Session 3: Constructing Understanding

Contents

Session Overview

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

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

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

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

Background Information for Presenter

Constructivism

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

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

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

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

Alternative Conceptions

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

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

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

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

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

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

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Science Content: Moon Phases and Eclipses

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

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

What are common alternative conceptions about shadows and Moon phases?
It can be difficult for a learner 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.

Common Alternative conceptions About Shadows

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

Common 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 is the positions of the Sun, Earth, and Moon relative to one another. No matter what phase the Moon is in, HALF of it is ALWAYS lit by the Sun. (Which half is always lit? The half that is facing the Sun.) The reason that the Moon does not always appear half lit to us is because of Earth's position relative to the Moon and the Sun. As the Moon moves in its orbit, different portions of it appear (to us) to be lit up as we look at it from Earth. This is why we see lunar phases. When the Moon is between the Earth and the Sun, the lit side is facing away from us, and the shaded side is toward the Earth. That's a new Moon, when we can't see the Moon. When the Moon has orbited one quarter of the way around the Earth, we see half of it lit by the Sun, and half shaded.

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

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

Does the Moon make its own light?
The Moon does not make any light of its own light. The Sun lights up one side of the Moon; the other side is dark. When we see the Moon from Earth, we see different amounts of 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 Earth, the side that's dark is constantly changing. During a new moon, the far side of the Moon is fully lit by the Sun. Sometimes the part of the Moon that's not directly lit by the Sun is visible. This happens most often just after a new moon, when you can see the full circular shape of the Moon with the crescent shape lit up on one edge by the Sun. The light that makes the darker part of the Moon visible is also from the Sun, but it's Earthshine—sunlight that is reflected off Earth.

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

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

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

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

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

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

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

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

Materials and Preparation

Materials Needed

For the class:

❑ "Private Universe" video, can be ordered from Annenberg Media, learner.org, http://www.learner.org/catalog/series28.html or can be viewed online at: http://www.learner.org/vod/vod_window.html?pid=9

❑ 1 overhead transparency or slide of each of the following sheets:
— "Kids on Love"
— "Sun Moon Observation Chart"
— "Pre-unit 4 Questionnaire, page 1"
— "Strategies for Building on Student Ideas"
— "Aims of Constructivist Science Teaching"
— "Small Group Discussion Question"

❑ 1 marker for writing on overhead transparencies
❑ 1 overhead projector or LCD projector
❑ 1 lamp socket with plug—no shade
❑ 1 25-foot extension cord
❑ 1 40-watt clear light bulb or 1 75-watt clear light bulb

For each group of 3–5 participants:

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

For each student:

❑ 1 copy of "Strategies for Addressing Student Ideas" (master on page 28)
❑ 1 copy of the "Pre-unit 4 Questionnaire, page 1" (master on page 29)
❑ 1 two-inch polystyrene ball, with a hole big enough for a pencil
Note: Styrofoam balls will work if painted with white latex or other water-based paint. Just about any other balls will also work, as long as they are opaque.
❑ 1 unsharpened pencil to hold polystyrene ball

Preparation

1. 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
(608) 884-9877

Styrofoam balls will also work if painted with white latex or other water-based paint.

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

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

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

— ”Kids on Love”
— ”Sun Moon Observation Chart”
— “Pre-unit 4 Questionnaire, page 1”
— ”Strategies for Building on Student Ideas”
— ”Aims of Constructivist Science Teaching”
— ”Small Group Discussion Question”

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

5. Prepare for the Moon Phases exemplar.

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

Test to see which light bulb to use. Before class, determine 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.

Instructor's Guide

Session Objectives

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

— learning is an active process of engaging and manipulating objects, experiences, and conversations in order to construct a mental picture of the world.

— learners come to learning experiences with preconceived ideas and explanations for things, and these mental frameworks affect how they assimilate new information.

— alternative conceptions come from intelligence and are often impressively reasoned (even when inaccurate); these alternative conceptions are born of an irrepressible need that humans have to make sense of the world and are the product of not having all the experiences and information that are needed to construct more accurate explanations.

— mental frameworks (sometimes incorrect) can be quite persistent and resistant to change.

— uncovering student ideas is very valuable for teachers so they can more effectively design experiences to challenge inaccurate ideas and build new understandings.

— uncovering student ideas is very valuable for students, so they can connect new knowledge to what they already know, and actively build their own mental frameworks.

— social and cultural interactions with peers and educators (or with novice and experienced individuals) are necessary for the construction of knowledge to take place.

Participants will also:

— learn a variety of strategies that research has shown to be effective in helping learners build and modify their understandings.

— gain a working knowledge of a constructivist approach to learning and teaching.

— reflect on their own ideas about teaching/learning and/or scientific conceptual understanding.

Time Frame: Total Workshop: 2 hours

- Kids Ideas on Love (10 minutes)
- Introducing Constructivism (20 minutes)
- Exemplar: Modeling a Constructivist Approach to Teaching Moon Phases (40 minutes total)
  - Questionnaire & Observing the Moon (10 minutes)
  - Modeling Moon Phases (15 minutes)
  - Modeling Lunar and Solar Eclipses (5 minutes)
  - Discussing Moon Phase explanations (10 minutes)
- Debriefing the Moon Phases Exemplar Experience (10 minutes)
- Watching and Discussing *A Private Universe* Video (30 minutes)
- Strategies for Addressing Students' Ideas (5 minutes)
- Constructivist Goals, and Individual Quick Write (5 minutes)

Session Activities at a Glance

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

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

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

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

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

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

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

Introduce Session

Discussing Kids' Ideas on Love

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

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

Kids on Love

WHAT IS THE PROPER AGE TO GET MARRIED:
• "Eighty-four! Because at that age, you don't have to work anymore, and you can spend all your time loving each other in your bedroom." (Judy, 8)
• Once I'm done with kindergarten, I'm going to find me a wife!" (Tom, 5)

WHAT DO MOST PEOPLE DO ON A DATE:
• "On the first date, they just tell each other lies, and that usually gets them interested enough to go for a second date." (Mike, 10)

WHEN IS IT OKAY TO KISS SOMEONE:
• "You should never kiss a girl unless you have enough bucks to buy her a big ring and her own VCR, 'cause she'll want to have videos of the wedding." (Jim, 10)

CONCERNING WHY LOVE HAPPENS BETWEEN TWO PARTICULAR PEOPLE:
• "No one is sure why it happens, but I heard it has something to do with how you smell. That's why perfume and deodorant are so popular." (Jan, 9)
• "I think you're supposed to get shot with an arrow or something, but the rest of it isn't supposed to be so painful."(Harlen, 8)

ON THE ROLE OF GOOD LOOKS IN LOVE:
• "If you want to be loved by somebody who isn't already in your family, it doesn't hurt to be beautiful." (Jeanne, 8)
• "It isn't always just how you look. Look at me. I'm handsome like anything and I haven't got anybody to marry me yet."(Gary, 7)
• "Beauty is skin deep. But how rich you are can last a long time." (Christine, 9)

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

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

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

Participant: You could tell them about love until you're blue in the face, but they probably won't really believe it until they experience it for themselves.
Presenter: So you're saying that until they have direct experience with something, they can hear a lot about other viewpoints, but they may not truly believe them.

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

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

4. Point out difficulty in knowing what kids truly understand. Explain that a person could try to explain love to a child, but even if the child says they understand, it, one can never be sure how well it is understood or if their understanding matches the explainer's. This is true of adults as well, of course!

Introducing Constructivism

1. Set the context for the session. Say that today the class is going to take a look at students' ideas in science through the lens of a useful theory about knowledge and learning called constructivism. Explain that the points just made about kids' ideas on love served as a light-hearted introduction to constructivist theory.

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

3. Introduce Constructivism. Display "Constructivism" slide. Constructivism is a perspective on learning grounded on the premise that we *construct* our own understanding of the world through our experiences. Explain that this theory is based upon a vast body of research, and is commonly referred to in the educational community as the rationale supporting best practices. As educators we must recognize that students enter school with boundless curiosity and a great thirst to learn more—and they also bring with them quite elaborated mental frameworks to try to explain and make sense of what they have already experienced of the world.

Exploring and Discussing Research Findings

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

2. Each group shares an idea. After about 10–15 minutes of small group discussion, ask each group to share one idea of how classroom teaching might be influenced by the research on student learning. As appropriate, ask groups to comment on each other's ideas.

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

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

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

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

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

Exemplar: Modeling a Constructivist Approach to Teaching Moon Phases

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

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

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

Questionnaire & Observing the Moon (10 minutes)

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

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

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

Exploring Shadows

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

2. Open exploration of shadows. Tell participants to explore shadows in the room for a minute or so. Tell them to share their discoveries with each other. After about a minute, get the whole group's attention, and ask a few participants to share their discoveries with the large group.

3. Three parts of a shadow. Explain that shadows can be described as having three parts. One part is the shadow cast by one object on another object. Hold up your hand, and point out the shadow of your hand on the wall. Say this is the part of a shadow most people notice. Ask if anyone can identify other parts of your hand's shadow. If they don't mention them, 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 students see that it is in shadow. Point out that this part of the shadow can only be seen when you move an object into it.

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

Investigating Moon Phases with Moon Balls

Note to Facilitator: This activity could be conducted by the leader telling participants exactly what to do at each step, and telling them exactly what the model shows at each step. To model a more constructivist approach and to foster an atmosphere of critical thinking and inquiry, it is written up here as a series of investigations carried out by the participants, facilitated by the leader. The leader does introduce concepts and vocabulary to the participants, but judiciously and at appropriate times. As participants ask questions during the activity, in general refrain from answering their questions, but instead, if the question seems investigable, use the opportunity to encourage teams to "ask the objects," and use the model to attempt to answer the questions themselves through investigation and discussion with peers.

1. Pass out balls, pencils. Find three parts of shadow on moon balls. Pass out one moon ball and pencil "handle" to each participant. Show them how to stick their pencil in their moon ball. Tell them to find the three parts of their moon ball's shadow.

2. Explain Sun, Earth and Moon model, and ask for inaccuracies. Explain that in this model, the light bulb will represent the Sun and their heads will represent the Earth. The balls on the pencils represent the moon. Ask participants to share a few of the obvious inaccuracies of this model. Point out that models are extremely useful in science, but they can easily lead to misconceptions if the inaccuracies and limitations of each model aren't discussed.

3. Participants use model to explore phases of the Moon. Tell them to team up with a partner (or two) and use this model to begin to explore what causes the phases of the Moon. Encourage them to work with others, and to talk to each other while they explore the model. Encourage them to talk to each other as they manipulate the moon balls and investigate what happens when they move it around in the light from the "Sun". Circulate and make sure no one is left out, and to encourage exploration and discussion.

4. Participants share discoveries with large group. After a few minutes, get the whole group's attention. Ask participants to share what they discovered. Tell any participants who have done this activity before, or who already know the content really well to refrain from answering at this point, so those who have been making initial discoveries can share.

5. Leader facilitates small group investigations. As each participant shares her discoveries, encourage others to use their own moon balls to try out what they are talking about. If any interesting investigable idea or question comes up, challenge the group to explore it using their models, while discussing with a partner. After each exploration, regain the group's attention, and encourage additional sharing of their discoveries and questions.

Example #1:
Participant: I noticed that when you make a crescent moon, depending on how you hold the moon ball, it changes whether it looks like a "C" or a "U."
Leader: What did the shape of the last crescent moon you saw in this area look like?
Participant: It was a "U" shape.
Leader: Go ahead and try out what she's talking about. See what position the moon ball has to be in to make a "C," "U," or other shape.
After a few minutes of free exploration, the whole group's attention is regained for further discussion.
Leader: What did you discover?
Participant: You have to hold the moon ball up higher in order to see a "U" shape.
Leader: Everyone try that out. Does that make sense to you? Does anyone want to add to that or to disagree?

Example #2:
Participant: I noticed that half of the moon ball is always in shadow, and half is always in light.
Leader: Let's check that out. Try it with a partner see if you agree with that. And as you investigate, try looking at the moon ball from different perspectives: from above, from outside the orbit (watching someone else's moon ball as they orbit it around themselves), etc.
After a few minutes of investigation, the whole group's attention is regained for further discussion.
Participant: It's true, half is always in shadow, but it's not always the same half.

The part that's in shadow is always changing.
Leader: Let's investigate *that* now. Pick some kind of flaw or mark on your moon ball that is already there (don't add marks, unless they are stickers that can be removed). As the moon ball orbits, watch that spot, and see if it stays in light or dark, or if it changes.
After a few minutes of investigation…
Leader: What did you discover?
Participant: The spot is sometimes in dark and sometimes in light.

Modeling Moon Phases (15 minutes)

1. Face the "Sun" and hold up the Moon ball. After exploring and discussing a few of their discoveries, ask the participants to hold their Moon balls out in front of them, directly in front of the "Sun."

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

3. Check for understanding. Tell them to show the crescent on their Moon ball to the person next to them. Check to make sure that everyone can see the crescent-shaped light on the Moon ball. Adult learners don't usually have trouble with this, but the most common error that children make is not moving the moon ball far enough to the left. Another error is looking at the light bulb and ignoring the "Moon."

4. Ask which way the bright side of the Moon ball faces. When everyone can see the crescent of light, ask them to discuss with the person next to them the following question: "Is the bright edge of your Moon that's curved like the edge of a ball, facing toward the Sun, or away from it?" [Toward the Sun, as in their observations of the real Moon.]

5. Continue the orbit to the quarter Moon phase. Tell participants to continue orbiting their Moons around their heads in the same direction, until exactly half of the "Moon" is lit. (They will, of course, need to turn their bodies to the left, too.) This is the quarter Moon phase. Ask them to discuss with a partner: "As the Moon appears fuller, does it move toward the Sun or away from it?" [Away from it, just like the real Moon.] Again, ask the group if the lit part of the Moon that is curved like the edge of a ball faces toward or away from the Sun. [Toward.]

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

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

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

9. Move to quarter Moon phase. Instruct students to continue orbiting the Moon ball in the same direction until it is just half full again, another quarter Moon phase. Ask them to discuss with the person next to them: "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.]

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

11. Pairs do another Moon orbit, focusing on light and shadows. Direct participants through another orbit of the Moon with a partner. This time, instruct them to focus on what is making the bright part of the moon bright, and what is making the dark part dark.

12. Discuss what is making parts of the Moon bright. Get the whole group's attention, and ask:

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

Point out that this is an important question, because many people think that the moon generates its own light. 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 objects like mirrors, glass or water may do, and the idea of a rocky object like the Moon reflecting may be confusing.

13. Discuss what is making parts of the Moon dark. Now ask:

Q: 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 that the dark part is caused by the shadow of the Earth. This is a very common alternative conception, including among adults.

14. One orbit equals one month. Tell participants that the movement of the Moon from crescent to full models the two-week period when the Moon is visible in the evening. A full circle represents about a month (more precisely, 29.53 days). They have modeled one full cycle of the Moon, which takes a month.

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

Modeling Lunar and Solar Eclipses (5 minutes)

1. Make a solar eclipse. When it seems that the participants understand the phases of the Moon, ask them to move their moon balls directly in front of the sun to try to create an eclipse of the Sun.

2. Observe the Moon's shadow on the "Earth." While participants observe this eclipse of the Sun, tell them to hold their moon balls exactly where they are, and to glance around the room. Ask them to consider the following questions:

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

– 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 your ear?

Explain that only the people who live on your eyes can see an eclipse of the sun—the people on your ear or chin can still see the sun! This is why not everyone on that side of the Earth can view a Solar eclipse.

3. Create a lunar eclipse. Ask participants to move their moon balls around in a circle, as before, until they reach the full moon phase. This time, tell them to move their moons into the shadow of their heads.

4. Focus on the Earth's shadow on the Moon. While the moons are still in the shadow of participants' heads, explain that this is an eclipse of the moon. Ask: "Can you see the shape of your hair when the moon moves into eclipse?"
Point out that when there is an eclipse of the real Moon, you can see that the shape of the Earth is round, because it always has a curved shadow.

5. Viewing a lunar eclipse. While participants continue to observe the eclipse of the moon, point out that everyone who lives on the side of the Earth facing the Moon can see the Moon in eclipse. But during an eclipse of the Sun, only the people inside the shadow see the Sun being eclipsed.

6. Identify phases of the moon surrounding eclipse events. Ask participants to continue moving their moons around their heads until they again see an eclipse of the sun. Ask them to consider and discuss with their partner the following question:

– What phase is the moon in just before or just after an eclipse of the sun? [Thin crescent or new phase]

Tell them to continue moving their moons in a circle until they see another eclipse of the moon. Ask them to consider and discuss with their partner the following question:

– What phase is the moon in just before or just after an eclipse of the moon?" [Full]

7. Explain this was abbreviated experience. Tell participants that there are many more questions that can be investigated using the model than can fit into one experience with them. Remind them that the goal in this situation was to model strategies, not to teach complete sessions. Tell them you're going to have to cut off their questions and investigations for now, but that in a classroom situation you would provide multiple opportunities to investigate and discuss student questions using the moon balls. If they have further questions, encourage them to explore the model on their own (all you need is a light and a ball), or to look up questions later on.

Discussing Moon Phase Explanations (10 minutes)

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

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

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

Discussing the Moon Phases Exemplar (10 minutes)

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

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

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

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

- Student observations and recording of real phenomena (the real Moon).
- Helping students with fundamental understandings (parts of a shadow) that might block them from understanding phases of the Moon.

> ***Note****: This activity was developed in response to teachers discovering that students were struggling with understanding shadows and Moon phases*

because they didn't understand that the dark side of the Moon could be made by its own shadow.

• Use of models to represent phenomena (Moon simulation, moon balls)

• Encouraging students to use models to try out their ideas, and to figure out what's going on for themselves.

• Discussion of inaccuracies in the model used, to help prevent the model from creating additional alternative conceptions.

• Student-to-student discourse. Multiple opportunities for students to share their ideas with others, and to hear others ideas.

• Encouraging the use of evidence in discussions, and evaluating explanations based on *all* the available evidence.

• Use of questionnaire to find out what children's ideas are, including both multiple choice and more broad questions for children to write their ideas.

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

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

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

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

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

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

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

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

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

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

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

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

- Find out what students already think, elicit their prior ideas.
- Use what you learn about student's ideas to inform your teaching. Be flexible and adapt your curriculum to be relevant and responsive to student needs.
- Cultivate a classroom environment that celebrates good thinking and struggling with evidence-based explanations, more than knowing the "right answer."

- Provide multiple opportunities for meaningful conceptual learning.
- Focus on reasoning, comprehension, and depth, not memorization of information.
- Set up learning situations and/or discrepant events where students need to grapple with conflicting ideas and alternative conceptions.
- Facilitate open discussion of alternate ideas.
- Rather than only provide evidence that shows why a certain explanation is "correct," also provide opportunities and evidence for students to see why other explanations are inaccurate.
- Use real-world investigations and materials.
- Make use of models, but be aware of and discuss their limitations.
- Give students ample chance to think, re-think, discuss, reflect, and apply their ideas to new situations. It takes time to construct new concepts.

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

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

The Aims of Constructivist Science Teaching

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

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

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

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

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

Summarize your thinking about constructing understanding. If you can, include:
- How have your ideas about constructing understanding changed.
- What do you think made your ideas change?
- How might you use this in your science teaching?

Session Handouts

— Research-based information on Teaching and Learning ("Research Cards")

— Strategies for Addressing Student Ideas/The Aims of Constructivist Teaching

— Pre-Unit 4 Questionnaire

"Research Cards"—Research-Based Information About Student Learning

- Students all arrive at school with their own often quite elaborate ideas and explanations about a variety of natural phenomena. They are not "blank slates." Some of these ideas are difficult to change. (Osborne, R. J. & Gilbert, J. K. A technique for exploring students' views of the world, *Physics Education*, 1980)

- Students can "parrot" and memorize explanations and ideas without believing or fully understanding them. When ideas are not fully understood or connected with pre-existing knowledge, they are difficult for students to retrieve or apply to new situations. (Fisher, K.M. & Lipson, J.I. Twenty questions about student errors, *Journal of Research in Science Education*, 1986)

- Students can learn a concept to pass a test, but go back to their old ideas outside the classroom. (Wandersee, J.H., Mintzes, J.J., & Novak, J.D. Research on alternative conceptions in science, in *Handbook of Research on Science Teaching and Learning*, 1994.)

- If you teach new ideas and explanations—without first dealing with alternative conceptions that students already have—students will frequently revert to their old ideas. (Nussbaum, J. & Novick, S. Alternative frameworks, conceptual conflict and accommodation: towards a principled teaching strategy, *Instructional Science*, 1982)

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

- The American classroom is dominated by teacher talk. (Flanders, N. *Analyzing Teaching Behaviour*, 1970. Goodlad, J. *A place called school: Prospects for the future*, 1984)

- Teachers vastly overestimate the gain in knowledge their students achieve after their course. This is especially true with concepts (as opposed to facts) for which students have strong, underlying misconceptions. (Lightman, A. & Sadler, P. Teacher Predictions Versus Actual Student Gains, *The Physics Teacher*, 1993)

- There is a "perseverance effect:" the finding that people's beliefs persist even after the evidence supporting these beliefs is discredited. (Aronson, E., Wilson, T.D. & Akert, R.M. *Social Psychology*, 2004)

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

- Social and cultural interactions with peers and educators (or with novice and experienced individuals) are necessary for the construction of knowledge to take place. In this way, learners are constructing their own learning within a social context where they share ideas, and meaning making is created and expanded by interaction with their environment (Rogoff, B., Cognition as a collaborative process, in *Cognition, perception and language: Handbook of child psychology*, 1998)

Strategies for Addressing Student Ideas

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

The Aims of Constructivist Science Teaching

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

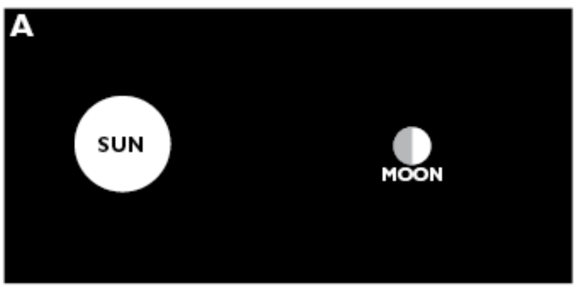
— Roger Osborne
from *Taking the Plunge*, edited by Wynne Harlen

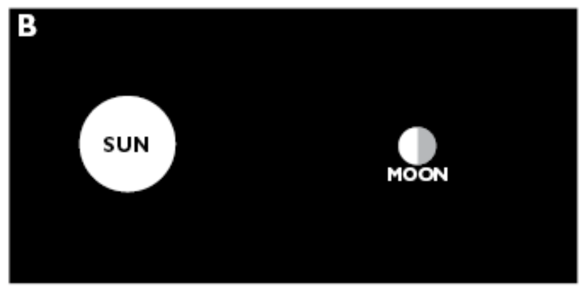
Pre-unit 4 Questionnaire

1. Which picture below is wrong: A or B? (Circle one.)
Drawings are not to scale.
It is wrong because. . . ____

____

____





2. Here are some pictures of how the Moon looks at different times of the month.

Why does the Moon seem to change its shape during the month?
(Circle A, B, C, or D.)

A. The Moon gets smaller and bigger.
B. Clouds block part of the Moon from our view.
C. The Earth's shadow covers part of the Moon.
D. We see portions of the sun-lit side of the Moon.

Presentation Slides

— Kids on Love

— Constructivism

— Blank Slates or Clever Minds?

— Research Findings

— Sun Moon Observation Chart

— Discussing Moon Phases Activity

— Strategies for Addressing Student Ideas

— The Learning Cycle

— Aims of Constructivist Science Teaching

— Small Group Discussion Question

Kids on Love

WHAT IS THE PROPER AGE TO GET MARRIED:

- "Eighty-four! Because at that age, you don't have to work anymore, and you can spend all your time loving each other in your bedroom." (Judy, 8)
- Once I'm done with kindergarten, I'm going to find me a wife!" (Tom, 5)

WHAT DO MOST PEOPLE DO ON A DATE:

- "On the first date, they just tell each other lies, and that usually gets them interested enough to go for a second date." (Mike, 10)

WHEN IS IT OKAY TO KISS SOMEONE:

- "You should never kiss a girl unless you have enough bucks to buy her a big ring and her own VCR, 'cause she'll want to have videos of the wedding." (Jim, 10)

CONCERNING WHY LOVE HAPPENS BETWEEN TWO PARTICULAR PEOPLE:

- "No one is sure why it happens, but I heard it has something to do with how you smell. That's why perfume and deodorant are so popular." (Jan, 9)
- "I think you're supposed to get shot with an arrow or something, but the rest of it isn't supposed to be so painful."(Harlen, 8)

ON THE ROLE OF GOOD LOOKS IN LOVE:

- "If you want to be loved by somebody who isn't already in your family, it doesn't hurt to be beautiful." (Jeanne, 8)
- "It isn't always just how you look. Look at me. I'm handsome like anything and I haven't got anybody to marry me yet."(Gary, 7)
- "Beauty is skin deep. But how rich you are can last a long time." (Christine, 9)

Constructivism — a widely accepted, research-based theory of learning

Blank Slates

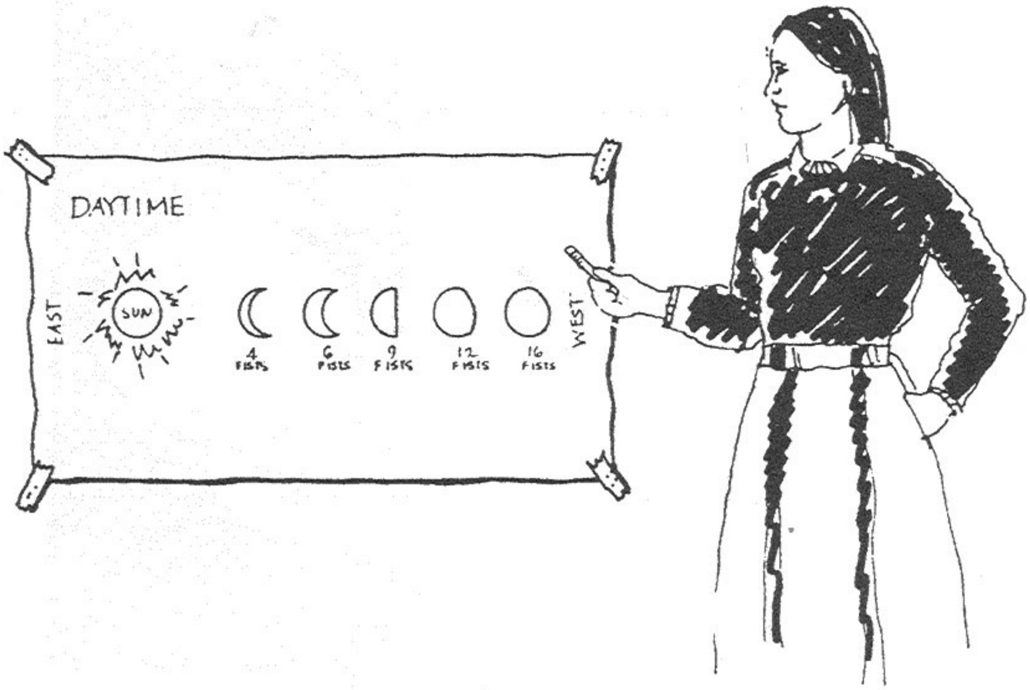
or

Clever Minds?

Read each research finding aloud.

Discuss each finding and how classroom teaching could be structured to take this information into account.

Sun Moon Observation Chart



Discussing Moon Phases Activity

- What strategies were modeled that help find out children's ideas about the topic?

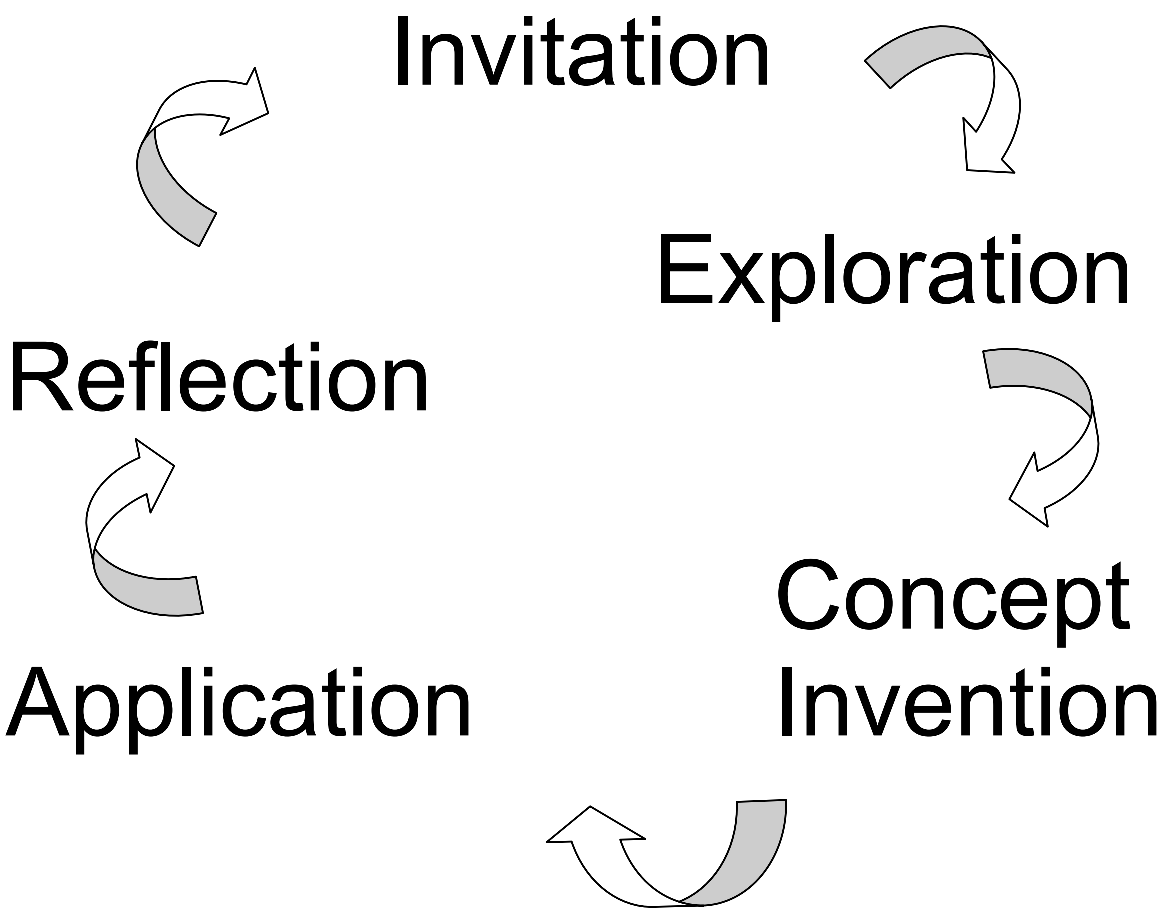
- What strategies were modeled that help deal with children's alternative conceptions on the topic?

- What strategies have you experienced or seen in other classroom situations that educators have used to help learners make better sense of their world?

Strategies for Addressing Student Ideas

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

The Learning Cycle



The Aims of Constructivist Science Teaching

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Small Group Discussion Question:

If there's only five minutes left in class, and some students still have the "wrong" answer, what do I do?

Alternative Activities

Applying Constructivist Ideas to the Classroom (20 minutes)

1. Display discussion prompt. Tell small groups of participants to spend a few minutes discussing the question below. Remind them to consider what they have discussed and experienced about teaching and learning so far in the course.

> Question: *If there's only five minutes left in class, and some students still have the "wrong" answer, what do I do?*

2. Groups share out key points. Ask one person from each small group to briefly share with the class a few key points from what their group discussed.

Fish is Fish Introductory Activity (10 minutes)

1. Read aloud and show the *Fish is Fish* book. Using either the actual book or a PowerPoint slide of selected pages, read aloud and show the images of the children's book, *Fish is Fish*. Begin with the page that starts with "Then one day, with a happy splash that shook the weeds, the frog jumped into the pond." Continue reading the next nine pages (stopping at the two-page pictorial spread showing the fish's ideas about birds, cows, and people).

> ***Note:*** *In the book, a frog tries to explain birds, cows, and people to a fish. The fish imagines each of these as fish-like creatures. This can serve as an engaging introduction to some of the ideas of constructivism. A similar discussion can be used as an introduction to this session using the children's book* August Explains *by Phil Ressner.*

2. Lead a brief discussion about thinking, learning, and the fish's conceptions of birds, cows, and people. Ask the participants the following questions as appropriate in order to stimulate and direct a discussion about the book:

- How do you think these pages might relate to how children think and learn?
- What might the frog be able to do to find out what the fish's ideas are?
- How might the frog be able to lead the fish to more accurate understandings?
- Would simply telling the fish more information be effective? Why or why not?

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