Mateo Outdoor Education, Walden West Outdoor School, Westminster Woods.

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Photos: Pages 1 and 3 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Beetle by Ola Möller; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; &Time by Wayne Middleton all from The Noun Project.

Funding from 2012-2015 for BEETLES publications such as this one has been generously provided by the S.D. Bechtel, Jr. Foundation, The Dean Witter Foundation, and the Mary A. Crocker Trust.

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BEETLES™ Professional Learning Materials

Constructing Understanding

Contents

TEACHING ABOUT TEACHING

This session is the "theoretical backbone" BEETLES session, because it addresses how people learn. If you've presented other BEETLES sessions with your staff, it's useful now to help them make connections between what they've learned in other sessions, and what we know about how people learn. Some opportunities for making these connections are called out in notes in the script.

PRESENTATION OPTION

While many of the BEETLES professional learning sessions can be modified to be done completely outdoors, this session relies on an indoor model student activity as well as a video, which make it best suited to be led completely indoors.

TIMING TIP

Keep things moving. The prompts provided in the session are purposefully designed to generate productive and interesting conversations, but interesting discussions can make it challenging to stay within the estimated time frame. You may need to gently limit some of the discussion, and then pick up on the topic at another time, perhaps after staff has had some experience with applying the teaching strategies.

SESSION OVERVIEW

	Constructing Understanding	Activity Locations	Estimated Time
Invitation	**Introducing How People Learn** Humorous quotes from young children describing their understandings of love are shared to inspire discussion that encourages thinking about how people learn and change their ideas.		10 minutes
Exploration	**Exploring Information from Research** In small groups, participants read aloud Research-based Information About Student Learning cards. They discuss how instruction might be structured to take each piece of information into account.		35 minutes
Exploration	**Conceptual Frameworks** The idea of conceptual frameworks is introduced by looking at poison oak/ivy. Then participants compare two content delivery methods through a lens of conceptual frameworks. Finally, they create their own conceptual framework about moon phases.		20 minutes
Exploration	**Modeling a Student Activity: Moon Balls** Participants experience model activities on the phases of the Moon that illustrate strategies for uncovering learners' ideas and helping them examine and either change or reinforce those ideas.		60 minutes
Concept Invention	**Debriefing Moon Balls** Participants brainstorm strategies from the model activities and their own experiences to help find out learner's ideas, and address alternative conceptions.		10 minutes
Application	**Watching and Discussing A Private Universe Video** Participants watch and discuss a video that shows students who are taught a seemingly effective lesson—and even perform well on a test—while still retaining their previous alternative conceptions.		30 minutes
Application	**Reflecting on How People Learn** Participants make a diagram of how people learn, as a way to synthesize and illustrate their understandings, followed by a quick write discussion.		15 minutes
	TOTAL	3 hours	180+ minutes

PREPARATION

Before the day of the session:

1. **Prepare to present.** Choose who will present each part of the session (see below for info on model student activity). Consider including staff who have already experienced the session. Read through the session write up, slides, handouts, sidebars, and background section (page 34) to prepare to present. The more each presenter is able to "own" the session, the better the presentation. Write notes on a printed version of the session, or however you prefer.
2. **Set up projection system/review multimedia.** Set up and test the projection system to be sure participants will be able to see.
3. **Obtain balls and pencils for Moon Phases exemplar.** Get one polystyrene ball and one pencil for each participant. Polystyrene balls have a very reflective surface and come with pre-punched holes, so that participants can easily stick them onto the end of a pencil in order to conduct the model. Polystyrene balls may be purchased inexpensively from: Molecular Model Enterprises, 116 Swift Street, P.O. Box 250, Edgerton, WI 53534. they can be reached at (608) 884-9877 for questions. Styrofoam balls will also work if painted with white latex or other water based paint. As a cheap alternative, you can use of oranges (without pencils, of course), though the shadows can be harder to see.
4. **Read and familiarize yourself with the *Moon Balls* student activity guide; assess your ability to lead it.** If you're not comfortable leading the activity yourself, choose a staff member most experienced with successfully asking broad questions, leading discussions, and being a "guide on the side." The main body of the write-up is embedded in this *Constructing Understanding* write-up. If you'll be teaching the activity using the embedded write-up, we suggest you read through the separate *Moon Balls* BEETLES activity write-up, which includes additional teaching notes and a detailed teaching support section.
5. **Prepare for the Moon Phases activity:**
   - **Prepare the room.** Find a room that you can darken completely. This can often be accomplished by simply turning off the lights while conducting the activity at night, but at times of year when it stays light late, you'll need to do so by drawing curtains or taping black paper over the windows. Use the extension cord to plug in the lamp. Make sure the cord is long enough for the lamp to be placed in the center of the room. Tape the cord down to the floor for safety. Have a box of balls and a bag of pencils on hand to give your participants. The activity can be done in rooms that are not completely dark, but it's less effective.
   - **Test to see which light bulb to use.** Before the session, determine whether the 40-watt or the 75-watt is best by placing one of them into the socket and darkening the room. Stand about the same distance from the lamp as the participants will stand. Hold a "moon ball" in your hand and move it to one side until you see a crescent. Observe the contrast between dark and light sides of the ball, then change the bulb and again observe the contrast. Brighter light bulbs usually provide more contrast if you have a large room, or if there is some light coming into the room from outside. Dimmer bulbs provide greater contrast on the "moon balls" if you have a smaller room with white walls.
6. **Prepare copies.** See list at right.
7. **(*Optional*) Make Session Overview to post on wall.** You may choose to make a Session Overview to post on the wall during this session. Some presenters & participants prefer having it, so they can see the trajectory of the session.

MATERIALS

For the Group:

- ❏ projection system
- ❏ computer
- ❏ slides
- ❏ "Private Universe" video, *can be viewed online at: (http://www.learner.org/vod/vod_window.html?pid=9)* or *ordered from Annenberg Media, learner.org: (http://www.learner.org/catalog/series28.html)*

For Each Participant:

- ❏ 1 two-inch polystyrene ball, with a hole big enough for a pencil.
- ❏ 1 unsharpened pencil to hold polystyrene ball

Copies and Printed Materials:

- ❏ Strategies for Addressing Student Ideas, page 33, (1 per participant)
- ❏ Research-Based Information About Student Learning, page 29, (1 per participant)
- ❏ What Research Tells Us About How People Learn, page 32, (1 per participant)
- ❏ Canned Spiel script, page 31, (5 copies total)
- ❏ *[optional]* Moon Balls student activity guide (available on beetlesproject.org)

Introducing How People Learn

YOU ARE HERE:

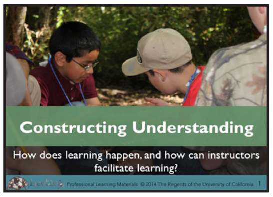
10 minutes

or

TEACHING NOTES

Related session. The end of this session includes a reference to the Learning Cycle, an extremely valuable model for curriculum that is introduced in the BEETLES *Teaching & Learning* session.

1. **Show slide 1:** *Constructing Understanding.* **Introduce the session.**
   a. Welcome participants and check in with them.
   b. Make sure everyone's ready to begin.



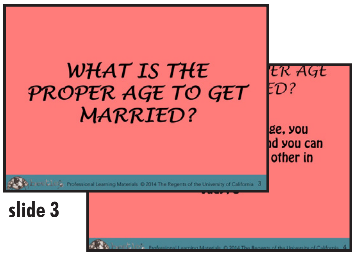
slide 1

2. **Explain that this session focuses on how people learn:**
   - We're going to think about this guiding question more in-depth in a few minutes, but first we'll do a quick activity.

3. **Show slide 2:** *Kids on Love*. **Explain:**
   a. I'll show you responses children gave to an interviewer asking about their understanding of love.
   b. These are from the Internet and we do not know if they represent serious research.

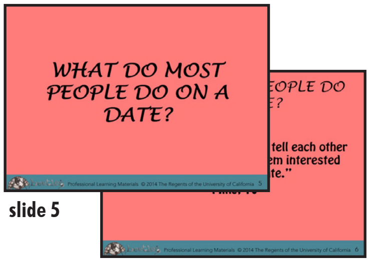
slide 2

4. **Show slides 3-11.**
   - Read each question out loud, then unveil each response one at a time.



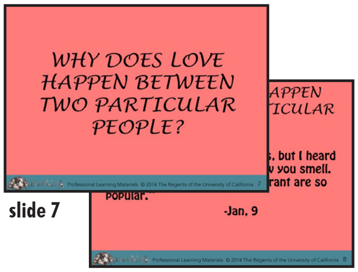
slide 3

slide 4



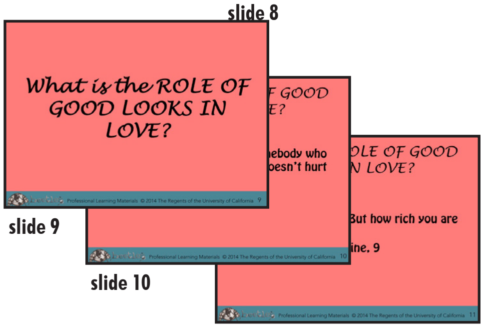
slide 5

slide 6



slide 7

slide 8



slide 9

slide 10

slide 11

5. **Lead a brief discussion about children's conceptions of love:**
   a. Ask:

      ▶ *How do you think these kids came up with these ideas? How does learning happen?*

   b. As participants comment, help them generalize or translate their responses to the context of learning and teaching situations they encounter. Here's an example of what participants might say and how you could respond:
      - **Participant**: Kids overhear adults say these things or they hear bits and pieces of things on TV, and they misinterpret them. **Presenter**: Ah, so learners gather bits and pieces of information that they don't understand, and then they fill in the empty spaces with their own explanations in some way that makes sense to them.

6. **Ask for suggestions for how you could change children's ideas.**
   a. Ask:

      ▶ *What could you do to improve these children's understandings about love?*

   b. Take a few responses. Here are a couple examples of what participants might say and how you could respond:

- **Participant**: You could tell them about love until you're blue in the face, but they probably won't really believe it until they experience it for themselves. **Presenter**: So you're saying that until they have direct experience with something, they can hear a lot about other viewpoints, but they may not understand or truly believe them.
- **Participant**: They'll eventually change their ideas about love, because they'll see or experience their own relationships, and find out what's wrong with their ideas. **Presenter**: So with direct experience or further observations they may come across conflicting information, and that helps them to replace their old ideas with new ones?

TEACHING NOTES

Of course understanding love is not the same as understanding scientific ideas, but it makes the point in an engaging way.

7. Explain that both learners and instructors have to try to figure out understandings & how to improve them:

a. Teaching and learning are interesting for both learners and instructors, because there's so much going on.

b. As learners, we all need to do our best to figure out our own understandings, and how we might improve them. Hopefully you'll do this yourselves during this session.

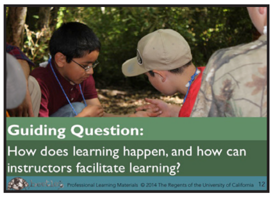
c. Even these amusing examples of kids' ideas on love were partially accurate, but incomplete, and it's not hard to see that they were based on observations and prior experiences.

d. As instructors, we need to get ideas and understandings out in the open, then try to nudge learners along toward more accurate understandings.

8. Show slide 12: ***Guiding Question*****. Ask pairs to discuss guiding question for the session:**

- Tell participants to pair up and discuss the guiding question for the session for 2–3 minutes.

▶ ***How does learning happen, and how can instructors facilitate learning?***



slide 12

9. Discuss the value of pair discussions:

a. That was a pair discussion without whole group sharing, so as the instructor I heard very little of what was just discussed, but I know there's tremendous value in what you just did.

b. Ask,

▶ *What do learners get out of peer-to-peer partner talk like we just did?*

c. Take a few responses. Bring up the following points if they don't:

- Each person had to actively access their prior knowledge on the topic, and synthesize their thoughts to be able to verbalize them to another.

TEACHING NOTES

- Each person also got to hear someone else's ideas to perhaps influence their own thinking.
- This helps set participants up for learning about a topic.

d. Explain: This is why peer-to-peer discussion is such an important part of learning, and why partner discussion routines are so useful.

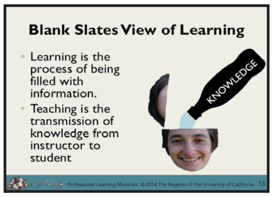
10. Set the context for the session. Explain:

a. We're going to take a look at how students form science ideas based on what we know from research on teaching and learning.

b. We'll continue to engage in activities and reflect "meta-cognitively" about the learning that occurred.

c. We'll start by looking at two views of learning that influence the way we teach: "blank slates" or "clever minds."

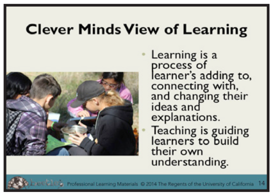
11. Show slide 13: ***Blank Slates View of Learning*****. Explain that the "blank slates" view is that an instructor can directly transmit what s/he knows into students' brains.**



slide 13

- This view is reflected in these statements:
  - "If I communicate accurate information to students, they will learn it."
  - "Students are empty vessels to be filled with knowledge by the instructor."

12. Show slide 14: ***Clever Minds View of Learning*****. Explain that the "clever minds" view is supported by research:**



slide 14

a. Learners already have lots of well-reasoned ideas and private explanations

b. This prior knowledge influences and filters how the learner understands new information. Each learner's prior knowledge and understandings are different.

c. A large body of research supports the "clever minds" view, and refutes the simplistic "blank slates" view.

d. If we teach with these understandings in mind, our instruction will be more complex than transmitting information.

13. Show Slide 15: ***How We Learn*****. Explain:**

slide 15

a. The "clever minds" view is supported by research in:

- cognitive psychology
- child development
- learning and transfer
- social psychology

- neuroscience
- collaborations by cognitive scientists, developmental psychologists, and educators

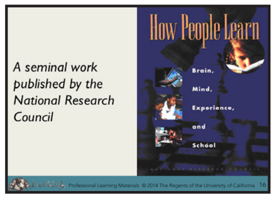
b. Research tells us that learners take in information through experiences and interactions with others, and construct their own understanding of the world.

c. This view of learning provides the basis for many best practices in education.

d. We're going to take a few minutes now to look more closely at some of the research.

Exploring & Discussing Information from Research

1. **Show slide 16:** *How People Learn*. **Explain:**



slide 16

a. This book is a seminal work published by the National Research Council.

b. It's a summary of what has been learned through research about learning, and what this tells us about how to set up effective learning situations.

c. It's a highly recommended read for anyone interested in the art of instruction. For a summary, you can read the introduction.

d. A number of citations/quotes on the sheet you're about to receive come from this book.

2. **Show slide 17:** *Discussing information based on research findings*. **Explain that groups of four read out loud each piece of information, then discuss how this might influence instruction:**

slide 17

a. You'll get a set of *Research-Based Information About Student Learning* sheets.

b. Take turns reading the pieces of information out loud in your small group.

c. Discuss two or more of the pieces of information. How might you structure instruction to take this information into account? Continue discussing the pieces of information, until I tell you to stop.

3. **Pass out the** *Research-Based Information about Student Learning* **handout and provide about 10 minutes of small group discussion time.**

4. **Each group shares an idea with whole group.**

a. After 10–15 minutes of small group discussion, get the whole group's attention.

b. Ask each group to share one idea of how instruction might be influenced by information from research on student learning.

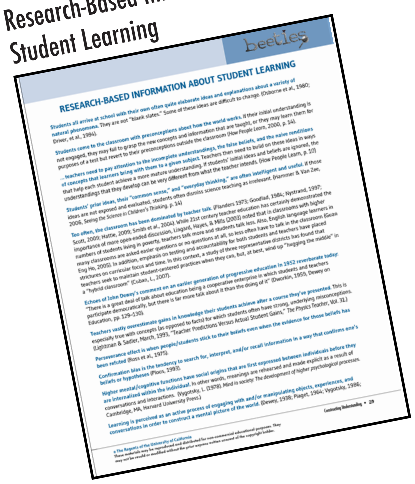
TEACHING NOTES

YOU ARE HERE:

35 minutes

How People Learn is available as a free PDF download from The National Academies Press. See the references section for more information.

Research-Based Information about Student Learning



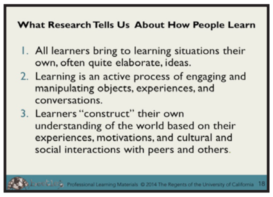
TEACHING NOTES

If participants bring up old dates on some of the research, point out that research on how people learn doesn't expire. Older research is still relevant, and is often built upon in ongoing current research. In particular, breakthrough studies in science education theory and practice derive from now "classic" work in the early 1960s, and had a foundation in earlier 20th century educational theory and educational psychology. More recent 21st century studies and commentary often credit this earlier work. For more on this see Background Information for the Presenter for this session and for the *Teaching & Learning* session.

Copernicus and Galileo famously challenged this Earth-centered notion, but their ideas met with much resistance and life-threatening opposition. We now know that the earlier explanation is inaccurate, and have gathered a great deal of evidence demonstrating that the Earth revolves around the Sun. It's also thought that the records of some ancient cultures and astronomers, in India, Egypt, and the Islamic world, as well as the Maya, Aztec, and Incas of the Americas, include some elements of the heliocentric model.

- **c.** Ask groups to comment on each other's ideas.

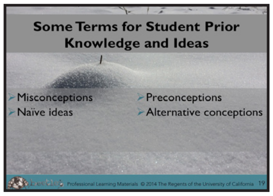
5. Show slide 18: *What Research Tells Us About How People Learn*. **Summarize research findings (students must struggle to learn):**



slide 18

- **a.** Learner's frameworks need to be taken into account as new learning takes place.
- **b.** Learning is an active process, not a passive one.
- **c.** To learn, students need some struggle with ideas.
- **d.** The construction of a new understanding results from a combination of experiences, motivation, and social interactions.

6. Show slide 19: *Some Terms for Student Prior Knowledge & Ideas*. **Explain use of different terms for ideas about science that students bring to learning experiences:**



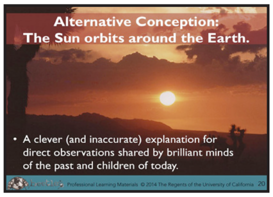
slide 19

- **a.** When inaccurate or incomplete, these ideas are sometimes called "misconceptions," or "naive ideas."
- **b.** They have also been called "preconceptions" to indicate that they precede more evolved concepts.

7. Define the term "alternative conceptions:"

- **a.** Students' prior knowledge is often based on their experiences and is intelligent and useful.
- **b.** Students' prior understandings are often called "alternative conceptions" to give more value to the ideas students have worked out for themselves.
- **c.** Even though they are not fully accurate, these ideas are often based on accurate bits of information, are often complex, and part of an extensive mental framework developed over time.
- **d.** Whichever term(s) you choose to use, including "misconceptions," it's critical that the meaning behind whatever term is used should reflect this respect for children's ideas.

8. Show slide 20: *Alternative Conception*. **Share "Sun moving around Earth" example of how children's ideas may reflect historical alternative conceptions of great thinkers:**



slide 20

- **a.** For more than a thousand years, many of the greatest thinkers in the world agreed that the Sun revolved around the Earth.
- **b.** Children may come up with the same explanation based on their own observations—that's brilliant!

c. It's not a sign of deficient thinking—it's an important stage of conceptual development.

d. It's also not surprising that children, like many great thinkers, may resist more accurate but less obvious explanations.

e. They may need repeated experiences with evidence and discussion in order to shift their understandings.

9. Explain that children have their own "common sense" explanations that must be addressed in science education.

a. Children (and adults) have alternative conceptions about all kinds of things.

b. They have developed a collection of "common sense" ideas about the world, based on their own experiences, media, and from social interactions.

c. When we teach, we can expect to directly encounter students' common sense ideas about phenomena.

Conceptual Frameworks

1. Show slide 21: *[image of leaves].* **Ask participants to identify the plant (poison oak/ivy) in each of the slides.**

slide 21

a. Show the first slide and ask participants to identify the plant.

b. If they don't recognize it, tell them it's poison oak.

c. Show the second slide, and if they don't recognize it, tell them it's poison ivy.

2. Show the next five slides in succession & ask the same question.

- Note: Slides 22 and 23 are poison ivy. Slide 21 and 24-26 are poison oak.

slide 22

slide 23

slide 24

slide 25

slide 26

3. Poison oak/ivy are part of many field instructors' rich conceptual frameworks that serve us like sense-making machines that are usually correct.

a. Some of those were poison oak and some were poison ivy.

b. Field instructors are usually quick to identify the different forms of these important plants that live in the ecosystem(s) where they work.

c. Our conceptual frameworks are like sense-making machines that help us get the correct answer most of the time.

TEACHING NOTES

YOU ARE HERE:

20 minutes

or

If you don't have poison oak/ivy in your area, consider replacing the poison oak/ivy slides with something you know all your participants will recognize (and that students may have trouble recognizing).

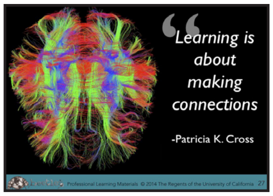
TEACHING NOTES

John Muir famously said, “When we try to pick out anything by itself, we find it hitched to everything else in the Universe.” The idea of everything being connected is common to many cultures, including Native American and other Indigenous cultures, and is supported by science. From an environmental educator’s perspective, it could be said that learning is about discovering/making these connections.

If your instructors have already done the *Making Observations* BEETLES session, remind them that this is why it’s important for students to be making their own observations, asking their own questions, and making their own connections, as they do with the routine, *I Notice, I Wonder, It Reminds Me Of.*

“Canned Spiel” vs Facilitating Students Observations and Connections

4. **Show slide 27:** *Learning is about making connections*. **Explain that learning is making connections between ideas & experiences, as well as physical connections between brain cells.**



slide 27

   a. We make connections between brain cells as we learn new knowledge. When we learn we actually change the structure of our brains.

   b. Physical connections in the brain correspond to the connections we are making between ideas and information we encounter.

   c. The richer your connections between ideas and experiences, the more enduring your knowledge will be about a topic.

5. **Demonstrate a “canned spiel” describing poison oak vs. facilitating students observations & connections.**

   a. Pass out copies of the “Canned Spiel” vs. Facilitating Students’ Descriptions and Connections sheets to 6 different participants.

   b. Explain: These are dialogues recorded from two different field instructor’s introducing students to poison oak. The first represents a “canned spiel” approach; the second represents an approach in which the instructor facilitates students making their own observations and connections.

   c. Tell one volunteer to read the part of the instructor from the Scenario #1 script.

   d. Tell the remaining five volunteers to read the parts of the instructor and students from the Scenario #2 script.

6. **Discuss why canned spiel tends to be less effective than the second approach:**

   a. Explain: If you’ve used a canned spiel on poison oak/ivy with students, you might have found that the students keep asking afterwards, “is this poison oak/ivy?” is that poison oak/ivy?” “What about that, is that poison oak/ivy?”

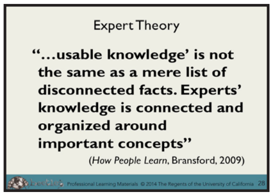
   b. Ask,

      ▶ *Why might the second approach be more effective than the canned spiel?*

   c. Listen to their ideas.

   d. If no one mentions it, explain: Did everyone notice that the second approach included some direct instruction, as well. Direct instruction has its place.

7. **Show slide 28: Expert Theory. Explain that more elaborate conceptual frameworks make it easier to learn:**



slide 28

   a. Studies of experts have shown that the more you know about a particular thing, the more easily you can learn more about it.

b. For example, it's usually easier for you to learn new things about plants in your area than for a student who knows less about the subject because the more you know the more easily you can learn about a topic.

c. Exposure to many learning experiences helps you develop a more elaborate conceptual framework that enables you to expertly add new information to it.

d. "Experts" do not necessarily have greater memories than others–their conceptual framework allows easy access to what they know.

8. Emphasize the importance of eliciting student ideas & helping students make connections, rather than delivering a "canned spiel."

a. Share the points below if participants have not already brought them up:

- Every child comes to you with understandings and misconceptions about animals, plants, air, water, time, etc.
- An effective field instructor will try to find out what those ideas are, help students make connections, and challenge them to adjust their prior ideas with evidence from their observations in nature, and more normative science concepts.
- Canned presentations are not very effective, because they don't respond to the learner.
- If you present a topic the same way to every audience, you are probably short-changing some learners.
- To be effective instructors, we need to find out as much as we can about students' ideas, and help them to connect and build upon them.
- Most importantly, you need to give students frequent opportunities to share their ideas with peers.

9. Show slide 29: Conceptual Framework for a Bird. Explain that concept maps can be used to diagram a person's conceptual framework:

slide 29

a. It helps to have learners create a visual diagram, or concept map, of their conceptual framework.

b. We'll use the concept of a bird as an example. When we are young we learn some basics about birds and begin forming conceptual frameworks about them. (For example, they have two legs, wings, feathers, and beaks, they are fast...)

c. As we observe birds, have experiences with birds, read about birds, and hear about birds, our conceptual frameworks become more complex.

10. Use participant input to draw a concept map about birds.

a. Explain: We can't draw conceptual frameworks, but we can make models of them by drawing concept maps.

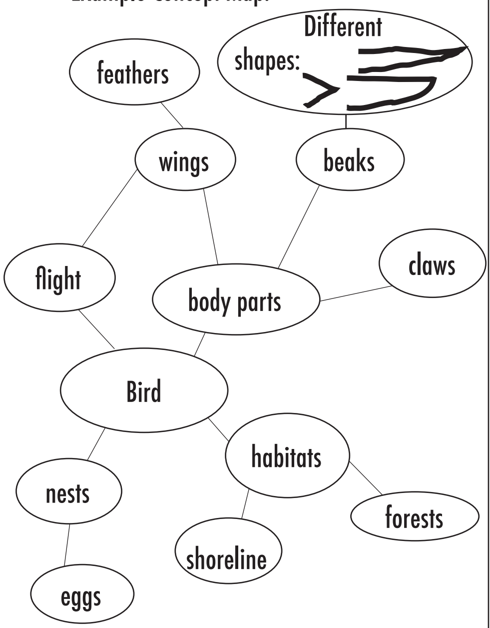
TEACHING NOTES

If your instructors have already done the BEETLES *Questioning Strategies* session, remind them that this is why it's so important to ask broad questions and to be "guides on the side." Broad questions uncover student ideas for both learners and instructors, and an instructor can use them to guide learning.

Examples of how awareness of conceptual frameworks might be important for instruction: lichen & night sky objects. Children will arrive at your program with experiences and ideas related to the topics you're teaching, but be aware of possible gaps in their understanding.
Lichen example: Describing lichen as a relationship between an alga and a fungus may not make much sense to a student who has little experience with algae or fungi.
Night sky object example: With night sky, if they have little understanding of how distance affects the apparent size of space objects, chances are they will struggle with understanding that stars are distant suns, or that the Sun is much larger than the Moon.

TEACHING NOTES

Example Concept Map:



b. Write the word "bird" on the center of a piece of butcher paper or a white-board and ask participants to call out some things they know about birds.

c. Using participant input, draw an example of a conceptual framework in the form of a concept map of their understanding about birds. Your concept map might look something like the example to the right.

d. Starting with very simple ideas, elicit more and more information from the group and record it through words and drawings, with lines between to show how they are connected.

e. As they provide ideas about birds, ask for additional labels and connections and create a concept map that becomes more and more complex.

11. Show slide 30: *Moon Phases*. Tell participants to create concept maps for phases of the Moon; explain:

slide 30

a. You'll make your own concept map that represents your ideas about the Moon and why it changes its appearance over the course of a month.

b. Take 3-5 minutes to jot down some ideas in boxes or circles and draw lines between related ideas.

12. Tell participants to compare their concept maps, without "teaching" each other.

a. After ~three minutes, ask participants to share their concept map with someone and note similarities and differences in concepts and explanations about Moon phases (not in how it's drawn).

b. Explain: this is NOT a time for one person to "teach" the other person about what causes Moon phases, but to share their map and explanation, then try to understand the other person's map and explanation.

13. Explain that each person's conceptual framework is unique, and learners benefit from awareness of their own conceptual frameworks:

a. We all have conceptual frameworks in our minds, but each person's is somewhat different.

b. Our conceptual frameworks are built from our individual collection of life experiences, and filtered through our unique brains.

c. It's important for learners to become more aware of their own conceptual frameworks so they can actively connect new knowledge to what they already know, and actively build and adjust their own frameworks.

Model Activity: Moon Balls

YOU ARE HERE:

60 minutes

or

TEACHING NOTES

We've chosen Moon Balls as a model student activity, because many adults, including science educators, have alternative conceptions about the phases of the Moon, not unlike those of students. Many of your instructors will probably arrive with the (inaccurate) explanation that the Earth's shadow causes phases of the Moon, but, this activity provides a genuine opportunity for them to authentically adjust their conceptual frameworks with new evidence and reflection. Some participants might be reticent about sharing their perspectives publicly, because they don't want to look "bad" in front of their peers. Those with stronger prior knowledge are often more confident and eager to participate, but their participation can sometimes derail the discussion and activity, while probably unintentionally intimidating their peers.

To provide a successful experience for your participants, and to model how it looks when done with students, it's best to try to keep whole group discussion focused on evidence discovered by participants on causes of the phases of the Moon. Ask questions, such as, "What is something that surprised you during your explorations about what causes the phases of the Moon?" or "Can someone share with us some evidence you discovered through the model about an explanation for the phases of the Moon?" If participants begin to talk about the angle of the orbit, or other secondary questions, such as "does the Moon spin," etc., let them know that their questions are interesting, and they're free to explore them individually or in small group time, but for the sake of this session, redirect the whole group discussion back to causes of the phases of the Moon.

1. **Introduce Moon Phases model activity. Explain:**
   - **a.** Many children and adults hold alternative conceptions about Moon phases.
   - **b.** The following activity is excerpted from the *GEMS Space Science Curriculum Sequence*, an astronomy unit for grades 3–5, but it's been adapted for use as an evening program in outdoor schools.
   - **c.** The concept map you just did is not part of the BEETLES student activity. Instead, students are shown a few explanations to choose from, and they make marks for the explanation they think is best.

2. **Focus participants on strategies used in Moon Balls. Explain:**
   - **a.** The purpose in presenting this abbreviated set of activities is for you to experience—as learners—effective strategies for addressing students' ideas and prior knowledge.
   - **b.** These strategies help students make connections to what they know, and to build deeper understanding of the content.
   - **c.** As you take part, pay attention to strategies used both to expose and address conflicting ideas.
   - **d.** Notice how the activities create situations in which learners find evidence that makes them confront, and perhaps change, the mental constructs and frameworks they already have in place.

3. **Reassure participants that many adults don't understand the causes of Moon phases.**
   - Explain that this is a topic that many of you probably will struggle with like students, and that's why the activity was chosen. If your understandings about phases of the Moon evolve during the session—that's awesome!

4. **Explain how to participate in the activity:**
   - **a.** As with students, it's OK to admit you are learning, and in fact, the activity hinges on you doing so, without worrying about what others may think of you.
   - **b.** It's a sign of flexible scientific thinking to be able to publicly change your mind based on evidence.
   - **c.** For those of you who may have more experience and prior knowledge about Moon phases:
     - It is not your job to teach others in the group what you know.
     - Allow other learners to struggle for themselves through the process of figuring out the explanation using the model and discussion.

TEACHING NOTES

How should staff behave during model activities? Some leaders ask participants to behave like children during model activities. We've found that this often leads to exaggerated negative behaviors, and the modeling suffers (sometimes the experience is ruined). Instead, ask them to participate as adults, while *imagining* how students would respond. There may also be times when they might get carried away with discussion of adult content to the point that it loses its effectiveness as a model, and as leader you may need to point this out and ask them to remember the level of their students, and tone down the content.

Throughout the activity, as much as possible, when participants ask questions, tell them to "ask the objects." Instead of delivering an answer, encourage them to use the model while in discussion with others to try to figure it out.

- Your job is to come up with your own questions about aspects you do not understand, and use the model to push your own understandings deeper.
- During discussion with peers, feel free to share your ideas using evidence from the model, but do it from the position of an equal collaborator, not as an instructor teaching "the right answer."
- During whole group discussion, allow others who are struggling with explaining the phases of the Moon to carry the conversation.

Exploring Shadows

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

2. **Allow participants to explore shadows.**
   a. Tell learners to explore shadows in the room for a minute or so. As they are exploring, model making hand puppets, moving your hands closer to or farther from the light source, etc.
   b. Tell them to share their discoveries with each other.
   c. After about a minute, get the whole group's attention, and ask a few learners to share their discoveries with the large group.

3. **Explain that shadows can be described as having three parts.**
   a. Explain: One part is the shadow cast by one object on another object. This is the part of a shadow most people notice
   b. Hold up your hand and point out its shadow on the wall.
   c. Ask,

      ▶ *Can anyone can identify other parts of your hand's shadow?*

   d. If they don't mention these themselves, be sure to point out:
      - The backside of your hand facing away from the light bulb, which is dark.
      - The area in the air on the side of your hand away from the light bulb. Draw attention to this part of the shadow by putting a finger from your other hand there and letting learners see that it's in shadow. Point out that this part of the shadow can only be seen when you move an object into it.

TEACHING NOTES

e. Explain: We'll call the part of the shadow that is cast on another object (the wall in this case), the end of the shadow. The part of the shadow on the backside of an object (the back of our hands) can be referred to as the beginning of the shadow, and the in-between part, the part you only see if you move another object into it, can be referred to as the middle of the shadow.

4. **Tell learners to explore these three parts of shadows with a partner, focusing on the shadows of each other's heads.**

Investigating Moon Phases

5. **Set up each learner with a moon ball, & tell them to find the three parts of the moon ball's shadow:**
   a. Pass out one Moon ball and pencil "handle" to each learner.
   b. Show them how to stick their pencil in their Moon ball, and hold onto the pencil so that the "moon's" shadow is uninterrupted.
   c. Explain: Take a minute to find the beginning, middle, and end of your Moon ball's shadow.

6. **Explain the Sun, Earth & Moon model, & discuss inaccuracies:**
   a. Explain: In this model, the light bulb will represent the Sun and your heads will represent the Earth. The balls on the pencils represent the Moon.
   b. Ask,

      ▶ *What are some obvious inaccuracies of this model?*
   c. Listen to a few participant ideas.
   d. Explain: Models are extremely useful in science, but they can easily lead to misconceptions if the inaccuracies and limitations of each model aren't discussed.

7. **Learners use model to explore phases of the Moon. Explain:**
   a. Team up with a partner (or two) and use this model to begin to explore what causes the phases of the Moon.
   b. Work with others, and talk to one another as you explore the model, manipulating the Moon ball and investigating what happens when you move it around in the light from the "Sun."

8. **Circulate to make sure no one is left out, to encourage exploration & discussion.**

9. **Students share discoveries with large group.**
   a. After a few minutes, get the whole group's attention.

TEACHING NOTES

Adult learners don't usually have trouble with this, but the most common error that people make is not moving the Moon ball far enough to the left. Another error is looking at the light bulb and ignoring the "Moon."

b. Ask learners to share what they discovered. If any learners have already done an activity like this or already know the content really well, ask them to refrain from answering at this point, so those who've made initial discoveries can share.

10. Facilitate small group investigations.

a. As each learner shares their discoveries, encourage others to use their Moon balls to try out what's described.

b. If any interesting investigable idea or question comes up, challenge the group to explore it using their models, while discussing with a partner.

c. After each exploration, regain the group's attention, and encourage additional sharing of discoveries and questions.

Modeling Moon Phases

11. After exploring & discussing a few of their discoveries, ask the learners to hold their Moon balls out in front of them, directly in front of the "Sun."

12. Demonstrate crescent Moon Phase. Explain:

a. The Moon orbits the Earth.

b. Move the Moon ball to your left until you can see a thin, bright crescent lit up on the ball, then stop.

c. This is the crescent Moon phase.

13. Check for understanding:

a. Tell them to show the crescent on their Moon ball to the person next to them.

b. Check to make sure that everyone can see the crescent-shaped light on the Moon ball.

14. Discuss which way the bright side of the Moon faces:

a. Ask,

▶ *Is the bright edge of your Moon, that's curved like the edge of a ball, facing toward the Sun, or away from it?*

b. [Learners should respond that the bright side of the moon is facing toward the Sun.]

15. Continue the orbit to the quarter Moon phase. Explain:

a. Keep orbiting your Moon around your head in the same direction, until exactly half of the "Moon" is lit. (They will, of course, need to turn their bodies to the left, too.)

b. This is the quarter Moon phase.

c. Discuss with the person next to you:

TEACHING NOTES

- As the Moon appears fuller, does it move toward the Sun or away from it? [Away from it, just like the real Moon.]
- Again, does the lit edge of the Moon that's curved like the edge of a ball face toward or away from the Sun. [Toward.]

16. Demonstrate gibbous Moon phase. Explain:

a. Keep turning and orbiting your Moon ball in the same direction, until it's halfway between a quarter Moon and a full Moon.

b. This is the gibbous Moon phase.

17. Demonstrate full Moon phase. Explain:

a. Keep moving the Moon ball along its orbit until the part you see is fully lit. The light bulb should be behind your back.

b. You'll have to hold the Moon ball just above the shadow of your head.

c. This is the full Moon phase.

d. Discuss with the person next to you:

- When the Moon is full, is it between the Earth and the Sun, or on the opposite side of the Earth from the Sun? [It is on the opposite side of Earth from the Sun.]

18. Demonstrate gibbous phase, again. Explain:

a. Keep moving the Moon ball in its orbit until it is in gibbous phase once again.

19. Move to quarter Moon phase. Explain:

a. Keep orbiting the Moon ball in the same direction until it is just half full again, another quarter Moon phase.

b. Discuss with the person next to you:

- Is the curved side facing toward or away from the Sun? [Toward.]
- As the Moon moves toward the Sun, does it appear to get fuller or thinner? [Thinner.]

20. Model crescent & then new Moon phase. Explain:

a. Keep moving your Moon ball so you see a very thin crescent again.

b. Most of the time the Moon does not pass directly in front of the Sun, but just above or below the Sun. When the Moon can't be seen at all, this phase is called the new Moon.

c. You have now modeled one full cycle of the Moon.

21. Pairs do another Moon orbit, focusing on light and shadows.

a. Direct participants through another orbit of the Moon with a partner.

b. This time, ask them to focus on what is making the bright part of the Moon bright, and what is making the dark part dark.

TEACHING NOTES

22. Discuss what's making parts of the Moon bright & dark.

a. Get the whole group's attention, ask and discuss:

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

- If someone says that the light is being reflected by the Moon, ask them to explain what they mean by "reflected." Point out that many learners think of reflection only as something that reflects objects like mirrors, glass or water—but the idea of a rocky object like the Moon reflecting may be confusing.

▶ *What is making the dark side of the Moon dark? [The beginning of the Moon's own shadow.]*

- Point out that this is another important question to ask students, because many people think the dark part is caused by the shadow of the Earth. This is a very common alternative conception, including among adults.

23. Explain that one orbit equals one month:

a. The movement of the Moon from crescent to full models the two-week period when the Moon is visible in the evening.

b. A full circle, what we were just modeling, represents about a month (more precisely, 29.53 days).

Modeling Lunar and Solar Eclipses

24. Ask participants to try to create a solar eclipse:

a. Now move your Moon balls directly in front of the Sun to try to create an eclipse of the Sun.

25. Tell participants to observe the Moon's shadow on the "Earth." Explain:

a. Hold your Moon balls exactly where they are, and look at the faces across from you.

b. Notice the shadows over everyone's eyes—what's making these shadows? Remember that your head is the Earth.

c. The people who live where your eyes are see an eclipse of the Sun, but how about the people who live on your chin? Or in Lake "Earie?"

d. Only the people who live around your eyes can see this eclipse of the Sun—but the people on your ear or chin can't.

e. This is why people often have to travel across the Earth to see a Solar eclipse.

26. Create a lunar eclipse.

a. Move your Moon ball around in a circle, as before, until you reach the full Moon phase.

b. This time move your Moon into the shadow of your head to create a lunar eclipse.

27. Focus on the Earth's shadow on the Moon. Explain:

a. This is an eclipse of the Moon.

b. Ask,

▶ *Can you see the shape of your hair when the Moon moves into eclipse?*

c. When there is an actual eclipse of the Moon, you can see that the shape of the Earth is round, because it always has a curved shadow.

28. Explain that viewing a lunar and solar eclipse on earth is different:

a. Everyone who lives on the side of the Earth facing the Moon can see a lunar eclipse.

b. But during a solar eclipse, only the people inside the shadow see the Sun being eclipsed.

29. Identify phases of the Moon surrounding eclipse events. Explain:

a. Keep moving your Moon ball around your head until you see a solar eclipse again.

b. Discuss with partner(s) the following question:

- What phase is the Moon in just before or just after a solar eclipse of? [Thin crescent or new phase]
- What phase is the Moon in just before or just after a lunar eclipse?" [Full]

Reflecting on Explanations and Evidence

30. Apply this to the real Moon whenever you see it. Explain:

- Whenever you look at the Moon from now on, try to figure out where the Sun is, and why certain parts are lit up and other parts are in shadow.

31. Explain this experience was abbreviated:

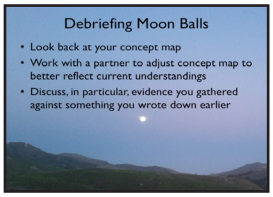
a. There are many more questions that can be investigated using the model than can fit into one experience.

b. If you have more questions, you can keep exploring this model and ask other people to discuss your ideas and questions with you later on.

Debriefing the Moon Phases Activity

1. Show slide 31: *Debriefing Moon Balls*. Tell participants to adjust their concept maps:

a. Spend a few minutes alone, or with a partner, making adjustments to your concept map, so it's a better reflection of your current understandings.



slide 31

TEACHING NOTES

YOU ARE HERE:

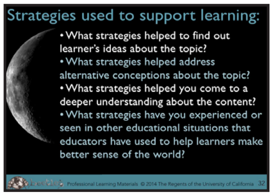
10 minutes

TEACHING NOTES

b. Discuss with a partner any evidence that contradicts something you have written and how to change what you wrote to have a more accurate statement.

2. **Explain that these changes represent how their conceptual frameworks change:**
   a. These changes in your concept maps are an extremely crude representation of how your conceptual frameworks may have changed.
   b. One episode, no matter how great, is probably not enough for deep learning. You probably need more experiences, including spending some time looking at the actual Moon and applying what you've learned.

3. **Show slide 32:** *Strategies used to support learning*. **Tell participants to discuss in small groups the strategies used in Moon Balls activity.**
   - Tell participants to get back together with their original small groups and discuss the questions on the slide related to the Moon phase activities.



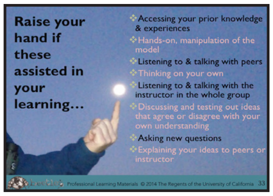
slide 32

4. **With the whole group, discuss strategies used.**
   a. After about 5 minutes, discuss with the whole group the same questions, asking participants to share some of the ideas their small group discussed.
   b. Add in the following ideas, if they are not brought up by participants:
      - Addressing foundational understandings about shadows that could influence their understandings about Moon phases
      - Facilitating students accessing their own understandings about the topic at the beginning, then adjusting them at the end.
      - Using a model to represent the phenomenon.
      - Encouraging learners to use models to try out their ideas, and to figure out what's going on for themselves.
      - Discussion of inaccuracies in the model, to help prevent the model from creating additional alternative conceptions.
      - Peer-to-peer discourse. Multiple opportunities to share ideas with others, and to hear others' ideas.
      - Whole group directed modeling and discussion led by the instructor.
      - Encouraging the use of evidence in discussions, and evaluating explanations based on all the available evidence.

If your instructors have already done the *Evidence & Explanations* BEETLES session, connect the final strategy on the list with that session.

TEACHING NOTES

5. **Show slide 33:** *Raise your hand if any of these assisted in your learning*. **List learning & teaching strategies they may have just experienced.**



slide 33

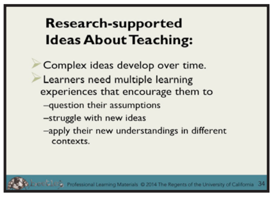
   a. Explain: Raise your hands as I read off each strategy if it influenced your learning during the model activity.

   b. Read off the following list of learning and teaching strategies one at a time, leaving space for participants to raise hands after each one.

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

If your instructors have already done the *Teaching & Learning* BEETLES session, remind them this is why learning cycle-based instruction is effective. It incorporates needs of learners, such as accessing prior knowledge, giving students time to become curious and struggle with ideas, to learn from peers and from the instructor, apply concepts, and reflect back on the learning experience.

6. **Show slide 34:** *Research-supported Ideas About Teaching*. **Explain that students can't just be told something, or only "do hands-on" to learn; they need to actively struggle with ideas:**



slide 34

   - To firmly grasp challenging concepts, students need multiple learning experiences that encourage them to question their assumptions, struggle with new ideas, and apply their new understandings in different contexts.

7. **Explain that the content vs. process perception is a false dichotomy:**

   a. Did you notice the combination of exploration and content invention during that activity?

   b. Those who are accustomed to a content delivery approach sometimes simplistically think of these strategies as all process and, therefore, anti-content, which is far from true.

   c. Students can be engaged in learning content even when the instructor is not constantly delivering it.

   d. A research-based approach includes relevant content judiciously and thoughtfully invented by students and introduced by instructors at appropriate moments.

It might be useful to more accurately reframe the content vs. process perception as quality vs. quantity. When instructors deliver a steady-stream of content, they might think there is more content learned, but students are learning it in a less meaningful/ and sticky way.

8. **Show slide 35:** *Shallow & Slippery Learning*. **Explain:**

slide 35

   a. What if I only told you directly about what causes the phases of the Moon? Perhaps you could repeat it back, but it would likely be shallow and slippery learning.

TEACHING NOTES

b. Or what if I gave you the model, but I just told you what to do with it step-by-step, and how it represents what causes the phases of the Moon, without you having opportunities to explore with it, ask questions, try things out, see why some explanations are not accurate, and talk with your peers?

c. These exposures would not be nearly as effective.

d. Shallow exposures can work for learning vocabulary and skills, but not as well for deep concepts.

e. In general, students do not acquire concepts simply by having a teacher tell them the content or even by (only) performing a hands-on activity.

9. **Show slide 36:** *Deep & Sticky Learning*. **Explain:**

slide 36

a. Longer learning episodes with students struggling with ideas tend to lead to "deep and sticky" learning.

b. Learning is a process. One learning episode, no matter how great, probably won't lead to a big understanding. Learners need more episodes for deeper and stickier learning.

c. As field instructors, we can give students powerful experiences that will inspire more memorable episodes in their learning about the natural world.

10. **Show slide 37:** *Surprise! (and learning).* **Explain how focusing on surprises can help students learn:**

slide 37

a. Raise your hand if anything surprised you during the activity.

b. Moments of surprise can be opportunities for learning, if we are curious about them. They often lead to questions and to trying to figure something out.

c. This is useful language (what surprised you?) to use with students when asking them to admit when they have adjusted their understanding (which can be hard for learners to do).

d. Raise your hand if you answered one or more questions for yourself through the model lesson experience.

e. Raise your hand if you now have other questions that are unanswered.

YOU ARE HERE:

30 minutes

Watching & Discussing A Private Universe Video

1. **Show slide 38:** *A Private Universe Video*. **Introduce the video; explain:**

slide 38

a. We'll see an intriguing video that explores alternative conceptions that university and high school students have about the phases of the moon and the seasons.

b. It's a classic in science education circles.

2. **Show the Private Universe video. (Running time about 20 minutes.)**

3. **Discuss issues raised by the Private Universe video.**

   a. After the end of the video ask some of the following discussion questions:

   - What did you find interesting in the video?
   - What motivated Heather to change her ideas about the phases of the Moon?
   - Do you think it's possible to teach a concept to every child in a class, and to know they "got it?" Is it important? Is it desirable?
   - When asked to explain what causes Moon phases, one boy in the video answered, "clouds." If you were the teacher, what might you do with that information?

4. **Provide some additional information about Heather:**

   ▶ *The video is very well known in science education circles, but Heather didn't realize her role in it until a number of years later, when people recognized her and asked her about the video. Twenty years after it was made, she was invited to give a talk at NSTA. She said, "I wasn't that smart, but I always got good grades. I was really good at reading what a teacher wanted from me, and giving it to them. I don't remember much about when they filmed me, but I do remember that the interviewer (Phil Sadler) didn't give me any cues about whether I was right or wrong. I couldn't 'read' him, and I had to just keep talking until I figured out what I was trying to say, what I was actually thinking."*

   - Explain: This is an interesting example of why when we're leading students in discussion it's useful to give neutral accepting responses to their ideas

5. **Show slide 39:** *"Whether or not…"*. **Explain that in order for the learner & instructor to address them, the ideas have to be uncovered:**

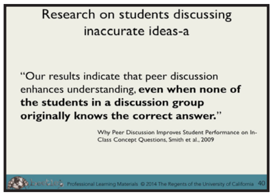
slide 39

   a. Some instructors worry that if students voice their misconceptions, other students may adopt them.

   b. But whether an educator has learners share inaccurate ideas or not, those ideas still exist and influence learning.

   c. When these ideas are out in the open, learners and instructors can address them.

6. **Show slide 40:** *Research on students discussing inaccurate ideas-a*. **Explain:**



slide 40

   a. Take a moment to read the slide.

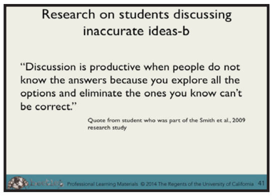
TEACHING NOTES

You may want to halt the video after Heather has explained how she was able to change her ideas about lunar eclipses. The ending paints a somewhat discouraging picture with regard to challenging student misconceptions. Ending the video at this point does not prevent participants from hearing and discussing the critical points from the video.

TEACHING NOTES

b. Even when the instructor may not hear them, alternative conceptions can also be exposed and challenged by peers.

7. **Show slide 41:** *Research on students discussing inaccurate ideas-b*. **Explain:**



slide 41

   a. Take a moment to read the slide.

   b. Other researchers (Osborne, 1996) have emphasized that it's as important for students to figure out what is wrong about inaccurate ideas, as it is to understand what's right about accurate ideas.

8. **Explain that this is why it's so important to use & participate in discussion routines, like** *Walk & Talk***, with students:**

If your instructors have already done the *Promoting Discussion* BEETLES session, ask them why it's important to use a mix of different types of discussion routines. Then, only bring up points in the next step that they've not already brought up.

   a. Frequent use of discussion routines allows for both peer-to-peer and students-instructor exchange of ideas.

   b. When you partner with students during discussion routines, it's an opportunity for one-on-one discussion where you can ask about an individual student's ideas.

   c. Many of the benefits of paired discussion routines you will never get to witness, because you'll only be hearing a tiny fraction of the idea exchanges going on.

   d. Uncovering student ideas is not only for the instructor. It's an important part of learning for students to uncover their own and one another's ideas.

9. **Explain that students can pass a test or repeat back to an instructor what she wants, while privately still holding onto alternative conceptions.**

   a. If alternative conceptions are ignored, students will probably hold onto them.

   b. Even if told the accurate answer over and over again, students may be able to pass a test by repeating the correct answer, but will likely still maintain their own "private universe" belief system.

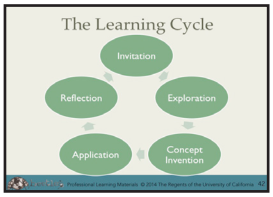
YOU ARE HERE:

15 minutes

Reflecting on How People Learn

Optional. If your staff is familiar with the Learning Cycle, then make the connection between how people learn and the stages of the Learning Cycle.

1. **[optional] Show slide 42:** *The Learning Cycle*. **Describe how teaching based on how people learn connects with & relates to the learning cycle phases:**



slide 42

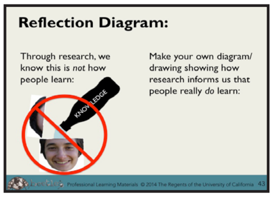
   a. Through these phases students have the opportunity to:

      - access their prior knowledge
      - make observations and discover information that can challenge their ideas
      - construct new frameworks, add to and apply existing frameworks

- reflect on how new and prior frameworks are connected.

b. That's how a learning cycle-based model for instruction supports teaching based on how people learn.

2. Show slide 43: ***Reflection Diagram*****. Explain that each participant will make a diagram showing how people learn:**



slide 43

a. As part of your reflection, you'll now make a diagram synthesizing your understandings about how people learn.

b. Here's a diagram of a way we know learning doesn't happen.

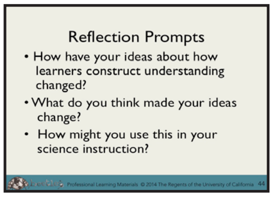
c. Make your own diagram showing how learning does happen.

d. Use the handouts for information to include in your diagram to make it as useful as possible.

3. Distribute the following handouts.

- *Strategies for Helping Students Build on their Ideas*
- *What Research Tells Us About How People Learn*

4. Show slide 44: ***Reflection Prompts*****. Explain the prompts:**



slide 44

a. Get out your journal or a piece of paper and quietly write your thoughts about how this session has affected your ideas about teaching and learning.

b. Write about any of the reflection prompts that inspire you.

5. Share diagrams:

a. After about 10 minutes, tell participants to share their diagrams and thoughts with one or two other people.

b. After 2–3 minutes, conclude the session by asking if anyone has a diagram for how people learn that they'd like to share with the whole group.

APPLYING SESSION TO INSTRUCTION

The session is not over! A critical phase of learning anything new is application, when the learner takes new knowledge and applies it. There's some application included in the session, but—with all professional learning for instructors—the rubber meets the road (or trail) when instructors apply what they've learned to their instruction, and when they keep thinking and discussing with their peers. If you want your instructors to try out "new" activities/approaches, they'll need ongoing support from you. Even if they're excited by new ideas, it's easy for instructors, especially veteran instructors, to keep doing what they've been doing already, and not try out new activities/approaches. Some might react to content of this session as being simple, and that they "got it," but continue asking mostly narrow questions in their practice without realizing it. Some are able to transition to a more broad question-focused approach pretty naturally, but there are many who really struggle with it, and may continue asking mostly narrow questions, or ask a broad question, then give students the "answer," or not really listen to student ideas. Below are a variety of follow-up activities and discussions to dig deeper into the topic, and help you facilitate thoughtful implementation.

- Staff brainstorm of what they and you can do to encourage incorporation of [main idea of session]. After the session reflection, your staff will have already written ideas they have about implementation into their instruction. You can tap into these, as well as other ideas, through a brainstorm of what they plan to do, and how you can support them in doing it.
- Instructor Observations. If you do observations of instructors, discuss how you might incorporate elements from this session into the observations.
- Continuing a discussion. If there was a topic that came up during discussion that you had to cut off, and it seems like your staff is still interested, set aside some time to continue the discussion.
- Watch and discuss one or both of these videos:
  - AfterSchool KidzScience, How Do People Learn, Center for the Collaborative Classroom: https://www.youtube.com/watch?v=-LqKvSgmsVo. Note: The learning cycle presented in this KidzScience video is a 3-step cycle. The BEETLES project uses a 5-step cycle, which is more detailed and informative, and which is introduced to instructors in the BEETLES session, Teaching & Learning.
  - Lessons From Thin Air: Minds of Our Own series: https://www.learner.org/resources/series26.html, produced by the Harvard-Smithsonian Center for Astrophysics. 1997.
- Assign your staff a reading related to the ideas in this session. Tell them to use active reading strategies like underlining important points, writing out questions and connections in the margins, and asking critical questions like who wrote this, who is the audience, etc. Have them pair up with someone else and compare their notes and ideas, then bring this discussion into the whole group. Here are some suggested readings:
  - http://gsi.berkeley.edu/gsi-guide-contents/learning-theory-research/social-constructivism/
  - http://www.ucdoer.ie/index.php/Education_Theory/Constructivism_and_Social_Constructivism

RESEARCH-BASED INFORMATION ABOUT STUDENT LEARNING

Students all arrive at school with their own often quite elaborate ideas and explanations about a variety of natural phenomena. They are not "blank slates." Some of these ideas are difficult to change. (Osborne et al., 1980; Driver, et al., 1994).

Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom (*How People Learn*, 2000, p. 14).

... teachers need to pay attention to the incomplete understandings, the false beliefs, and the naive renditions of concepts that learners bring with them to a given subject. Teachers then need to build on these ideas in ways that help each student achieve a more mature understanding. If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends. (How People Learn, p. 10)

Students' prior ideas, their "common sense," and "everyday thinking," are often intelligent and useful. If those ideas are not exposed and evaluated, students often dismiss science teaching as irrelevant. (Hammer & Van Zee, 2006, *Seeing the Science in Children's Thinking*, p. 14)

Too often, the classroom has been dominated by teacher talk. (Flanders 1973; Goodlad, 1984; Nystrand, 1997; Scott, 2009; Hattie, 2009; Smith et al., 2004). While 21st century teacher education has certainly demonstrated the importance of more open-ended discussion, Lingard, Hayes, & Mills (2003) noted that in classrooms with higher numbers of students living in poverty, teachers talk more and students talk less. Also, English language learners in many classrooms are asked easier questions or no questions at all, so less often have to talk in the classroom (Guan Eng Ho, 2005). In addition, emphasis on testing and accountability for both students and teachers have placed strictures on curricular focus and time. In this context, a study of three representative districts has found that teachers seek to maintain student-centered practices when they can, but, at best, wind up "hugging the middle" in a "hybrid classroom" (Cuban, L., 2007).

Echoes of John Dewey's comment on an earlier generation of progressive education in 1952 reverberate today: "There is a great deal of talk about education being a cooperative enterprise in which students and teachers participate democratically, but there is far more talk about it than the doing of it" (Dworkin, 1959, Dewey on Education, pp. 129–130).

Teachers vastly overestimate gains in knowledge their students achieve after a course they've presented. This is especially true with concepts (as opposed to facts) for which students often have strong, underlying misconceptions. (Lightman & Sadler, March, 1993, "Teacher Predictions Versus Actual Student Gains," *The Physics Teacher*, Vol. 31.)

Perseverance effect is when people/students stick to their beliefs even when the evidence for those beliefs has been refuted (Ross et al., 1975).

Confirmation bias is the tendency to search for, interpret, and/or recall information in a way that confirms one's beliefs or hypotheses (Plous, 1993).

Higher mental/cognitive functions have social origins that are first expressed between individuals before they are internalized within the individual. In other words, meanings are rehearsed and made explicit as a result of conversations and interactions. (Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA, Harvard University Press.)

Learning is perceived as an active process of engaging with and/or manipulating objects, experiences, and conversations in order to construct a mental picture of the world. (Dewey, 1938; Piaget, 1964; Vygotsky, 1986;

How People Learn, 2000; Osborne, 1996.)

Social and cultural interactions with peers and educators (or with novices and experts) are necessary for the construction of knowledge to take place. In this way, learners are constructing their own learning within a social context where they share ideas, and meaning making is created and expanded by interaction with their environment (Rogoff, 1998; *How People Learn*, 2000).

Students (K–12 to University) show greater understanding when they engage in collaborative dialogue with peers where they provide explanations as part of arguments and justifications and seeking and providing help (Mercer et al., 2004; van Blankenstein et al., 2011; Veenman et al., 2005; Venville & Dawson, 2010).

"CANNED SPIEL" VS. FACILITATING STUDENTS' DESCRIPTIONS AND CONNECTIONS

Scenario #1: "Canned Spiel"

Instructor: Everyone see this plant right here? You can tell if it's poison oak because it has three leaves: "Leaves of three, let it be." And you can tell it apart from blackberry because poison oak leaves have wavy edges and blackberries have jagged edges. Everybody feel your ear lobe. Poison oak edges are called "lobed," which you can remember because they are like ear lobes.

End Scene

Scenario #2: Facilitating Student Descriptions and Connections

Instructor: That plant right there is poison oak. Without touching it, call out some observations you can make.

Student 1: It's green.

Student 2: It's shiny.

Student 3: The leaves are in groups of three.

Instructor: You can tell if it's poison oak because it has three leaves— "Leaves of three, let it be."

Instructor: How might you describe the edge of that poison oak leaf? What does it remind you of?

Student 4: Like the edge of a drawing of a cloud.

Student 1: Like the bumps on your knuckles.

Student 3: Like an oak leaf.

Instructor: But blackberries also grow in threes. How might you describe the edge of that blackberry leaf? What does it remind you of?

Student 2: Like a saw.

Student 3: Like teeth.

Instructor: Poison oak leaves can cause rashes on a lot of people, so let's try to recognize and avoid them during the hike. Blackberry leaves may have spines, but they don't cause rashes, and are OK to touch. Pay attention to the leaves on plants around you. See if you can recognize poison oak leaves and blackberry leaves.

End Scene

WHAT RESEARCH TELLS US ABOUT HOW PEOPLE LEARN

1. All learners arrive at any learning situation with their own often quite elaborate ideas, explanations & theories. They are far from "blank slates."
2. Learning is an active process of engaging & manipulating objects, experiences, ideas & conversations.
3. Learners "construct" their own understanding of the world based on their experiences, motivations, cultural and social interactions with peers and others.
4. Complex ideas develop over a long period of time.
5. Learners must encounter multiple learning experiences that encourage them to: a) question their assumptions, b) struggle with new ideas, and c) apply their new understandings in different contexts.

Some Useful Quotes

"Learning is about making connections"

— K. Patricia Cross, 1999, Alliance for Community College Innovation

"Surprise is triggered when our schemas (conceptual frameworks) fail...and this prepares us to try to understand why the failure occurred."

— Made to Stick, by Chip Heath & Dan Heath

"However, the research also shows clearly that 'usable knowledge' is not the same as a mere list of disconnected facts. Experts' knowledge is connected and organized around important concepts…it supports understanding and transfer (to other contexts) rather than only the ability to remember."

— How People Learn, John D. Bransford, Ann L. Brown, and Rodney R. Cocking, editors, 2000)

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

— Roger Osborne

from Taking the Plunge, edited by Wynne Harlen

"If all we needed was the real world, we wouldn't have education."

— Chris Dede, Harvard

STRATEGIES FOR HELPING STUDENTS BUILD ON THEIR IDEAS

Avoid Show & Tell. Let go of the belief that if you simply tell students stuff they will learn what you tell them.

- Use real-world investigations & materials, involving observation & exploration.
- Make use of models, but be aware of and discuss their limitations.

Use Learning Cycle-based Instruction. Situate learning experiences within the learning cycle: invitation, exploration, concept invention, application, reflection.

- Provide learning experiences in which students explore, become curious, discover, struggle with new ideas, make connections, etc.
- Tell information strategically (in small bits, usually only what students aren't likely to discover on their own, at just the right moments when they're interested to hear it).
- Set up learning situations where students need to grapple with conflicting ideas & alternate conceptions.

Do More Deep & Sticky Learning and Less Shallow and Slippery Learning: longer episodes with students struggling with ideas and fewer short episodes with telling, memorizing, regurgitating

- Provide multiple opportunities for meaningful conceptual learning.
- Focus on reasoning, comprehension, and depth, less on memorization of information.
- Give students opportunities to think, re-think, discuss, reflect, and apply their ideas to new situations. It takes time to construct new concepts.
- Provide evidence that shows why a certain explanation is "correct," AND provide opportunities and evidence for students to see why other explanations are inaccurate.

Avoid Canned Spiels. Ask the students to make sense of their experiences. What does it remind you of? What does it look like to you? Have you heard of anything like that before?

- Use what you learn about student's ideas to inform your teaching.
- Be flexible and adapt your instruction to be relevant and responsive to student needs.

Broad Questions and Listening. Ask lots of interesting broad questions, and listen to students' ideas.

- Cultivate a learning environment that celebrates good thinking and struggling with evidence-based explanations, more than "knowing the right answer."
- Find out what students already think, elicit their prior ideas.

Student Discourse. Give students lots of opportunities to talk to one another and to you about science ideas

- Facilitate open discussion of alternative ideas.
- Provide ways for students to represent their ideas (peer-to-peer discussion, whole group discussion, drawing, writing)
- Help students struggle with multiple perspectives and ideas to build their own more complete understanding.

BACKGROUND INFORMATION FOR PRESENTERS

Constructivism

In order to avoid jargon, we have not included the term "constructivist" in the session, but feel free to use it if you think it would be helpful to your staff. Constructivist learning theories have led educators to develop teaching strategies that can help make explicit connections between new learning and previously learned knowledge. These strategies are effective in helping learners develop new ideas, deeper understandings, and construct more complete mental frameworks. These strategies engage and motivate the learner with interesting, culturally/socially-relevant activities and experiences that allow them to discover, infer, reflect upon, and apply concepts. They also provide opportunities for learners, peers, and educators to engage in meaningful conversations about the experiences and content. A constructivist approach to learning transforms the educator into a facilitator of learning, rather than a transmitter of information. In the words of the Brazilian educator Paulo Freire, "To teach is not to transfer knowledge but to create the possibilities for the production or construction of knowledge," and he adds, "Liberating education consists in acts of cognition, not transferrals of information."

Constructivism groups together a number of related learning theories and educational ideas based on the research and practices of educational psychologists, cognitive scientists, and a wide range of educators. With roots in the work of John Dewey, Maria Montessori, Jean Piaget, Lev Vygotsky, Jerome Bruner, and many others, it has branched out in a multitude of directions. Social constructivism is now a widely used term in education and science education circles. The central claims of constructivism are that human knowledge is acquired through a process of active construction; concepts are invented rather than discovered; and learners' prior knowledge and experiences are important (Duit, 1995). Each of us generates our own "rules" and "mental models," which we use to make sense of our experiences. Learning, therefore, is perceived as an active process of engaging and manipulating objects (Piaget, 1983), experiences (Dewey, 1938), and conversations (Vygotsky, 1986), and in examining various claims and the evidence that support them (Osborne, 2002). Learning is cumulative, iterative, and social. To understand and make sense of their world, individuals organize and relate new information and experiences with those in the past. In this way, learning is a contextualized process of making sense of experiences in terms of prior knowledge within social and physical contexts over time (Rennie & Johnston, 2004).

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

Learning is a social activity, and occurs through discourse within social interactions (Vygotsky, 1978, Osborne, 2002). This perspective requires a shift, from thinking of learning as something that happens to individuals to thinking of learning as something that results from things people do together, the things they use, the words they speak, and the actions they take (Rogoff, 1998). From this perspective, knowledge is co-constructed between participants in the activity, and knowledgeable experts and peers play important roles in helping less experienced learners make meaning out of new experiences. They promote learners' curiosity and persistence, direct learners' attention, structure experiences, support learning attempts, and regulate the complexity and difficulty of levels of information (Bransford, Brown, & Cocking, 2000). It's important to remember that constructing knowledge requires intellectual support. Without guidance, learners, and children in particular, may not be able to make sense of concepts, and so may leave an interaction with an incomplete or incorrect understanding of an idea (Grandy, 1997; Klahr & Nigam, 2004). A learner's potential—with such guidance—has been called the "zone of proximal development" or **zpd** (Vygotsky, 1978). The zpd concept addresses how experienced individuals can help less experienced learners extend their learning beyond how far they are able to go on their own, given their physical or developmental level." The zpd is the area between what a person can accomplish on their own, to that which they could achieve with the help of someone more experienced" (Hohenstein & King, 2007).

Alternative Conceptions

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

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

Research has demonstrated conclusively that alternative conceptions can be held on to quite stubbornly and creatively! (Lightman, A. & Sadler, P.,1993; Bransford et al., 2000; Minstrell, J., 1989; Lucariello, J. with Naff, D., 2014).

People do not part easily from their established frameworks and previous understandings. When confronted with new experiences and/or data that don't agree with their ideas, people sometimes question or discount the new information, or make elaborate explanations that reconcile it with their beliefs. To achieve new understanding, successive experiences of increasing sophistication are required over time, even from grade to grade. It can be especially helpful to work with phenomena, demonstrations, or models that behave in unexpected (or "discrepant") ways that cause students to directly confront their previous interpretations. Reflection and discussion drawn from these experiences can be instrumental in student development of more accurate conceptions in science.

Students' alternative conceptions are tenacious, but rather than this leading to pessimism about learning, students' ideas can be used as important teaching tools and more effective teaching strategies by educators who also have clever minds! Educators can help learners confront some of the most prevalent alternative conceptions identified by researchers, and provide learners with experiences that build more accurate ideas. These methods include active, experiential, "hands-on, minds-on" learning in which students engage in meaningful, relevant activities that allow them to discover, infer, reflect upon, and apply the scientific concepts involved. These approaches also involve encouraging learners to talk about and discuss their ideas. It is these kinds of experiences that are the most effective, over time, in helping students acquire new, more accurate ideas, deeper understandings, and construct more complete mental frameworks. Students often discover that their alternative conceptions are not "wrong." They are often made up of bits of accurate information that they have assembled or applied in naive ways. Constructivism views the role of the teacher as a facilitator of learning, not a transmitter of accurate information. Research shows that when students (of all ages!) grapple with alternative ideas raised by their own experiences, more accurate concepts are retained and meaningful learning takes place.

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

Having an awareness of common alternative conceptions is helpful in many ways. It can help a teacher decide where to start with her students, and can be very useful when assessing student understanding. As an instructor develops questioning strategies to gauge the depth of student comprehension and encourage students to explain their reasoning, it's likely that some of these mistaken ideas may come up. Having students draw or diagram what they think is going on can also help reveal underlying ideas. Curricula that take such alternative conceptions into account, and provide the instructor with concise research-based information on obstacles their students may encounter, are of course extremely helpful for instructors and students.

Science Content: Moon Phases and Eclipses

The science background information here is for the presenter. It is not meant to be read out loud to participants or passed out as a handout. The information is designed to help presenters respond to participant questions, and be aware of inaccurate ideas that research indicates students may bring to the classroom.

Moon Phases and Eclipses

The most useful way to learn about Moon phases is to look at the actual Moon periodically, and to explore the Moon/ball, Sun/light bulb, Earth/head model yourself. If participants ask content questions about Moon phases or eclipses, the best response from the presenter is often to say, "Let's ask the objects," and have participants use the model to try to figure out the answer themselves.

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

Common Alternative (and Inaccurate) Conceptions About Shadows

- A shadow is only the dark shape cast by one object on another object.
  - A shadow does not include the dark side of the object that is blocking the light.
  - It does not include the area behind the dark side of the object.
- Shadows are independent of the objects causing them.
- Shadows are the reflections of objects.
- Shadows are dark light.

Common Alternative Conceptions About Moon Phases

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

What causes the phases of the Moon?

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

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

What is a Shadow?

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

Does the Moon make its own light?

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

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

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

Is there a dark side of the Moon?

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

Why does the Moon appear to change size?

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

What Causes Eclipses?

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

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

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

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

Unlike total lunar eclipses, which can be seen from half the Earth (the night side) at a given time, total eclipses of the Sun can be seen only along a narrow "path of totality," which is, at most, 270 kilometers wide. The path of totality is the shadow of the Moon projected on the Earth's surface, and it moves from west to east at about

1,700 kilometers per hour. The shadow of the Moon covers only a small portion of Earth, so only people in the right locations can see a totally eclipsed Sun. People in a larger part of Earth can see the Sun partly covered by the Moon. That is a partial eclipse. On most of the Earth, the eclipse cannot be seen at all for most people, and it takes, on average, four centuries for a path of totality to touch a given place on the Earth. So avid total solar eclipse watchers typically need to travel to far reaches of the globe.

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

What is Waxing and Waning?

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

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