BACKGROUND INFORMATION FOR PRESENTERS

Constructivism

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

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

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

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

Alternative Conceptions

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

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

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

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

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

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

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

Science Content: Moon Phases and Eclipses

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

Moon Phases and Eclipses

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

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

Common Alternative (and Inaccurate) Conceptions About Shadows

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

Common Alternative Conceptions About Moon Phases

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

What causes the phases of the Moon?

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

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

What is a Shadow?

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

Does the Moon make its own light?

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

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

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

Is there a dark side of the Moon?

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

Why does the Moon appear to change size?

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

What Causes Eclipses?

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

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

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

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

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

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

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

What is Waxing and Waning?

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