Session 5: Constructing Knowledge, Building Understanding

Overview

In this session, the focus is on how learners build an understanding of the world around them, the role of learners' prior knowledge in building understanding, and the implications of these ideas on how we teach. This session presents the constructivist perspective on learning, which is grounded on the premise that learners "construct" their own understanding (or make sense) of the world based on their experiences, motivation and social interactions. Participants reflect on the role of prior knowledge, social interactions and the use of models in their personal experience as a learner, by doing an activity that places them in the role of the learner. They then apply research findings about constructivism and prior knowledge to their role as an educator.

Background Information for the Presenter

Constructivist Learning and Teaching

There is a large body of research showing that the ideas and frameworks learners bring into learning settings—even the youngest learners—are already quite well developed. We learn a huge amount as infants and young children. On their own, children make generalizations from their experiences with the world and social interaction with other young people and adults. They enter learning situations with boundless curiosity and a great thirst to learn more. Learners of all ages have devised quite elaborate mental frameworks to try to explain and make sense of their experiences in the world around them. Although these explanations may not be fully accurate, they are often complex, and part of an extensive mental framework that is developed over time.

Constructivism is a perspective on learning grounded on the premise that we construct (build, create) our own understanding of the world through our experiences. Constructivism groups together a number of related theories of learning and development and educational ideas based on the research and practice of 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. Constructivism is a widely used term in the science education community, and yet is no stranger to controversy and debate!

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) 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 to 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).

Furthermore, a learner's attitude is important for learning, so 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. Informal environments often provide the opportunity to engage a learner's personal interest and motivate them to learn more about a topic. Some have argued that the non-evaluative, free-choice nature of informal environments nurture learners' intrinsic motivation for learning (Csikszentmihalyi & Hermanson, 1995). 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. For example, Iyengar and Lepper (1999) found that children from cultures where members are more interdependent, such as East Asian cultures, are more motivated to engage in activities when choices are made for them by significant others. 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). The contributions of individuals and their social partners are examined together with the social and historical customs and materials that exist in the context as people engage in shared endeavors. 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 to do so. Without guidance, a learner, and children in particular, may not be able to make sense of concepts and potentially leave an interaction with an incomplete or incorrect understanding of an idea (Grandy, 1997; King, 2009; Klahr & Nigam, 2004).

We refer to this idea on guidance as the "zone of proximal development" or zpd (Vygotsky, 1978). ZPD 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).

Constructivist learning theories have led educators to develop teaching strategies that can help make explicit the connections between new learning and previously learned knowledge, and that have been shown to be most effective, over time, in helping learners develop new ideas, deeper understandings, and construct more complete mental frameworks. These strategies engage and motivate 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.

The Role of Prior Knowledge

Learners are not *tabulae rasae*, or blank slates, waiting to be filled with information through instruction—learning is not absorption of transmitted knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Instead learning begins with learners' prior knowledge, and is viewed as enriching existing understanding and conceptual change. Starting in infancy, learners develop a wide range of ways of understanding and organizing the world around them, and reasoning about the way the world works through their experiences and interactions. This prior knowledge exists at the levels of concepts, perception, focus of attention, procedural skills, modes of reasoning, generating and evaluating evidence, and beliefs about knowledge (Duschl, Scheweingruber, & Shouse, 2007; Roschelle, 1995). Enriching existing understanding is using prior knowledge to represent new facts, formulate new beliefs, make inductive or deductive inferences, and solve problems. Conceptual change is more complicated, and is the process of transforming these conceptions, usually from their everyday ways of viewing the world to scientific views (Posner, Strike, Hewson, & Gertzog, 1982).

Educators are encouraged to inquire of their learners, "what is their prior knowledge? What knowledge are the learners activating when they encounter activities, content, and concepts?" And then, teach the learners accordingly (Ausubel, 1963). Alexander articulated the role of learners' prior knowledge in learning as: "one's knowledge base is a scaffold that supports the construction of all future learning" (1996, p. 89). There is over four decades of research on children's ideas on science and the world around them that offer educators insight into how learners think and what learners know about scientific ideas across several domains, including physics, biology, chemistry, and astronomy. In valuing what learners already know, there is also a plethora of terminology to reference learners' ideas, such as alternative frameworks or theories, misconceptions, naïve theories or conceptions, preconceptions, learners' ideas (see Driver, 1995 for an extended review of the terminology). While there is not consensus on which term is best, and their differences are sometimes philosophically grounded, it is clear that teaching begins with what the learner already knows. In this session, we refer to learners' thinking as just that, learners' thinking, and also learners' ideas, conceptions, and understanding.

For our discussions, we focus on connecting new knowledge to be acquired with existing knowledge that learners have, in order to promote meaningful learning (Limón, 2001), whether learning is to enrich existing understanding or promote conceptual change. Learners reveal their thinking—how they conceptualize the scientific concepts and ideas under study—through their comments, explanations, and responses in conversations, writing, observations, interactions, and illustrations. Research reveals that the range of learners' thinking may be related to age, connected to instruction, associated with maturation and life experiences, divulged in conversations, and concomitant with understanding other concepts and ideas. The challenge for educators is two-fold. First, they must assess what learners know and compare learners' thinking with accepted scientific explanations of these ideas. Second, they must make connections with learners' prior knowledge to facilitate knowledge construction.

The knowledge system of learners consists of an unstructured collection of many simple elements (prior knowledge) that originate from everyday interpretations of the world around them. From this perspective, the process of building understanding is one of collecting and systemizing these pieces of simple elements into larger wholes (diSessa, 1988; Smith, diSessa, & Roschelle, 1993). Moreover, metacognitive abilities are critical to learning (Duschl, et al., 2007). Metacognition is "thought about thought," and refers to a broad range of processes, including monitoring, detecting incongruities or anomalies, self-correcting, planning and selecting goals, and even reflecting on the structure of one's knowledge and thinking (Gelman & Lucarriello, 2002). Metacognitive abilities enable learners to detect inconsistencies in their thinking.

Research on conceptual change provides evidence that instructional techniques with strong metacognitive components play a key role in learning. Typically, activities with a discrepant event are introduced to make learners aware of their initial ideas and produce dissatisfaction with these ideas by creating cognitive conflict. A discrepant event is a situation that cannot be explained by the learners' current conception, and instead usually contradicts learners' current thinking. The argument is that by making learners confront the inadequacy of their thinking, learners may be more willing to recognize their errors and open to changing their ideas (Posner, et al., 1982). From this revolutionary perspective on learning, misconceptions in science represent alternative theories, which must be replaced by more accurate scientific ones.

While conceptual change requires an ability to imagine and understand alternative ways of conceptualizing problems, further research has revealed that learners are also reluctant to abandon their initial ideas. They can avoid seeing or responding to discrepancies. Even when a discrepancy is recognized, this by itself does not necessarily enable learners to replace a prior idea with a better alternative (Driver, 1989). They may ignore or discount challenging data, think that their idea works most but not all of the time, or make local patches. Instead, learning takes place incrementally where learners' thinking evolves in small ways over time. From this evolutionary perspective on learning, misconceptions are not always well-formed and resistant to change, and learning is not about replacing 'incorrect' conceptions with 'correct' ones.

From both these revolutionary and evolutionary perspectives, it is argued that learners need to draw on existing resources in their conceptual framework—the things they already understand in some context or that make sense to them—their prior knowledge (Duschl, et al., 2007). Drawing on and connecting to these resources is essential if the new understanding is to be comprehensible to them. Some of these resources may come from *within* their initial understanding for a given domain; others may come from understandings they have *outside* the domain. Learners then need to use, and learn how to use, a variety of techniques and tools to exploit these resources in constructing new representations of the problem. These techniques may include reasoning with models and analogy, thought experiments, and drawing inferences to creatively extend, combine, and modify these existing resources to construct new mental models that explain, organize, and make sense of the scientific ideas. Tools may include spoken and written language, diagrams, pictures, mathematical representations, and other culturally-transmitted notational systems, which allow learners to make explicit representation of key relations in the new system of concepts.

Session Objectives

- Determine what is "building understanding" and "constructing knowledge".
- Discuss strategies facilitators use to help learners build understanding.
- Discuss the basic premise of constructivist approach to learning and teaching.
- Discuss the role of prior knowledge in building understanding.
- Engage participants in a learning experience and a reflection on how their prior knowledge, the use of a model, conversations with peers, and facilitation by the instructor influenced that experience.
- Discuss the major research perspectives regarding constructing understandings and building on prior knowledge.

Session Activities at a Glance

Quick Write about reading assigned for homework (5 minutes)
Roschelle, J. (1995). Learning in interactive environments: Prior knowledge and new experience. In J. H. Falk & L. D. Dierking (Eds.), Public institutions for personal learning: Establishing a research agenda (pp. 37-51). Washington, DC: American Association of Museums.

Introducing Constructivism (10 minutes)
The basic premise of constructivism is introduced and three main points considered. These points will be revisited after engaging in the Modeling Moon Phases and Eclipses activity.

Modeling Moon Phases and Eclipses and Debrief (30 + 15 minutes)
Participants engage in an active modeling activity on the phases of the Moon. They then discuss what they perceived as the role of prior knowledge, the "moon ball" model, conversations with their peers and facilitation by the instructor in helping them to construct knowledge and build understanding of the phases of the moon.

Research Findings About Constructing Knowledge, Building Understanding and Prior Knowledge (20 minutes)
In small groups, participants read aloud research findings, each of which describes relevant information from research on how people learn. For each piece of information, they discuss how facilitation in an informal environment might be structured to take this piece of information into account.

Ponder This–from an educator's point of view (10 minutes)
Participants are asked to gather and transition their thoughts from being in the role of learners to being reflective about the learning experience from an educator's point of view as they discuss the following question:

- How do you know what prior knowledge your learners are bringing with them to the experience?

Activity development discussion with partner and instructors (30 minutes)
Participants are given the opportunity to work with their partner to further develop and refine their own activity as the instructors circulate and answer questions and provide feedback.

***Tidepool Exploration* Activity Exemplar and debrief** (20 minutes)
The *Tidepool Exploration* activity is presented and participants engage with and learn about how to facilitate another activity they could choose to present on the museum floor. This exemplar activity is used to model how to elicit and connect to visitor's prior knowledge, and provide opportunities for peer-to-peer and learner-to-facilitator conversations. (You may decide to use this time to present a different activity or provide more time for the participants to work on and receive consultations about their activity development.

Reflection (5 minutes)
Participants do a quick write on how the session has affected their ideas about teaching and learning. This reflection can be done in class or as the online discussion prompt. Participants reflect and write about the following prompts:

- How can these ideas about learning, prior knowledge and metacognition be useful and relevant to you?
- When you teach, how might you help your learners to ***make sense*** of the science?
- What challenges might you face when applying these ideas in designing and engaging in learning experiences in an informal environment?

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

- **ACTIVITY DEVELOPMENT**
  - Assemble your materials and try out your activity with a friend to make sure it WORKS!
  - Receive feedback on activity proposal and refine activity.
  - Be ready to present activity to peers in one of the next two class sessions.

- **READING**
  - National Research Council. (2007). Chapter 6: Understanding how scientific knowledge is constructed. In *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: The National Academies Press.
  - Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). Chapter 5: Making thinking visible: Talk and argument. In *Ready, set,*

SCIENCE!: Putting research to work in K-8 science classrooms. Washington, D.C.: National Academy Press.

- Natural selection readings from Understanding Science website: http://evolution.berkeley.edu/evolibrary/article/evo_25 through "Misconceptions about natural selection"
- Moon phases readings:

  http://starchild.gsfc.nasa.gov/docs/StarChild/questions/question3.html

  http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970103b.html

  http://stardate.org/nightsky/moon/

— **PRESENTATIONS**
- Present at LHS once during Feb 20–28. (Not your own activity.)

Time Frame

Total Workshop: 2 hours 50 minutes

Quick Write (5 minutes)
Introducing Constructivism (10 minutes)
Modeling a Constructivist Approach to Teaching
    Modeling Moon Phases and Eclipses (30 minutes)
    Debrief of Moon Phases activity (15 minutes)
Break (10 minutes)
Research Findings About Constructing knowledge, building understanding and prior knowledge (20 minutes)
Ponder This–from an educator's point of view (10 minutes)
Activity development discussion with partner and instructors (30 minutes)
Tidepool Exploration Activity Exemplar and debrief (20 minutes)
Reflection (10 minutes)
Homework (5 minutes)

Materials Needed

Materials

For the session

- ❑ PowerPoint slides and projector
- ❑ Dry erase board or chart paper and markers
- ❑ Copy of research findings for pairs or small groups (see Getting Ready)

For Phases of the Moon Activity

For the whole group

- ❑ 1 lamp socket with plug—no shade
- ❑ 1 25-foot extension cord
- ❑ 1 40-watt or 1 75-watt clear light bulb

For each participant

- ❑ 1 two-inch polystyrene ball. *Note:* Styrofoam balls will work if painted with white latex or other water-based paint.
- ❑ 1 unsharpened pencil to hold polystyrene ball

Preparation of Materials

1. Assemble the materials.

Polystyrene balls. Inexpensive balls may be purchased from:

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

Styrofoam balls will also work if painted with white latex or other water-based paint and have the advantage that participants can stick the balls on the ends of pencils for easy holding. Just about any other balls will also work, as long as they are opaque.

2. Prepare for the moon modeling activities.

Prepare the room. Find a room that can be darkened completely by drawing curtains or taping black paper over the windows. Use the extension cord with the lamp and make sure it is long enough for the lamp to be placed in the center of the room. Tape cord down to the floor for safety. Have a box of balls on hand to distribute.

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

3. Duplicate one copy of the research findings–either Constructivism or Prior Knowledge for each pair or small group of participants. Be sure to copy enough of each so that about half the participants are given *Research Findings about Constructivism* and the other half are given *Research Findings about Prior Knowledge.*

Instructor's Guide–Session Details

Quick Write and Discussion of Homework

1. **Participants do Quick Write.** Display the Quick Write prompt about the reading that was assigned for homework (or other assigned reading) and give participants about 5 minutes to respond.

— Address Roschelle's assertion that "considering prior knowledge forces a shift to thinking of learning as 'conceptual change' ". How does this affect your activity design? Please give a specific example.

— Describe the types of seaweed and their role in ocean ecosystems.

Introducing Constructivism

1. Set the context for the session. Let students know that today the class is going to take a closer look how learning happens.

2. **Blank slates vs. clever minds.** Explain that there are different ways to consider learners: as "blank slates" which are open to learning information just as it is transmitted to them; or as having "clever minds" already full of preconceived ideas and private explanations that affect how the learner understands new information.

3. Refer to research base on student conceptions. Point out that there is a large body of research supporting the "clever minds" view, and refuting the "blank slates" view. The ideas and frameworks learners bring to the classroom and other learning situations—even in the earliest grades—are often well established. Humans go through a tremendous amount of learning as infants and young children. On their own, children make generalizations from direct experience and through social interaction with other youth and adults. They enter school with boundless curiosity and a great thirst to learn more—and 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.

4. **Display slide, "Basic Ideas of Constructivism."** Let students know that we will think and talk about learning from a theoretical perspective on knowledge and learning called constructivism. This perspective is based upon a vast body of research, and is well-accepted in the educational community. Display the slide and read it aloud. Emphasize that these frameworks need to be taken into account as new learning takes place. The *construction* of a new understanding and meaning making results from a combination of experiences, motivation, and social interactions.

- All learners arrive at any learning situation with their own often quite elaborate ideas, explanations and theories. They are far from "blank slates."

- Learning is an active process of engaging and manipulating objects, experiences, and conversations.
- Learners "construct" their own understanding of the world based on their experiences, motivations, and cultural and social interactions with peers and others.

5. **Introduce vocabulary about learners' thinking.** Point out that much research has been done on ideas about science concepts that students of different ages bring with into the classroom. When they are not accurate, or incomplete, these ideas are sometimes called "misconceptions." They have also been called "preconceptions" to reduce the negative connotation and indicate that they precede more evolved concepts, or called "alternate conceptions" to give more weight and value to the ideas that students have worked out for themselves compared to accepted scientific explanations. Even though the ideas may not be fully formed or accurate, they are often complex, and part of an extensive mental framework developed over time. While there is not consensus on which term is best, and the differences in usage are sometimes philosophically grounded, it's clear that teaching begins with what the learner already knows and thinks. In this session, we refer to learners' thinking as just that, learners' thinking, and also learners' ideas, conceptions, and understanding.

Modeling a Constructivist Approach to Teaching

Activity: Phases of the Moon

Introduce the Activity

1. Introduce *Phases of the Moon Activity*. Let participants know that we will take part in an astronomy activity excerpted from GEMS *Space Science Core Curriculum Sequence, (Unit 4: Moon Phases and Eclipses)*, an astronomy unit for grades 3-5, but adaptable for adults as well. The activity is about the phases of the moon that will serve as a shared experience to learn (co-construct) a science concept, and at the same time provide an opportunity to discuss our observations and ideas about constructivism and meaning making.

> *Note: Similar activity write-ups can also be found in the GEMS curriculum guide* **Earth, Moon and Stars**, *an astronomy unit for grades 5-8.*

2. Ask participants to pay attention to strategies used. Remind participants that while they engage in the activity, they should be aware of the strategies they are using to help make sense of the concepts for themselves, as well as the strategies used by the facilitator. They should focus on how the activities create situations in which they as learners confront, and perhaps develop more accurate mental constructs and frameworks than they already have in place.

3. Think-Pair-Share about observing the moon. Participants do a Think-Pair-Share with each of the following prompts:

- Think about the times you looked at the Moon. What did it look like? Did you see it last night? What shape was it?
- The different shapes and look of the moon is referred to as the phases of the moon. What do you think causes the phases of the Moon?

Exploring Shadows

1. Standing in 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 giant 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 play around with these three parts of shadows with a partner. Encourage them to explore parts of shadows cast by different objects. Make sure they explore the parts of their partner's head shadow.

Modeling Moon Phases

Note to Facilitator: *The following steps are an example of how the facilitator might guide the group as they work together to offer an explanation to the question of what causes the phases of the moon. The facilitator transitions often between small group and whole group discussions, as well as between* *demonstrations and free exploration. Throughout the activity, the facilitator asks and answers questions as needed. If possible, encourage participants to use the moon ball model whenever possible and attempt to figure out the answer for themselves using evidence from the model and through discussions of their ideas and findings with each other.*

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 moon balls represent the moon. Ask participants to share a few inaccuracies in this model.

3. Participants use model to explore phases of the Moon. Tell them to 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 as they manipulate the moon balls and investigate what happens when they move it around in the light from the "Sun".

4. Face the "Sun" and hold up moon ball. After a few minutes, ask the participants to hold their moon balls out in front of them, directly in front of the "Sun."

5. Thin Crescent. Tell participants that the Moon orbits the Earth. Instruct participants to move the moon ball to the left until they can see a thin, bright crescent lit up on the ball, and then stop (crescent moon).

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

7. Does the curved, bright side of the moon ball face toward or away from the Sun? When everyone can see the crescent of light, ask them to discuss with the person next to them the following question:

- Is the bright curved side of your Moon that's curved like the edge of a ball, facing toward the Sun, or away from it? [Toward the Sun]

8. Continue the orbit to the quarter Moon. Tell participants to continue orbiting their moons around their heads in the same direction, until exactly half of the "Moon" is lit (quarter moon). (They will, of course, need to turn their bodies to the left, too.) Ask them to discuss with the person next to them the following questions:

- What have you noticed about the Moon so far?
- As the Moon appears fuller, does it move toward the Sun or away from it? [Away from the Sun, just like the real Moon.]
- Again, ask if the part of the Moon that is curved like the edge of a ball faces toward or away from the Sun. [Toward.]

9. Gibbous Moon. Tell participants to continue turning and orbiting their moon balls in the same direction, until it is halfway between a quarter and a full Moon (gibbous).

10. Full Moon. Have them continue moving the moon ball in its orbit until the part that they see is fully lit (full moon). 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. Ask them to discuss with the person next to them the following question:

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

Give participants a few minutes to discuss with their partner and then ask for volunteers to share their ideas and what they have noticed so far.

11. Gibbous Moon Again. Tell participants to continue moving the "Moon" in its orbit until it is gibbous once again.

12. Move another quarter turn. Instruct participants to continue orbiting the moon ball in the same direction until it is just half full again (quarter moon). 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.]

13. Model thin crescent and then new moon. Finally, tell participants to continue to move their moon balls so that they see very thin crescents 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. Ask them to discuss with the person next to them the following question:

- What is the phase of the Moon called when we cannot see it? [New Moon. It is called new because it is at the beginning of its cycle. Some ancient peoples thought that a brand new moon was being born at this time!]

14. Do another orbit, focusing on light and shadows. Direct participants through another orbit. This time, instruct them to pause at various points, and ask them questions to discuss with their partner and then the whole group about light and shadow.

Q: What is making the bright side of the Moon bright? [Light from the Sun]
Q: What is making the dark side of the Moon dark? [The beginning of the Moon's own shadow]
Note: This is a particularly important question, because many people think that the dark part is caused by the shadow of the Earth.
Q: Using a finger from your other hand, can you find places around your Moon that are also in shadow?

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). Tell them that they have modeled one full cycle of the Moon, which takes a month.

Participants Explore the Model

1. Participants independently explore the model. Encourage participants to move their moons around their heads several times and explore light, shadows and moon phases. Ask them to share their discoveries, questions and understandings with a partner or small group and to challenge each other with questions and statements such as:

- Show me what you mean?
- How can you be sure of that?
- Can you help me figure this out?
- I get this part of the explanation, but I'm still confused about ______.
- What about ________?

2. Whole group share. Invite participants to share ideas and understandings about what causes moon phases with the whole group. Encourage the group to ask questions of one another and use the moon ball model to help explain what they are thinking. Ask guiding questions and answer questions from the participants where it seems appropriate and to help them make meaning.

> *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.*

Observing Eclipses

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 glance around the room. Ask them to consider the following questions:

- Do you see the shadows over everyone's eyes? 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?"

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!

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 them to consider and discuss with their partner the following questions:

- Can you see the shape of your hair when the moon moves into eclipse?

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. Invite participants to return to their tables for discussion.

Debriefing Phases of the Moon Activity

1. Whole group discussion about learning and teaching moments. Remind participants that the phases of the moon activity modeled how we can co-construct scientific explanations and understandings of concepts. Ask participants to think about and discuss the learning and teaching moments they experienced in that activity. Share with them that when we 'think about thinking', it is called being metacognitive. Use the discussion map below to facilitate a discussion using the following two prompts.

a. As a whole group, ask participants to share their thoughts on the experience.
b. How was prior knowledge elicited and used in the activity?
c. What did they do to make sense of what causes the phases of the moon?

Suggested Discussion Map:

– Listen to their responses.
– Ask for evidence, explanation, or clarification.
– Ask for agreements, disagreements, and alternative opinions.
– Synthesize their ideas as you reference their comments.
    • Listen to how they describe their experiences and characteristics of the learning and teaching.
    • Restate/summarize for the participants the characteristics they have identified. Ask them about the characteristics they have not mentioned.

2. Display learning and teaching strategies they may have just experienced. Tell participants you're going to read off a list of some learning and teaching strategies they might have encountered in the activity – some of which were mentioned in the discussion and possibly a few additional ones. 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 activity. 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 and talking with peers
- Thinking on your own
- Listening and 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 and making connections to prior knowledge and experiences

3. Whole group discussion about experiences and interactions. Pose three new questions for participants to consider that build on what they have been talking about. Give them a moment to consider the questions silently and then lead a whole group discussion.

- What makes experiences important for learning?
- What makes social interactions important for learning?
- What affect did your prior knowledge have on your learning experiences?

Remember the following:

- Listen to their responses.
- Ask for evidence, explanation, or clarification.
- Ask for agreements, disagreements, and alternative opinions and views.

4. Ask probing questions. Ask some probing questions that encourage participants to elaborate on their ideas further.

- What connections did you make between your prior knowledge and the new experience?
- When did those connections occur?
- What were you doing?
- What was the facilitator doing?
- What were others in your group doing?

Remember the following:

- Ask for evidence, explanation, or clarification
- Ask for agreements, disagreements, and alternative opinions and views with the ideas put forth.
- Listen to how they characterize connections to their prior knowledge – when those occurred, how they occurred, what they were doing, what the facilitator was doing.
- Synthesize their ideas as you reference their comments.
- Restate/summarize for the participants the characteristics they have identified.

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

Research Discussion–Key Ideas about Constructivism

1. Share key ideas from research about constructivism and prior knowledge. Tell participants they will receive a page of research findings that reflect a constructivist view of learning. Each excerpt features a piece of information that research has revealed about learning and has contributed to the validity of this theoretical perspective. They should first take turns reading each finding aloud in their small group and then together choose two or more of the statements and discuss the following questions:

- What are your experiences, impressions, and/or opinion of the ideas?
- Which statements would you like to discuss more fully and what about it leads you to want to discuss it further?
- How might you facilitate an activity in an informal learning environment (or even your own learning) to take the research on learning into account?

2. Distribute research findings. Distribute a copy of one of the two pages of research findings to each pair of participants. Tell participants that there are two different sheets so once they have a chance to share their ideas with their partner, they should then engage their small group and share what they each read about. Circulate around the room and encourage everyone to take part in the small group discussions.

3. Each group shares an idea. After about 10–15 minutes of small group discussion, ask each group to share one idea of how they might facilitate an activity in an informal learning environment (or even their own learning) to take the research on learning into account. Remember to do the following during the discussion:

- Listen to their responses.
- Ask for evidence, explanation, or clarification.
- Ask for agreements, disagreements, and alternative opinions and views.

Research findings about constructivism and prior knowledge

Constructivism

- 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, 1998).

- The "zone of proximal development" (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 (Vygotsky, 1978).
- Learners' prior ideas, their "common sense," and "everyday thinking," are intelligent and useful. If those ideas are not engaged, learners often dismiss science teaching as irrelevant (Hammer & van Zee, 2006, p. 14).
- Learners reveal their thinking—how they conceptualize the scientific concepts and ideas under study—through their comments, explanations, and responses in conversations, writing, observations, interactions, and illustrations. Informal ideas are not simply personal views of the world, but reflect a shared view represented by a shared language. This shared view constitutes a socially-constructed "commonsense" way of describing and explaining the world (Driver, et al., 1994, p. 8).

Prior Knowledge

- Enriching existing understanding is using prior knowledge to represent new facts, formulate new beliefs, make inductive or deductive inferences, and solve problems. Conceptual change is more complicated, and is the process of transforming these conceptions, usually from their everyday ways of viewing the world to scientific views (Posner, et al., 1982).
- The knowledge system of learners consists of an unstructured collection of many simple elements (prior knowledge) that originate from everyday interpretations of the world around them. From this perspective, the process of building understanding is one of collecting and systemizing these pieces of simple elements into larger wholes (diSessa, 1988; Smith, et al., 1993).
- Learners need to draw on existing resources in their conceptual framework—the things they already understand in some context or that make sense to them, their prior knowledge (Duschl, et al., 2007). Drawing on and connecting to these resources is essential for the new understanding to be comprehensible to them.
- Prior knowledge exists not only at the level of "concepts," but also at the levels of perception, focus of attention, procedural skills, modes of reasoning, and beliefs about knowledge (Roschelle, 1995).

Ponder This—from an educator's point of view.

1. **Small group discussions.** In this discussion, participants are asked to gather and transition their thoughts from being in the role of learners to being reflective about the learning experience from an

educator's point of view. Ask participants to break up into smaller groups to discuss the following question:

- How do you know what prior knowledge your learners are bringing with them to the experience?

2. **Facilitate whole group discussion.** Give participants about 5 minutes to discuss in small groups, or with a partner, then facilitate a whole group discussion. Responses to this question will likely include methods and strategies for eliciting learners' prior knowledge, such as asking questions and doing group polls. As you lead the group discussion, try to include the following strategies in order to engage more participants and insert more diverse viewpoints into the discussion:
   - Listen to their responses.
   - Ask for explanations, evidence, or clarifications.
   - Ask for agreements, disagreements, and alternative opinions and views.
   - Restate/summarize the participants viewpoints and suggestions. Ask them about points they have not mentioned.
   - Encourage the group to ask questions of each other by explicitly asking individuals to respond to other people's comments.

3. **Ponder on metacognition.** Share with participants that metacognitive abilities are also associated with learning and prior knowledge. Display the following statement and read it aloud.

   - Metacognitive abilities are critical to learning (Duschl, et al., 2007). Metacognition is "thought about thought," and refers to a broad range of processes, including monitoring, detecting incongruities or anomalies, self-correcting, planning and selecting goals, and even reflecting on the structure of one's knowledge and thinking (Gelman & Lucarriello, 2002). Metacognitive abilities enable learners to detect inconsistencies in their thinking.

4. **Whole group discussion about metacognition.** Ask participants how we have encouraged metacognition in the session today? For example, after the Moon Phases Activity when we asked the question: What effect did your prior knowledge have on your learning experiences?

   Concept explanation note. *Research on conceptual change provides evidence that instructional techniques with strong metacognitive components play a key role in learning (Duschl, et al., 2007). Even* *preschool children have some metacognitive abilities, although elementary school-aged children have greater capacity for metacognitively guided learning. Unfortunately, these abilities typically are untapped and overlooked, and thus they may fail to develop or even decrease.*

Activity Development

Partners discuss activity development plans. Give participants an opportunity to discuss their ideas and activity development progress with each other and their peers. Circulate around the room answering questions and providing encouragement and advice where needed.

Tidepool Exploration Activity Exemplar

1. Present the Tidepool Exploration Activity. Present the Tidepool Exploration activity (or some other activity of your choosing) and have participants engage in it as learners. Use this exemplar activity to model how to elicit and connect to visitor's prior knowledge, and provide opportunities for peer-to-peer and learner-to-facilitator conversations.

2. **Debrief activity exemplar.** Lead a debrief of the activity focusing on how prior knowledge was elicited, how connections with prior knowledge were made, and how conversations between peers and between learners and facilitator were encouraged.

Reflection

Ask participants to gather their thoughts from this session in writing using the following prompts:

– How can these ideas about learning, prior knowledge and metacognition be useful and relevant to you?
– When you teach, how might you help your learners to make sense of the science?
– What challenges might you face when applying these ideas in designing and engaging in learning experiences in an informal environment?

Note: If you are continuing to add to the "Key Characteristics of Exemplar Activities" chart started in *Session 4: Designing an Activity*, add the following points that were addressed in this session:

__ Is sensitive to the visitors' prior ideas and knowledge about this topic
__ Evokes "metacognition" (thinking about one's own knowledge/ideas) and reflection
__ Has relevance to visitors' lives or can show explicit connections to their lives
__ Uncovers/makes connections with visitors' current/prior understanding of the content
__ Encourages and provides opportunities for discussion/discourse and other social interactions between visitors or family/group members

__Includes opportunities to engage with and manipulate objects, experiences and conversations in a social setting
__ Includes opportunities for learners to engage in various teaching approaches including some or all of the following: free exploration, guided and open inquiry and problem solving
—Includes visual, verbal and/or physical interactions
__ Includes opportunities for visitors to make meaning individually, with peers and with someone more knowledgeable (e.g. facilitator/knowledgeable visitor)
__Presents the science content accurately

Homework

ACTIVITY DEVELOPMENT

Assemble your materials and try out your activity with a friend to make sure it WORKS!

Receive feedback on activity proposal and refine activity.
Be ready to present activity to peers in one of the next two class sessions.

READING

National Research Council. (2007). Chapter 6: Understanding how scientific knowledge is constructed. In Taking science to school: Learning and teaching science in grades K-8. Washington, DC: The National Academies Press.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). Chapter 5: Making thinking visible: Talk and argument. In Ready, set, SCIENCE!: Putting research to work in K-8 science classrooms. Washington, D.C.: National Academy Press.

Natural selection readings from Understanding Science website:
http://evolution.berkeley.edu/evolibrary/article/evo_25 through "Misconceptions about natural selection"

Moon phases readings:
http://starchild.gsfc.nasa.gov/docs/StarChild/questions/question3.html

http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970103b.html

http://stardate.org/nightsky/moon/

PRESENTATIONS

Present at LHS once during Feb 20 – 28. (Not your own activity.)

Science Content

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.

The science background information included here is for the presenter, and is not meant to be read aloud to participants. The information is designed to help presenters respond to some of the most common questions participants may wonder about.

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 we do not always see a Moon that is half lit is because of our 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. 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 us and the Sun. This change in position causes the seeming 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, e.g. 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 blocking the light from the Sun. (One of the most common misconceptions 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 of 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 probably came about referring to the far side of the Moon, which is always the same side, and which is always facing away from the Earth. But 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 is always a dark side of the Earth. But, like with Earth, the side that is 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 is 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 is 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. It lasts for a few minutes to a few hours, depending on the path of the Moon through Earth's shadow. 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. Lunar eclipses are much easier to see than solar eclipses. If you can see the Moon, you can see the eclipse, so people in half the world can see lunar eclipses, while people in a much smaller part of the world can see solar eclipses. There are no special safety precautions needed for observing a lunar eclipse.

What causes solar eclipses? Solar eclipses can happen during a new Moon when the Moon blocks the 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 is 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.

Research findings about constructivism

Constructivism

- 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, 1998).

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Research findings about prior knowledge

Prior Knowledge

- Enriching existing understanding is using prior knowledge to represent new facts, formulate new beliefs, make inductive or deductive inferences, and solve problems. Conceptual change is more complicated, and is the process of transforming these conceptions, usually from their everyday ways of viewing the world to scientific views (Posner, et al., 1982).

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- Learners need to draw on existing resources in their conceptual framework—the things they already understand in some context or that make sense to them, their prior knowledge (Duschl, et al., 2007). Drawing on and connecting to these resources is essential if the new understanding is going to be comprehensible to them.

- Prior knowledge exists not only at the level of "concepts," but also at the levels of perception, focus of attention, procedural skills, modes of reasoning, and beliefs about knowledge (Roschelle, 1995).