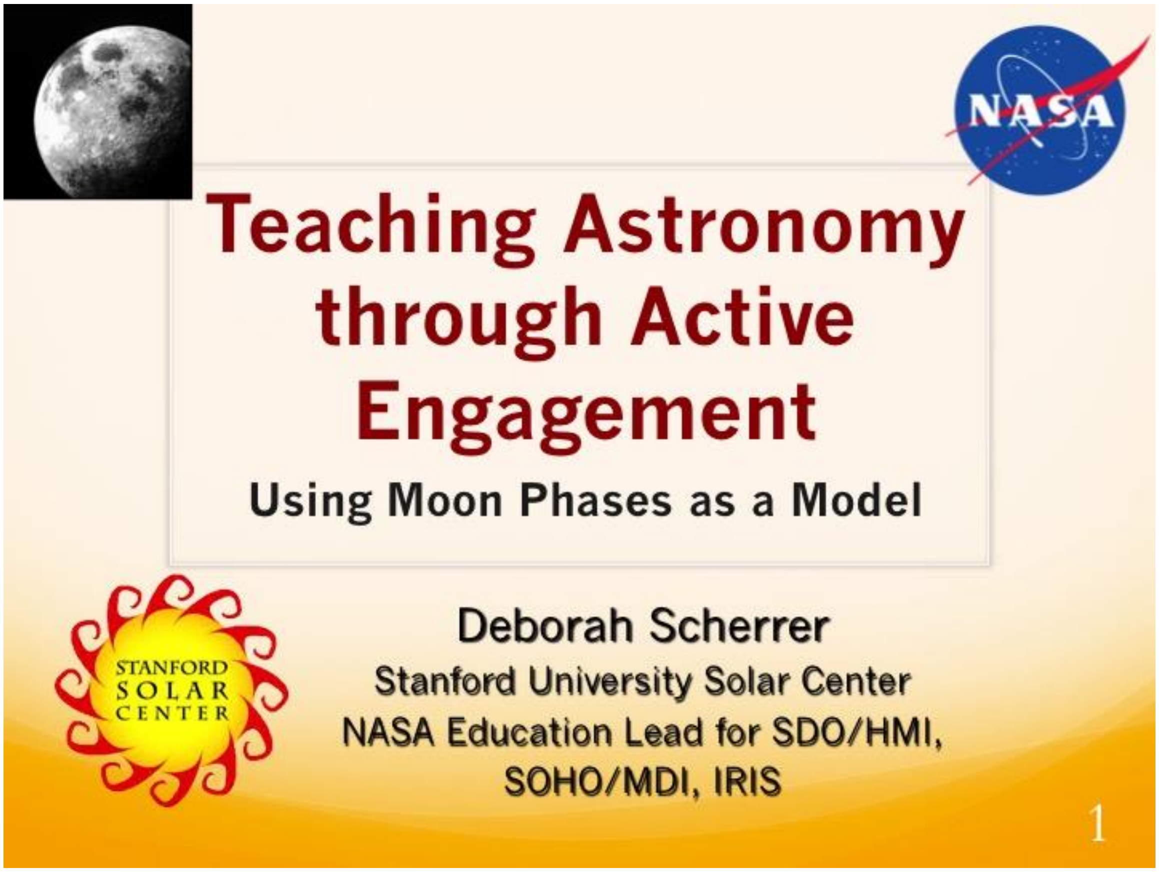


Slide 1

Teachers Guide to accompany the presentation '"Teaching Astronomy Through Active Engagement"

Table of Contents

Introduction

This workshop is designed to introduce teachers to the concept of teaching through Active Engagement. Teachers will learn new techniques to engage students as well as how to apply them by participating in a hands-on, interactive model of understanding and teaching the phases of the Moon and eclipses.

This workshop was developed as part of a program to bring modern science teaching techniques and activities to high school educators in Developing Countries, though the lessons are relevant to other locations and grade levels.

> "Students enter your lecture hall with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom."
>
> How People Learn, National Research Council,
> National Academy Press, 2000.

This workshop is also heavily inspired by the research of Dr. Edward E. Prather, of the University of Arizona, particularly his presentation "How Research into Student Beliefs and Reasoning Difficulties are Used to Create Effective Educational Environments", a presentation given at a NASA Forum Educational Workshop. See also *Research on a Lecture-Tutorial Approach to Teaching Introductory Astronomy for Non–Science Majors*, Prather, E. E.; Slater, T. F.; Adams, J. P.; Bailey, J. M.; Jones, L. V.; Dostal, J. A., Astronomy Education Review, 3(2) 2005.

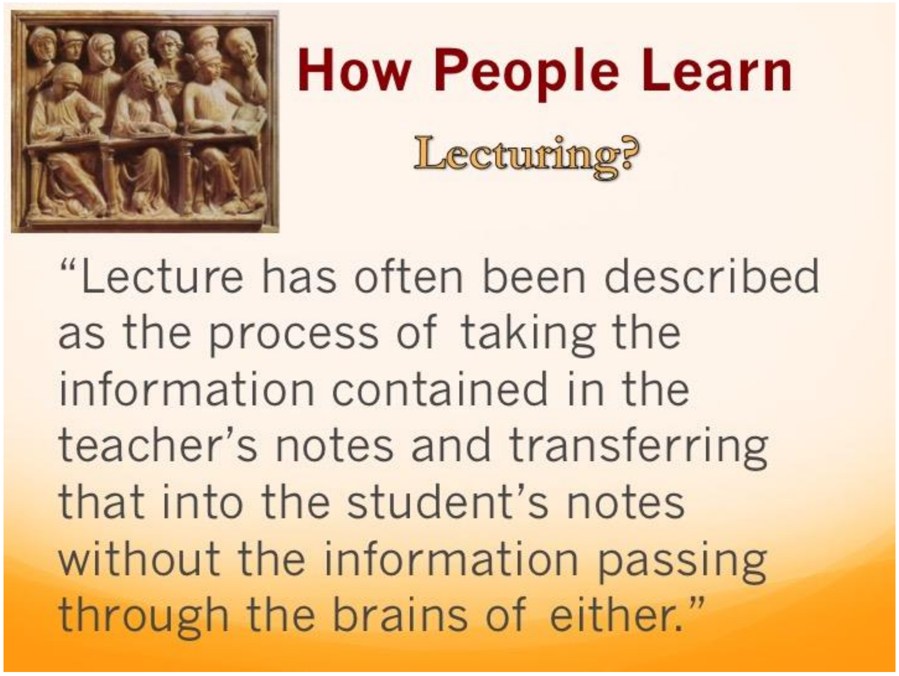
A good deal of the information in this presentation comes from "*How People Learn – Brain, Mind, Experience, and School*" by the Committee on Developments in the Science of Learning, John D. Bransford, Ann L. Brown, and Rodney R. Cocking, editors with additional material from the Committee on Learning Research and Educational Practice, M. Suzanne Donovan, John D. Bransford, and James W. Pellegrino, editors. Commission on Behavioral and Society Sciences and Education, US National Research Council, National Academy Press, Washington, D.C.

http://www.nap.edu/openbook.php?isbn=0309070368

This is one of the best books on teaching and learning available. It is highly recommended that participants obtain and read the book. It is downloadable for free.

> **Most ideas about teaching are not new, but not everyone knows the old ideas.**
>
> Euclid

How People Learn



Slide 2

How Effective is Lecturing?

Ask the teachers how many learned in school primarily through the lecture technique. Did they like it? Then ask them how many primarily rely on lecture technique to teach.

Lecturing is mainly a one-way method of communication that does not involve significant audience participation. Therefore, lecturing is often contrasted to active learning, which we will discuss later. The practice of lecturing evolved in the medieval university, before the invention of the printing press, where the instructor read from an original source to a class of students who took notes since they didn't have books.

Studies have shown there is more new vocabulary in an introductory science class than in a foreign language course. And teachers sometimes forget that the human brain can effectively hold only ~7 items in short-term memory. So if students receive 7 new vocabulary words at the beginning, there is little "space" left for other details and concepts. Focusing on concepts and in-depth understanding, rather than on vocabulary and unnecessary details, improves learning and retention in teaching astronomy.

According to research, the lecture method is a very difficult way to learn. Just by listening, students pick up only about 10% of what is heard.

However, some lecture is almost always necessary. If it is kept to brief periods (7-10 minutes) at a time, and interspersed with Active Engagement, then retention and understanding can be significantly improved.

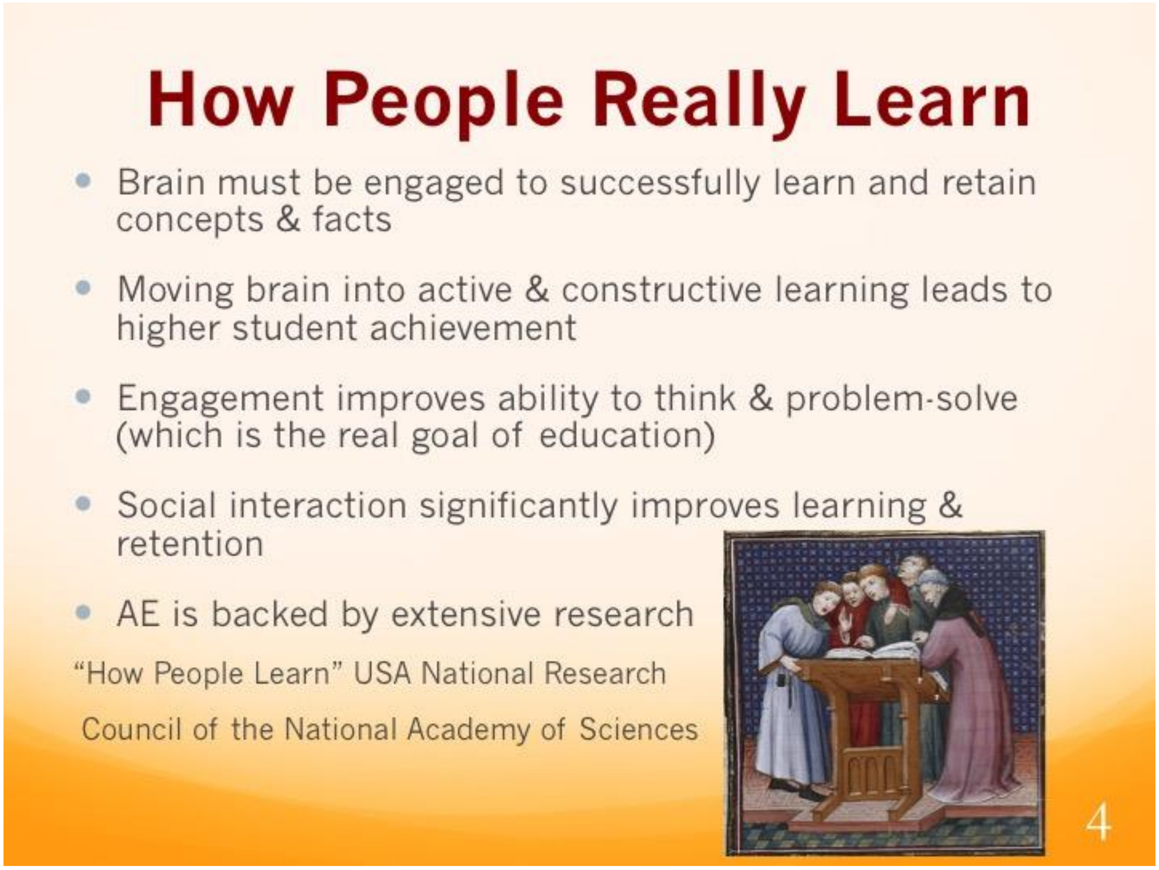
Source of the quote is unknown. It was taken from Ed Prather's presentation (see intro). The image is in the public domain.

Slide 3

What is Active Engagement?

Active engagement, or active learning, is a model of instruction that places more of the responsibility for learning on the learners.

According to Wikipedia: "It [AE] was popularized in the 1990s by its appearance on the Association for the Study of Higher Education (ASHE) report (Bonwell & Eison 1991). In this report they discuss a variety of methodologies for promoting "active learning". They cite literature which indicates that to learn, students must do more than just listen: They must read, write, discuss, or be engaged in solving problems. It relates to the three learning domains referred to as knowledge, skills and attitudes, and that this taxonomy of learning behaviors can be thought of as "the goals of the learning process". In particular, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. Active learning engages students in two aspects – doing things and thinking about the things they are doing."

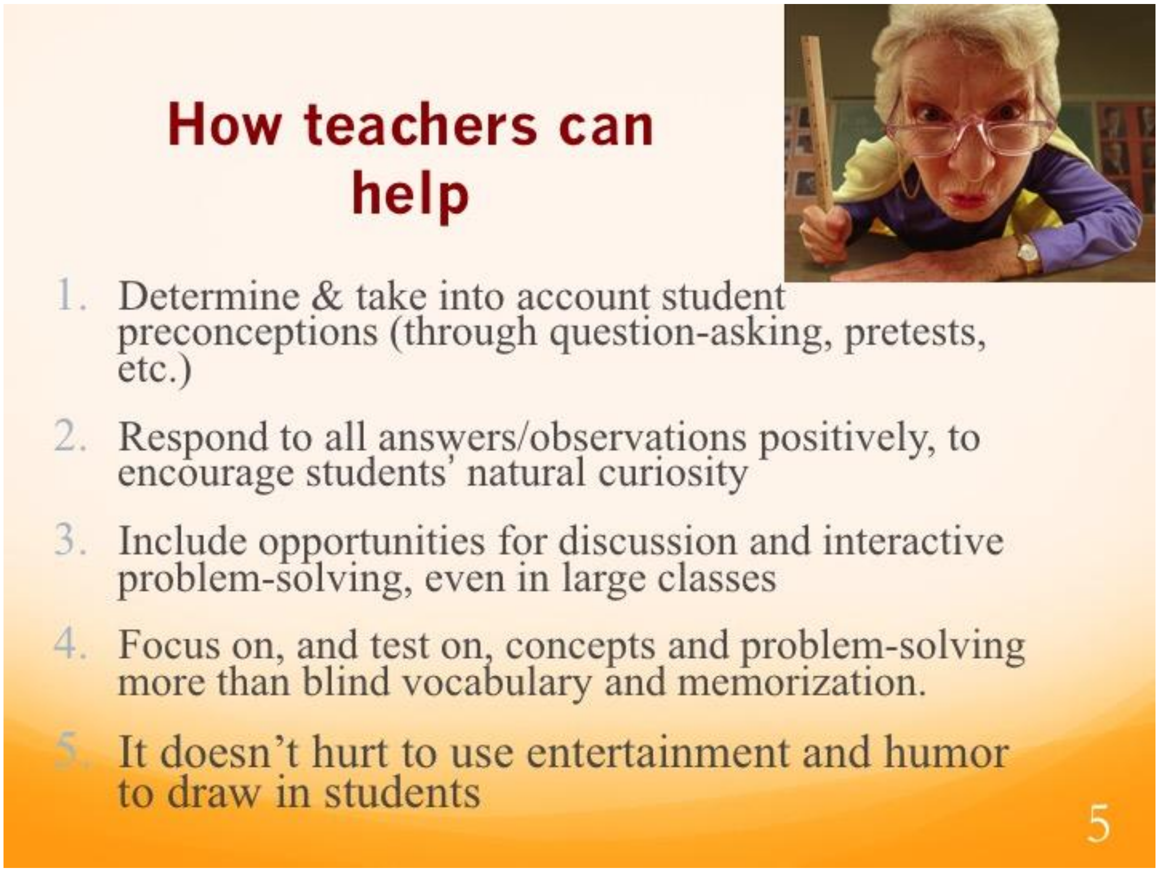


Slide 4

How People Really Learn

Numerous studies have shown that introducing active learning activities, especially done before, rather than after, lectures or readings, results in deeper learning, understanding, and transfer. In an active learning environment learners are immersed in experiences within which they are engaged in meaningful inquiry, action, imagination, invention, interaction, hypothesizing and/or personal reflection.

Image is in the public domain.



Slide 5

How Can Teachers Help?

Recent research shows that the human brain often discards information after about 30 days when that information hasn't been accessed. This reaffirms research that shows students after taking college courses based on memorization usually "forgot" most of the material within 6 months.

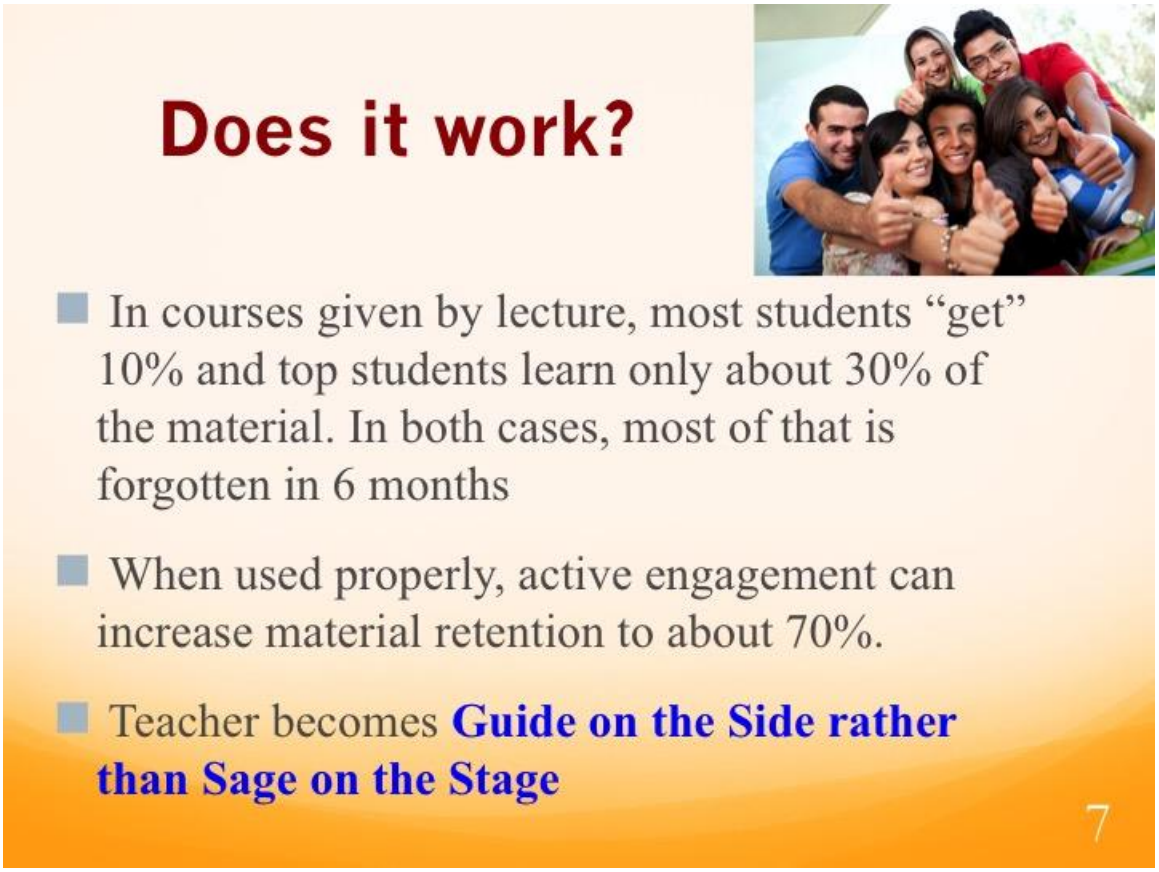
Image from: http://laborunionreport.com/2015/01/29/nea-insurance-scheme-exposed-a-teacher-explains-why-he-his-fellow-teachers-decertified-the-nea/

Slide 6

Examples of Active Engagement Techniques

We will spend the rest of the time experimenting with 3 of these techniques.

Image credit: Deborah Scherrer, engaging students at Exploration Station



Slide 7

Does Active Engagement Work?

Again, some lecture is almost always necessary. If it is kept to brief periods (7-10 minutes) at a time, and interspersed with Active Engagement, then retention and understanding can be significantly improved.

Research on a Lecture-Tutorial Approach to Teaching Introductory Astronomy for Non–Science Majors, Prather, E. E.; Slater, T. F.; Adams, J. P.; Bailey, J. M.; Jones, L. V.; Dostal, J. A., Astronomy Education Review, 3(2) 2005

Image is in the public domain.

Slide 8

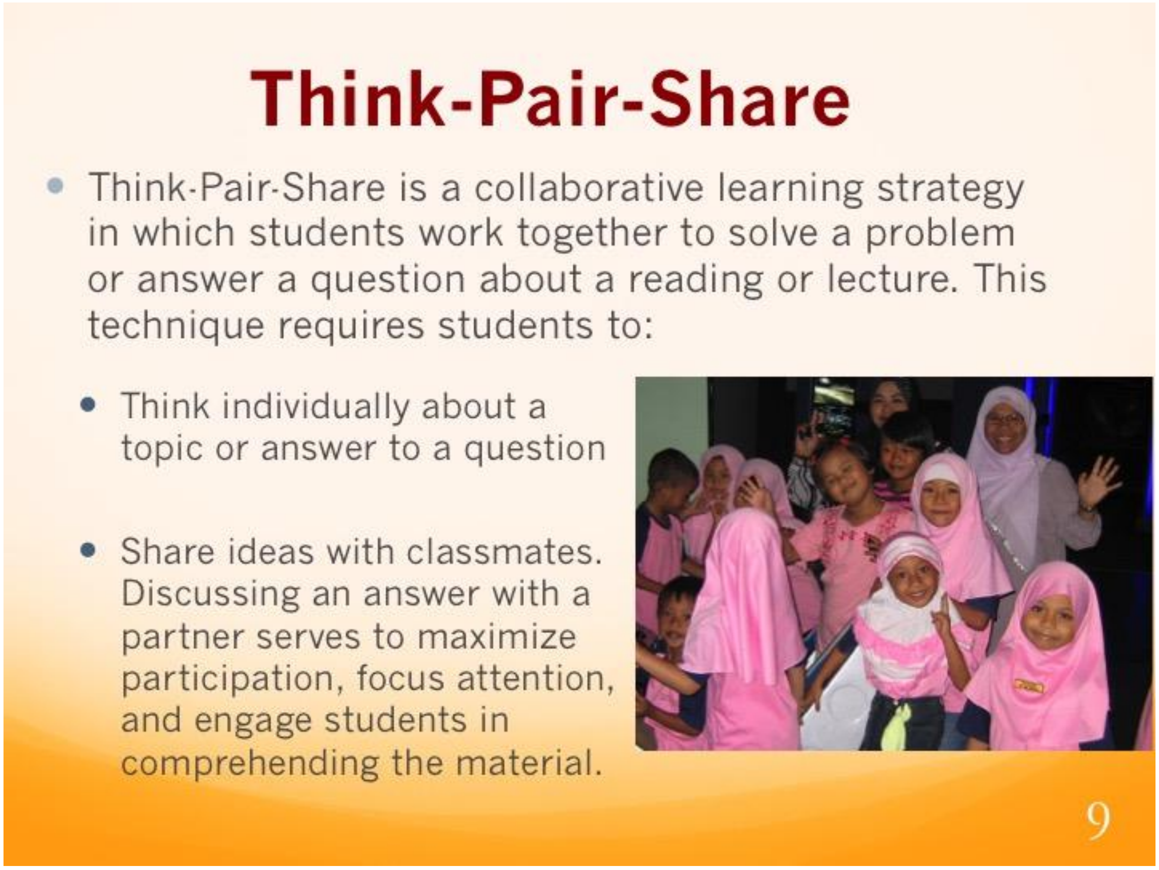
Let's Experiment

In this workshop we will experiment with 3 of the suggested forms of Active Engagement:

1. Think-Pair-Share
2. Signal Cards
3. Hands-on activities

Each experiment will relate to the teaching of Moon phases and eclipses.

Image is in the public domain.



Slide 9

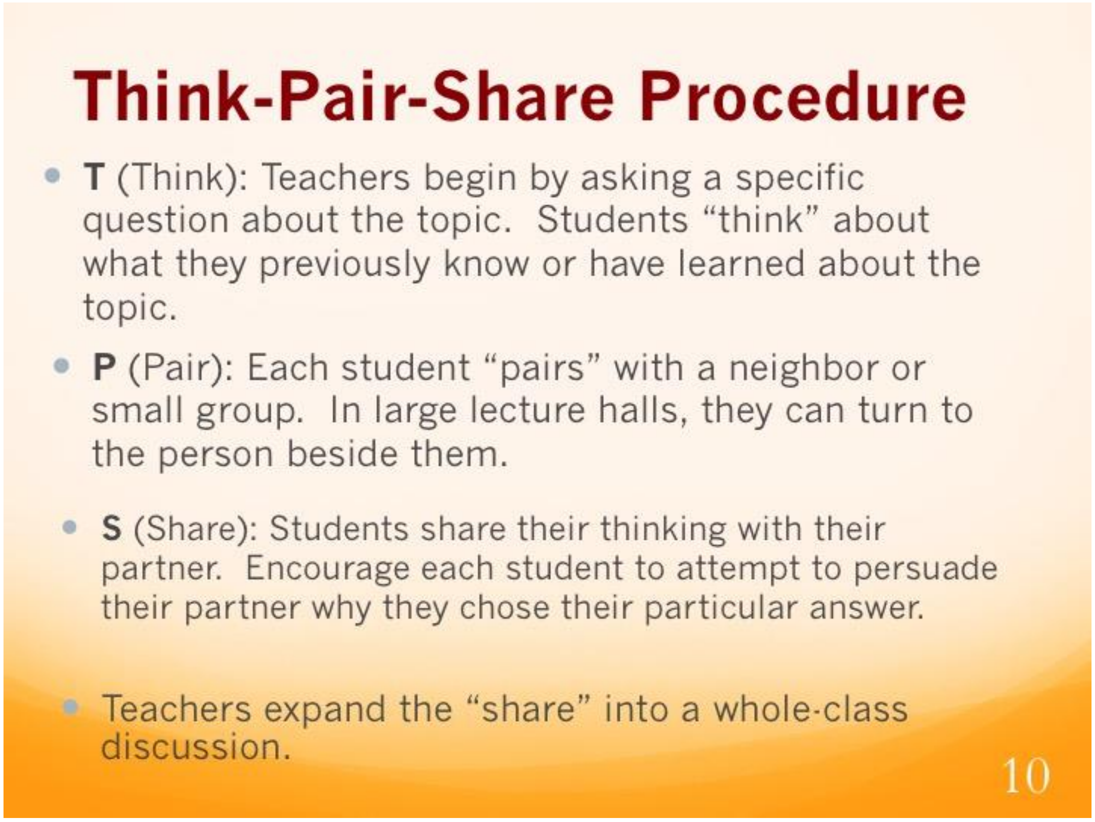
Think-Pair-Share

Reading Rockets describes the Think-Pair-Share method like this*:*
"Think-pair-share is a collaborative learning strategy in which students work together to solve a problem or answer a question about an assigned reading [or a lecture]. This technique requires students to

- Think individually about a topic or answer to a question
- Share ideas with classmates. Discussing an answer with a partner serves to maximize participation, focus attention and engage students in comprehending the reading material."

http://www.readingrockets.org/strategies/think-pair-share

Image credit: Deborah Scherrer, teacher and class in Malaysia



Slide 10

Think-Pair-Share Procedure

1. Decide upon the text to be read, a brief lecture to be given, or a topic to discuss. Then develop a set of questions or prompts that target key content concepts.
2. Describe the purpose of the strategy and provide guidelines for discussions.
3. Model the procedure to ensure that students understand how to use the strategy.
4. Monitor and support students as they work through the following:

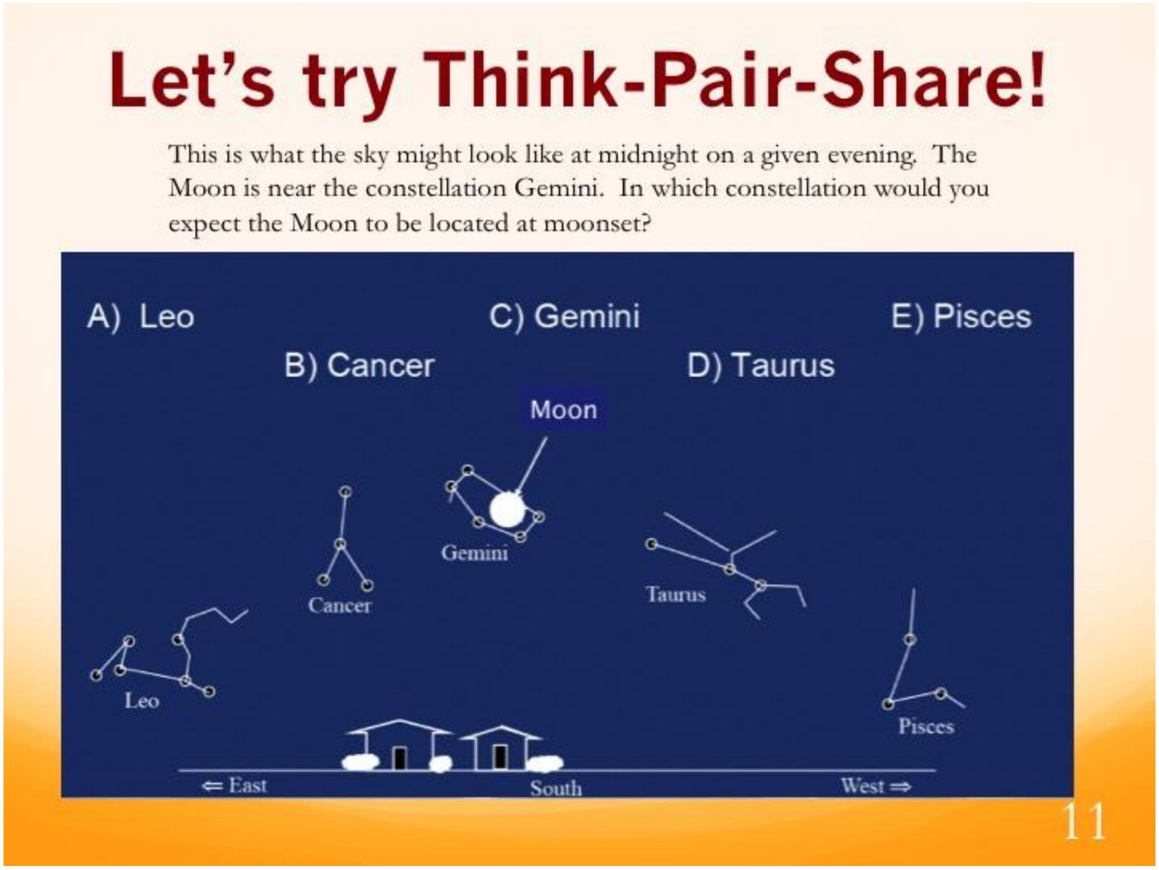
   T: (Think) Teachers begin by asking a specific question about the topic. Students "think" about what they already know or have learned about the topic.

   P: (Pair) Each student should be paired with another student or a small group. In large lecture halls, they can turn to the person beside them.

   S: (Share) Students share their thinking with their partner. Encourage each student to attempt to persuade their partner why they chose their particular answer.

5. Teachers expand the "share" into a whole-class discussion.

The Think-Pair-Share method is suitable for students from grades 2 though college and is commonly used in large lecture courses. For more information and examples, see http://www.readingrockets.org/strategies/think-pair-share

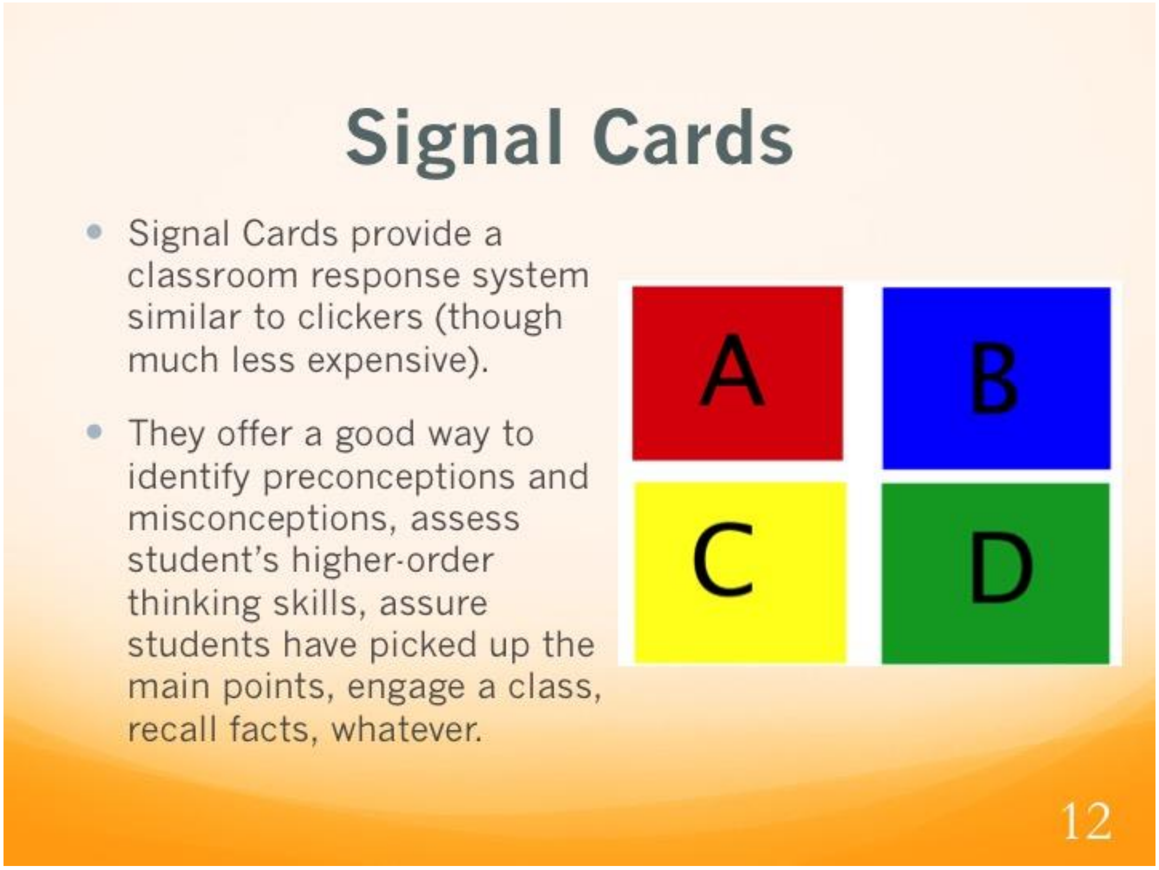


Slide 11

Let's try Think-Pair-Share

Use the Think-Pair-Share technique to determine the answer, which is C-Gemini. Help participants come to the conclusion that it is the Earth moving, not the Moon or constellations.

Activity developed by Ed Prather and show-cased in his lecture (see introduction)

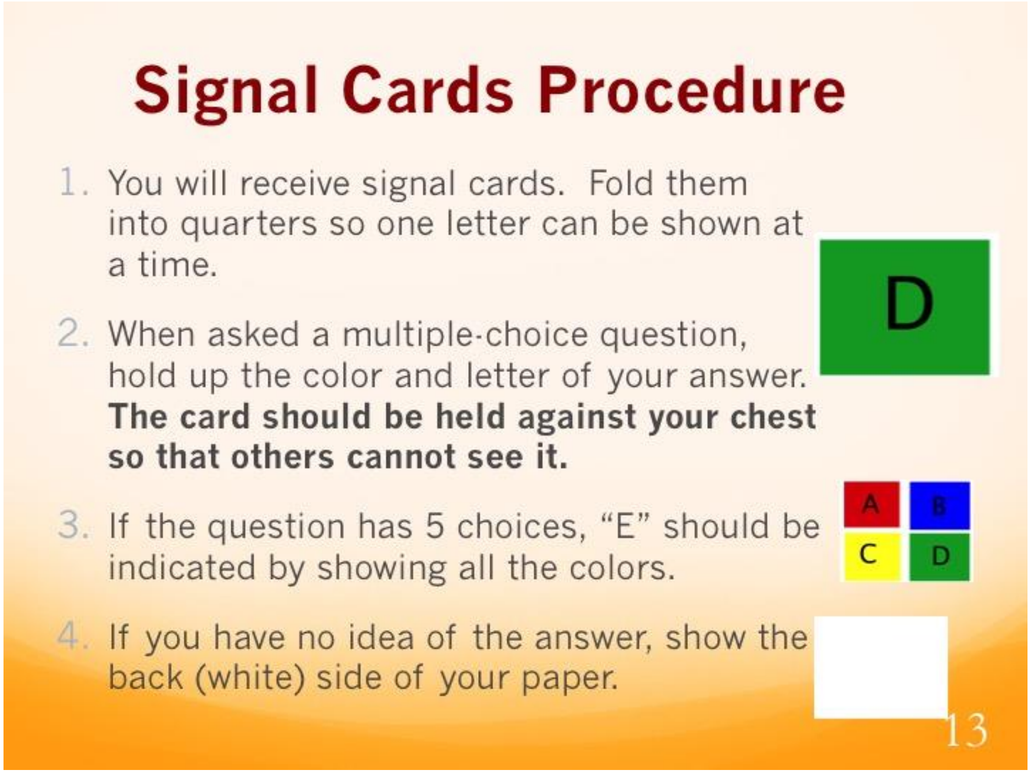


Slide 12

Signal Cards

Signal Cards provide a classroom response system similar to clickers (though much less expensive). They provide a good way to identify preconceptions and misconceptions, assess student's higher-order thinking skills, assure students have picked up the main points, engage a class, recall facts, whatever.

Sample Signal Cards are available in Appendix B.

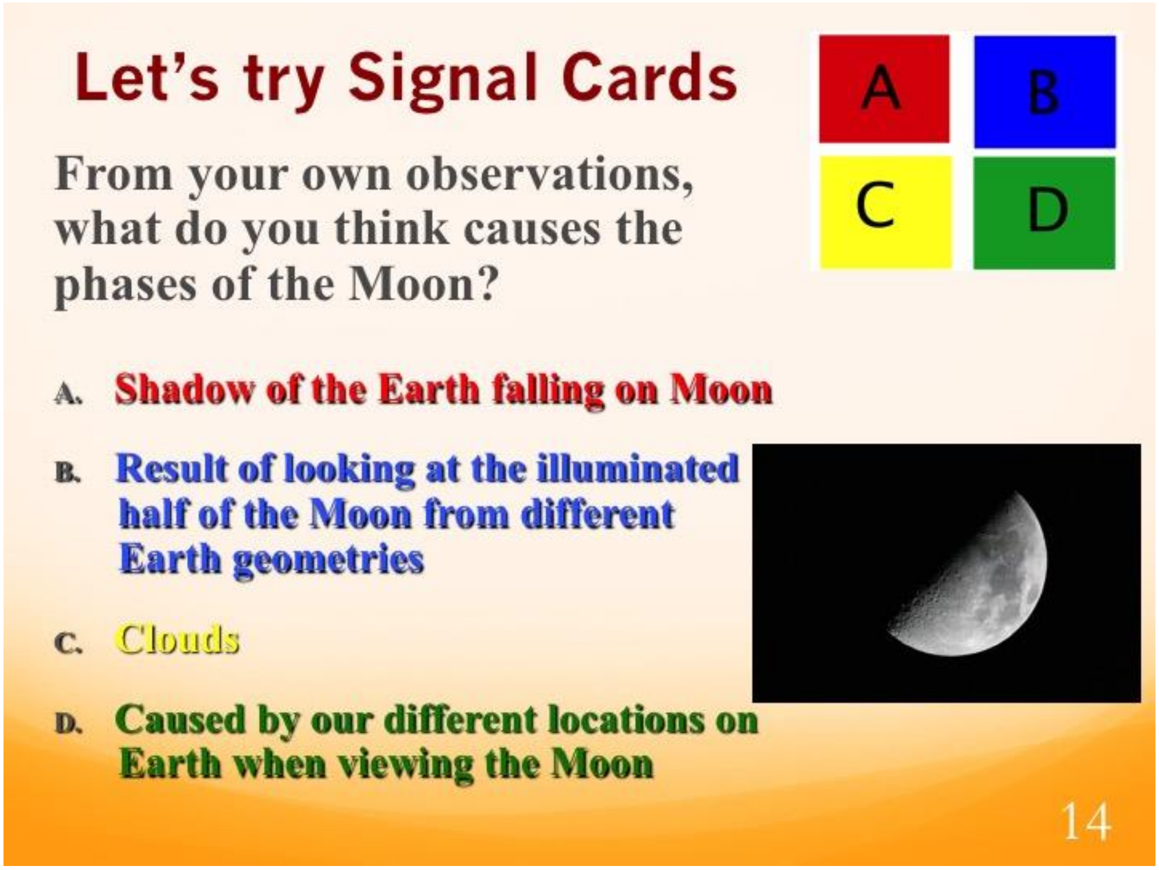


Slide 13

Signal Cards Procedure

1. Pass out the signal cards. Have participants fold them in quarters, with the colors showing.
2. Explain that, after you ask a multiple-choice question, and when an answer is called for, they should hold up the color and letter of their answer. **The card should be held against their chest so that others do not see it.** This both minimizes embarrassment and gets you, the presenter, information you need to proceed.
3. If a question has 5 possible answers, tell participants to hold up the opened sheet to signify "e".
4. If the participant doesn't have a clue what the answer is, they should hold up the blank side of the opened sheet.
5. Practice this once or twice by asking simple questions.
6. The next slide will pose a multiple-choice question to your participants. In your classroom, you might pose your question via an overhead or computer projector.
7. Each participant submits an answer to the question using their signal card, again held close to the chest so others cannot see their answer.
8. The presenter makes "on the fly" instructional choices in response to the cards; for example, leading students in a discussion of the merits of each answer choice or asking students to discuss the question in small groups.

Vanderbilt University Center for Teaching has an excellent website describing additional details. Though based on clickers, the information is applicable to signal cards as well: http://cft.vanderbilt.edu/guides-sub-pages/clickers/



Slide 14

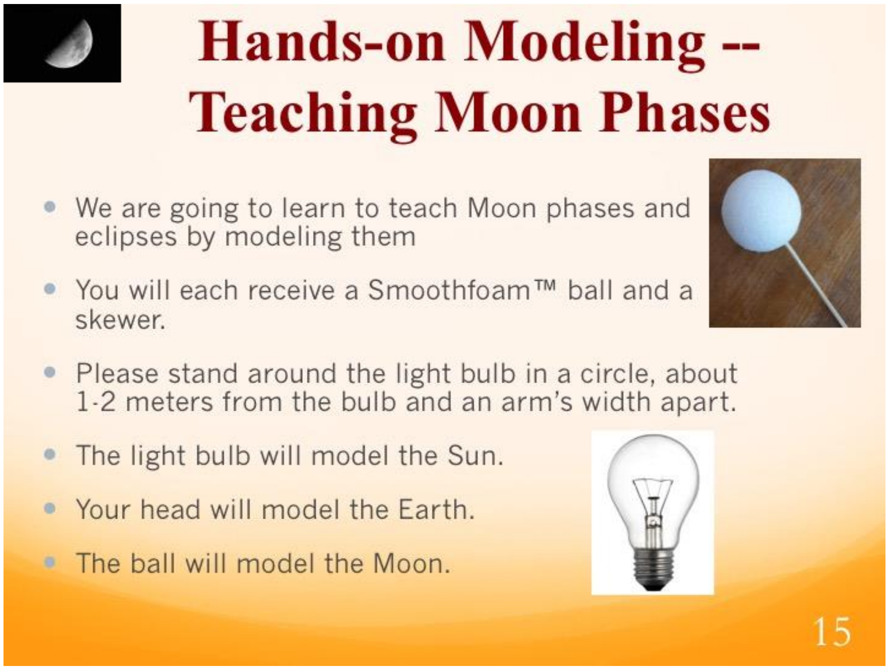
Let's try Signal Cards

Pass out the signal cards. Have participants fold them in quarters, with the colors showing. Explain that, after a question is asked, and when an answer is called for, they should hold up the color and letter of their answer. To minimize embarrassment, **the card should be held against their chest so that others do not see it.** In this case, pre-conceptions and ideas about the causes of moon phases should help the Presenter address these issues in the teaching exercise.

Ask participants to answer the question above with their signal cards. Do **not** tell them the correct answer, no matter how much they beg. They will soon discover it for themselves in the next activity.

Activity developed by Ed Prather, in his presentation to NASA Forum (see introduction)

Teaching Moon Phases Through Hands-on Modeling



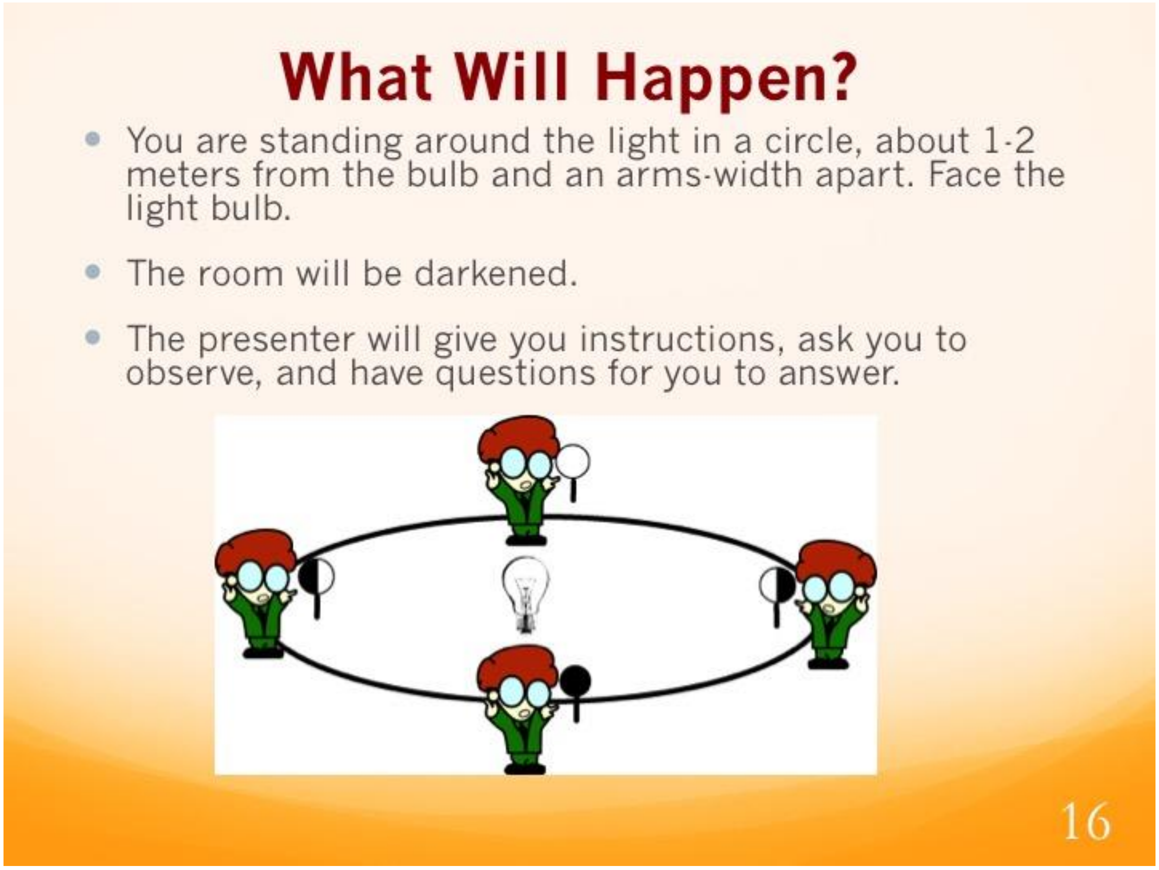
Slide 15

Teaching Moon Phases

Refer to the detailed procedures for doing the activity in Appendix A.

Start by having your participants stand around the light bulb in a circle, about 1-2 meters from the bulb and an arm's width apart. The bulb will model the Sun, participants' heads the Earth, and eventually they will receive a ball to model the Moon. If you choose to use the East/West cards, have participants tape or pin **East onto their left shoulder,** and **West onto their right shoulder**. Tell them when they turn they should turn towards the East/left.

This activity is inspired by one originally taught by Dennis Schatz to Project Astro participants. The full activity is described in "Astro Adventures", a publication of the Pacific Science Center. It is also available through the Astronomical Society of the Pacific shop, as part of their *Universe at Your Fingertips* DVD. It is highly recommended that teachers purchase one of these write-ups for doing a more extensive unit on moon phases and eclipses:
http://www.astrosociety.org/education/the-universe-at-your-fingertips-2-0/
and
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAAahUKEwiTrZ3qlrvHAhVQKYgKHSDkBBM&url=https%3A%2F%2Fwww.pacificsciencecenter.org%2Fwp-content%2Fuploads%2Fastro_adventures_order.pdf&ei=AqDXVZOkA9DSoASgyJOYAQ&usg=AFQjCNGqb_1F-qvHqt0jXCNdBpuR3uDoGA&sig2=EukJnLFQIgyZB-DRn27UYA



Slide 16

Modeling of Moon Phases Activity

1. Darken the room after participants have gathered around the light bulb, but do not pass out the Moon balls yet. Tell participants that:
   - The light bulb = Sun
   - Their head = Earth
   - Their nose = current location
   - Their left ear/shoulder = east
   - Their right ear/shoulder = west
   - The ball on a stick will eventually represent the Moon (but don't pass out the balls yet)

   Ask participants to stand where it is "noon", then midnight, sunrise, sunset. Remember, they should turn towards their left shoulders. When all participants get this right, have them
   - Turn around fully = 1 day
   - Walk around the Sun (counterclockwise) = 1 year
   - Repeat the daily cycle to make sure they "get it"

2. Pass out the ball Moons. Tell participants that the ball models represent the Earth's moon. Remind them that the Moon orbits the Earth (their head) in about 1 month ("moonth").

3. Ask participants where the light on the Moon comes from [the Sun]

4. Have them stand facing the Sun/lamp at "noon" and hold up the Moon between them/Earth and the Sun. What do they see? [New Moon or No Moon or a dark moon]

5. Have them stand at midnight, with the Moon opposite the Sun. Make sure people hold their Moon high enough for it to catch the light. What do they see? [Full Moon]

6. Go back to noon (New/No Moon) and move their Moon a bit to the left. What do they see? [small, waxing crescent]

7. Continue moving the Moon leftward to 1st quarter, waxing gibbous, full, waning gibbous, last quarter, and back to new. Give participants time to experiment with their Moons.

   Remind them that, all this time, their head/Earth is spinning through about ~29 day-night cycles during the time it takes for one month/*moonth* to go by.

8. Have participants figure out *roughly* what time of day the New Moon rises. [sunrise]
9. What time of day does the Full Moon rise? [sunset]

10. What time of day do 1st quarter and last quarter rise? [1st quarter=noon, last quarter=midnight)

11. What percentage of time is the Moon up during the day? [roughly half the time]

12. Ask them if all people on Earth see the same phase of the Moon on any given day? [yes]

13. Do the people in the southern hemisphere see the Moon in the same way as the northern hemisphere [yes, except that it is "upside down"]

Allow participants to experiment with all these concepts. Encourage questions and discussions with neighbors.

Slide 17

Modeling Eclipses Activity

Once participants are comfortable with moon phases, tell them they are now going to model eclipses.

1. Have participants model a solar eclipse by placing the Moon, at noon, between the Earth & Sun. In what phase is the Moon? [new]
2. Model a lunar eclipse by placing the Earth between the Moon and Sun at midnight. In what phase is the Moon? [full]
3. How many people on Earth can see a total solar eclipse? Refer to the small shadow that falls on peoples' faces. [Only a few can see the total solar eclipse.]
4. How many people can see a total lunar eclipse? [everyone on the night side]
5. Why don't we have solar eclipses and lunar eclipses every month? [the Moon's orbit is tilted so it rarely falls exactly in line with the Sun]
6. During a solar eclipse, what color is the corona? Refer to the image above. [white, assuming your light bulb is white]. Hence what color is the Sun? [white – see http://solar-center.stanford.edu/activities/SunColor/]
7. During a lunar eclipse, the Moon is often reddish. Again, refer to the picture above. Do your participants know why? [light is scattered through the Earth's atmosphere and only the long red & orange waves get through to illuminate the Moon – see http://solar-center.stanford.edu/activities/SunColor/What-Color-is-the-Sun.pdf]

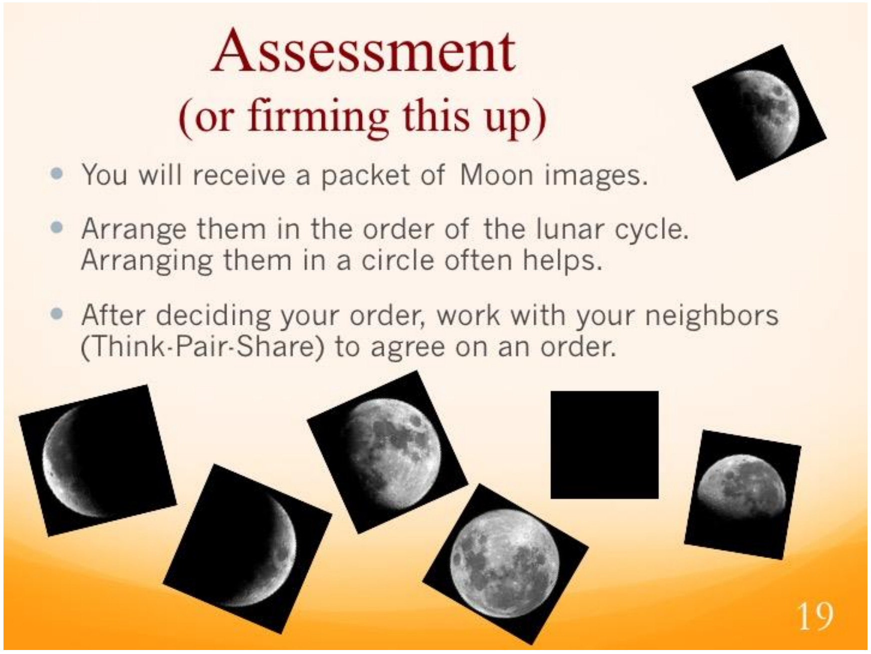
Image credit: Solar Eclipse Seen in Baja California This photo mosaic shows a view of the sun from Baja California during an eclipse on July 11, 1991, with the moon sliding in front of the Sun. Visit http://laps.noaa.gov/albers/onepage.html for more information on this image. Steve Albers, Boulder, CO; Dennis DiCicco, Sky and Telescope; Gary Emerson, E. E. Barnard Observatory Lunar eclipse: HERIBERT PROEPPER / ASSOCIATED PRESS FILE

Slide 18

Report Your Findings

After allowing time for participants to experiment with moon phases and eclipses, encourage them to report findings and ask more questions.

Image credit: NASA



Slide 19

Ordering Moon Phases Activity

More complete procedures are described in Appendix A.

1. Divide participants into pairs.

2. Copy a sheet of the Ordering Moon Phases imagery (Appendix A) for each pair. Either cut out the images beforehand, or have participants cut them out. If you wish to reuse the imagery, laminate the sheet before you cut it.

3. Ask participants to arrange the imagery in the order of the Moon phase cycle. They may start with any phase they want. It might help if they arrange the imagery in a circle.

4. Have participants discuss order with their pairs and come to a consensus.

5. Have pairs report to the group. Are there different interpretations? Encourage discussion.

This activity was also inspired by one originally taught by Dennis Schatz to Project Astro participants. The full activity is described in "Astro Adventures", a publication of the Pacific Science Center. It is also available through the Astronomical Society of the Pacific shop, as part of their *Universe at Your Fingertips* DVD. It is highly recommended that teachers purchase these write-ups for doing the complete activities:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAAahUKEwiTrZ3qlrvHAhVQKYgKHSDkBBM&url=https%3A%2F%2Fwww.pacificsciencecenter.org%2Fwp-content%2Fuploads%2Fastro_adventures_order.pdf&ei=AqDXVZOkA9DSoASgyJOYAQ&usg=AFQjCNGqb_1F-qvHqt0jXCNdBpuR3uDoGA&sig2=EukJnLFQIgyZB-DRn27UYA
and
http://www.astrosociety.org/education/the-universe-at-your-fingertips-2-0/
Image credits: NASA

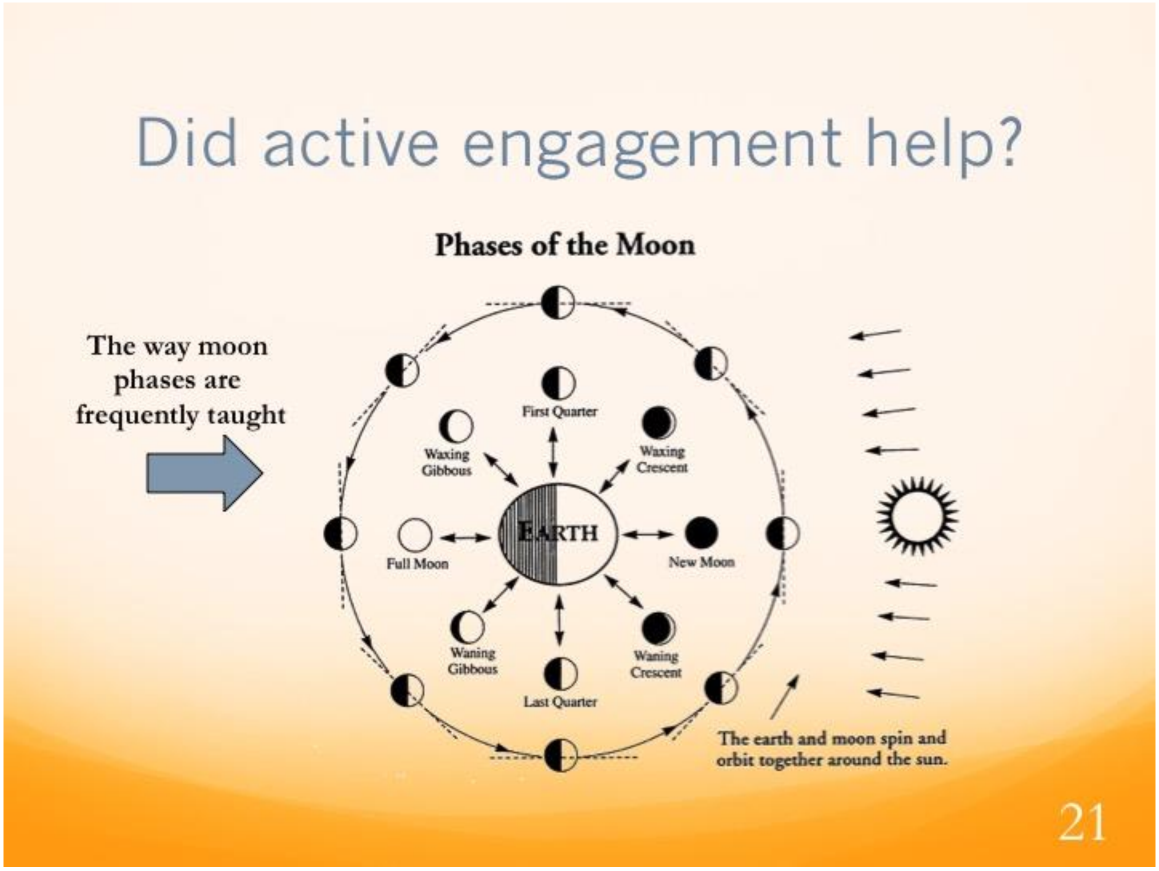
Slide 20

Report on Ordering Moon Phases Activity

Participants should eventually discover that not only must they correctly identify the Moon phase, but also use features on the Moon to determine which way is "up". Rather than indicating a right-or-wrong response, try to encourage participants to make discoveries on how they should arrange the imagery.

Image on left: Students in India aligning their imagery. Submitted by a teacher who took the workshop.

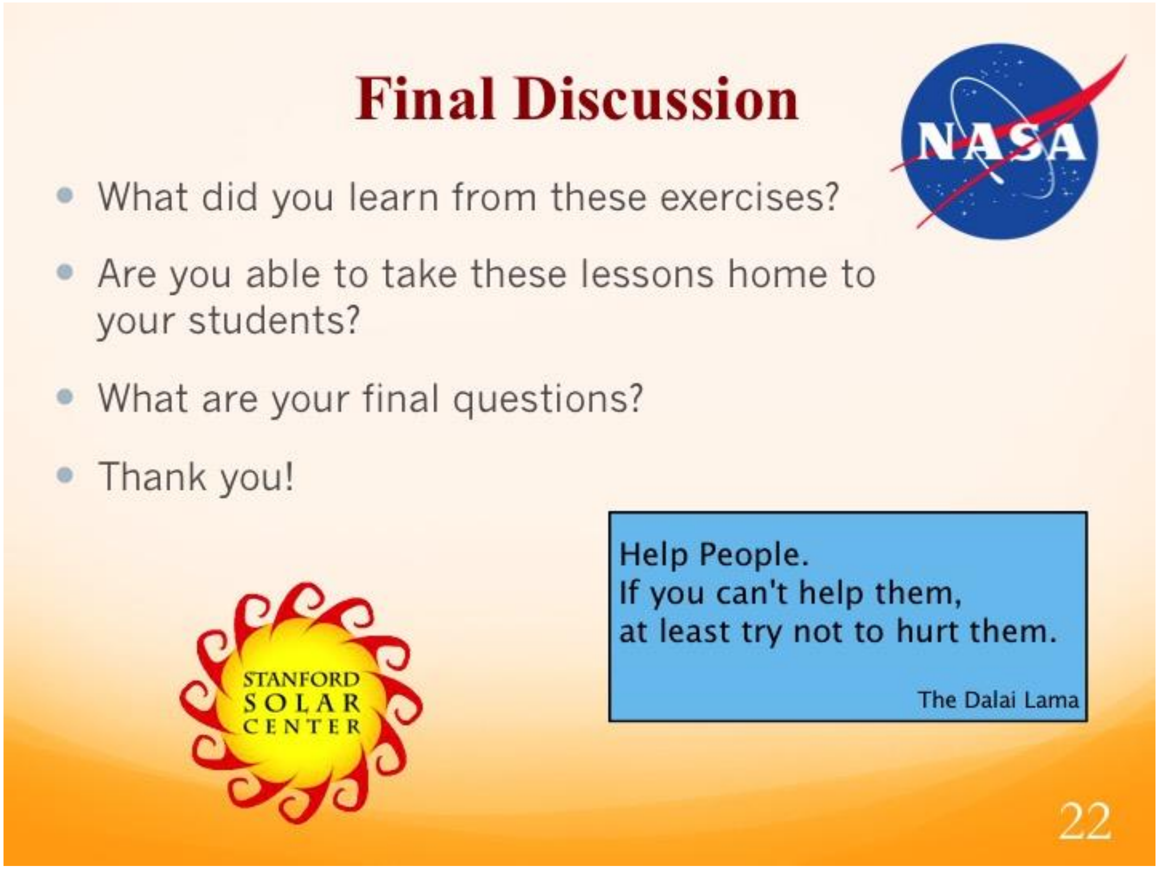
Wrapup & Final Discussion



Slide 21

Did active engagement help?

Discuss with your teachers the pros and cons of the Active Engagement approach. Was anything confusing, difficult? What problems might they have taking the lessons into their classrooms? How might the techniques be improved?



Slide 22

Final Discussion

Wrap up.

The following slides give additional activities. They can be used in the workshop or given to teachers to take back to their students.

Going Further

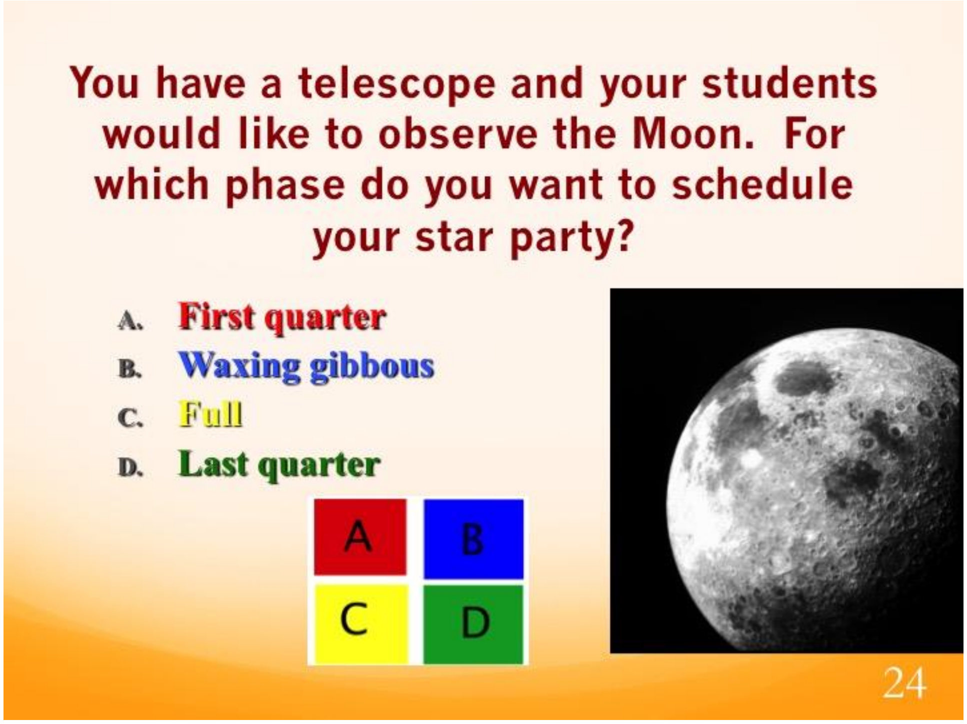
Slide 23

Challenge 1

Use Think-Pair-Share or signal cards to answer the question.

The answer is D.

Activity developed by Ed Prather, in his presentation to NASA Forum (see introduction)



Slide 24

Challenge 2

Moon phases timing is relative to latitude, longitude, and season. However, in a generalized world (e.g. at the equator):

- First quarter rises around noon & is highest at sunset.
- Waxing gibbous rises around the middle of the afternoon & is highest ~9 PM.
- Full moon rises around sunset & is highest at midnight.
- Last quarter rises around midnight and is highest around sunrise.
- (New moon rises at sunrise but is never visible.)

You can find a **Moon Phase Rise/Set time chart in Appendix C.**

1. The best time to observe the Moon, or any astronomical object, with a telescope is when it is high in the sky.
2. The *full* Moon is difficult to observe in a telescope because it is too bright. Even with a moon filter to cut down the light, there are no shadows so the craters and mountain ranges are difficult to see and appear washed out.
3. Best time to observe the Moon is when it is only partially lit. When you focus a telescope on the terminator (line between dark and light), you can see dramatic shadows.
4. Since the last quarter requires students to arrive in the middle of the night, it is not a particularly good choice for a star party.

So, around the first quarter or waxing gibbous phases are the best phases for observing and for public events.

Activity developed by Deborah Scherrer, based on real-world experience.

Slide 25

Challenge 3

Your principal wants to have a Star Party in 3 weeks. The best time for observing stars is when there is little or no moonlight to interfere. You happen to look out the window at 10 AM and see the Moon on the western horizon. Will a Star Party in 3 weeks work?

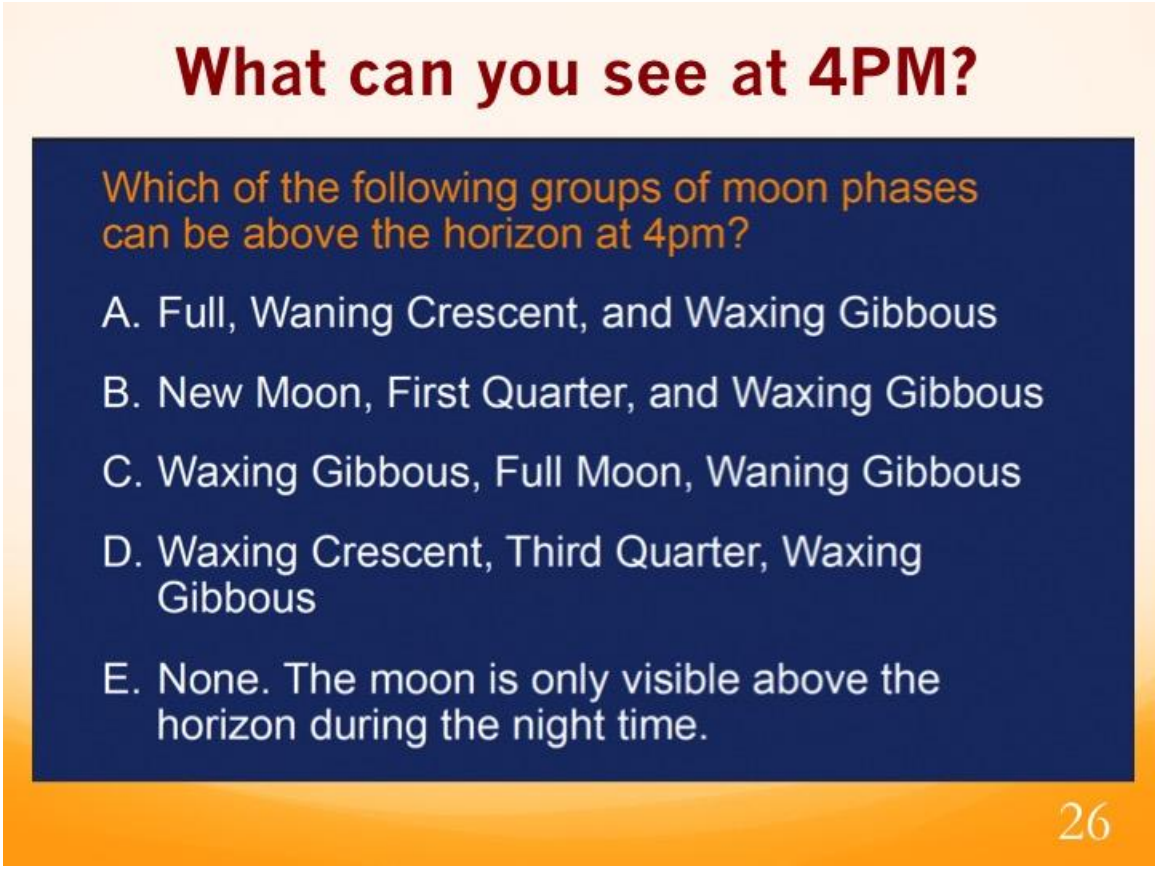
Consult the moon phases timing chart in Appendix C.

If the Moon is on the western horizon ~10 AM, it is probably a waning gibbous, or between a waning gibbous and last quarter.

3 weeks from then, the phases would be waning gibbous->waning crescent->new moon->waxing crescent->first quarter->waxing gibbous->full
So, no, in 3 weeks would be a bad time to schedule a Star Party.

Activity developed by Deborah Scherrer, again based on real-world experience.

Image credit: "The waning gibbous moon stands out boldly between the evergreens this morning around 9 o'clock. Credit: Bob King" - See more at: http://astrobob.areavoices.com/2013/09/24/place-your-bets-on-falls-high-rollin-moon/#sthash.WHx7ukyW.dpuf"



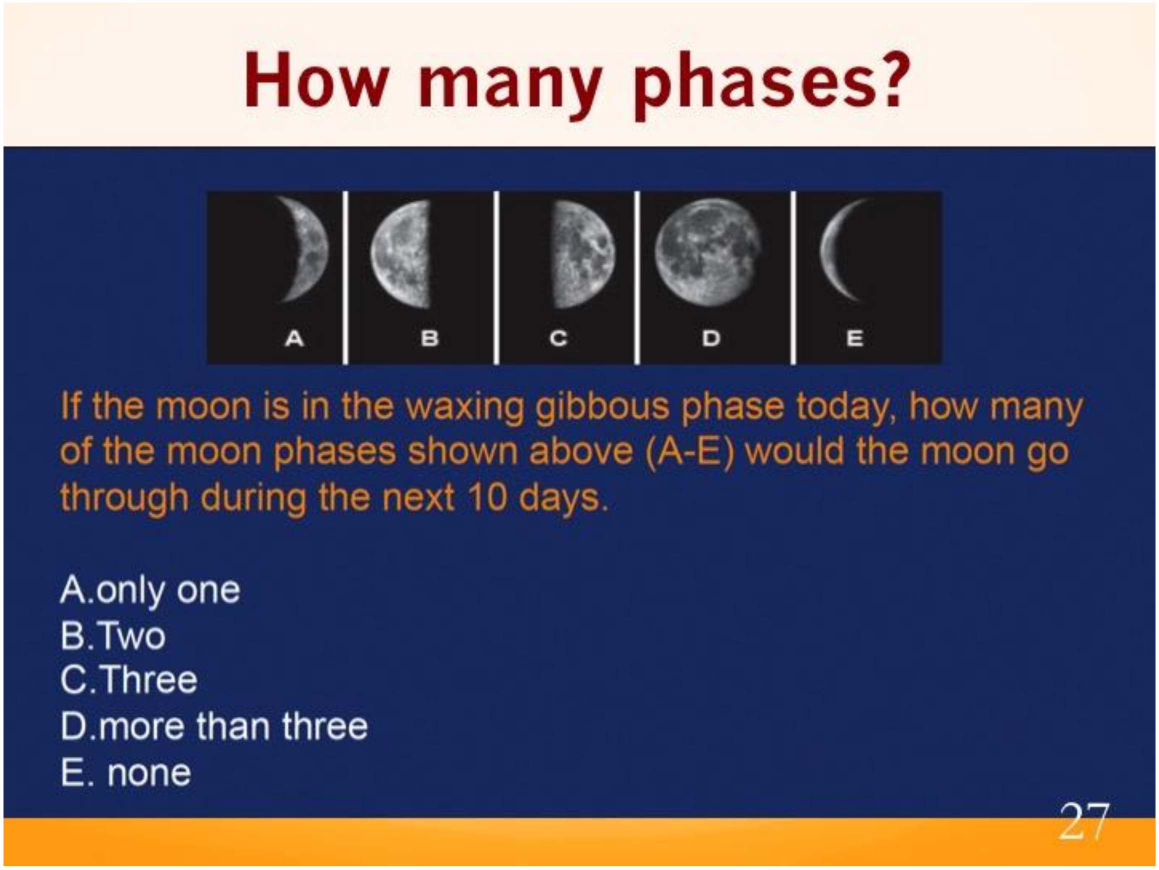
Slide 26

Challenge 4

Consult the moon phases timing chart in Appendix C.

B – new moon, 1st quarter, & waxing gibbous

Activity developed by Ed Prather, in his presentation to NASA Forum (see introduction)



Slide 27

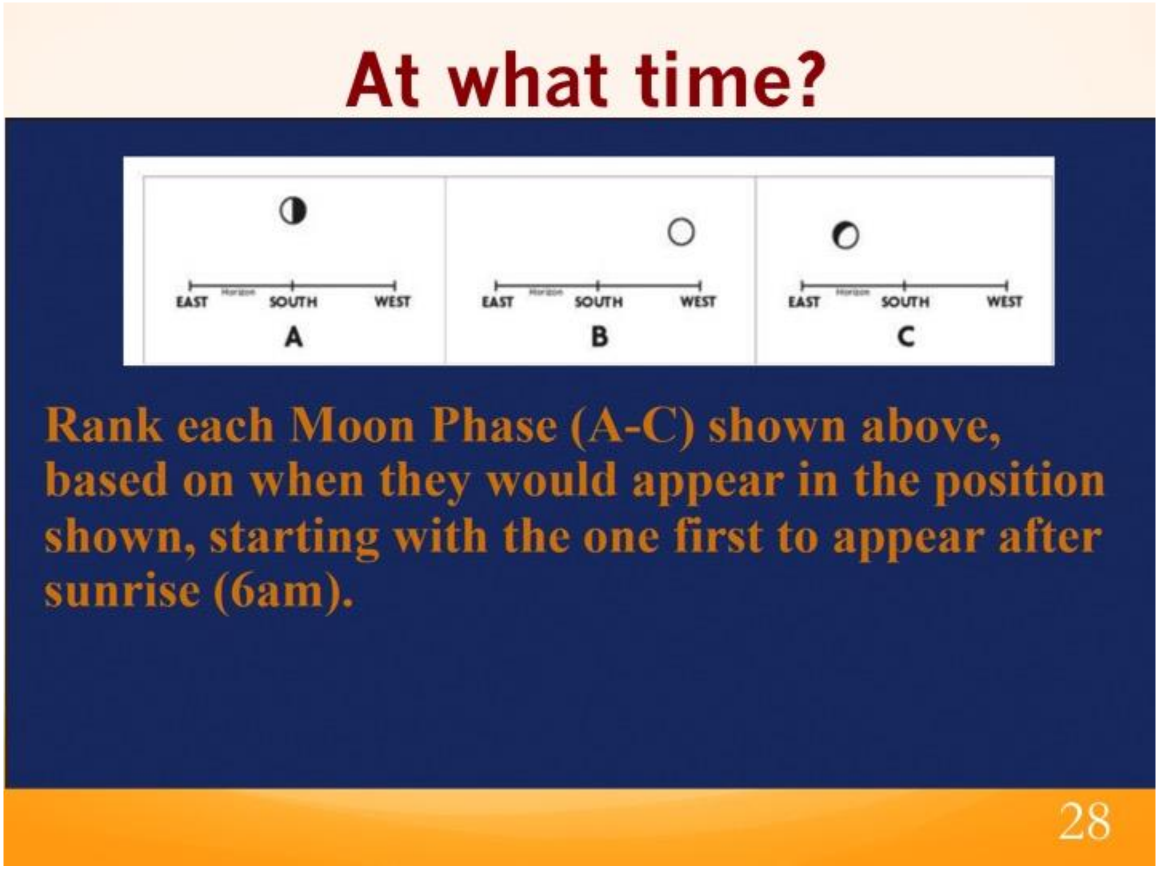
Challenge 5

Consult the moon phase timing chart in Appendix C.

A is a waxing crescent
B is last quarter
C is first quarter
D is just past full
E is a waning crescent

Waxing gibbous -> past full -> last quarter -> waning crescent
Days: 0 4 11
So the answer is Only 1 (A); though depending upon the exact place in the waxing gibbous phase, one might also argue for 2 (B)

Activity developed by Ed Prather, in his presentation to NASA Forum (see introduction)



Slide 28

Challenge 6

Consult the moon phase timing chart in Appendix C.

Assuming we are near the equator:
A = last quarter high in sky ~sunrise
B = Full moon before sunrise ~4 AM
C = waxing gibbous ~6 PM
So the order would be A – C – B
(or C – B – A if you explicitly ask "after" sunrise)

Activity developed by Ed Prather, in his presentation to NASA Forum (see introduction)

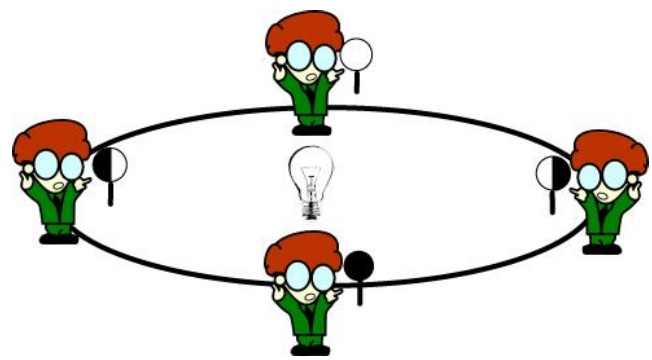
Appendices

Appendix A – Teaching Moon Phases -- Presenter Guide

Deborah Scherrer
Stanford University Solar Center
Activity originally developed by Dennis Schatz, Pacific Science Center

Age Range:
Grades 4-14

Duration:
30-45 minutes



Overview:
This is an activity to teach and learn Moon phases and eclipses through hands-on modeling. It has three sections:
1. Understanding what causes Moon phases activity
2. Understanding what causes eclipses activity
3. Assessment/Firm-up – ordering Moon phase imagery activity

This activity is inspired by one originally taught by Dennis Schatz to the Astronomical Society of the Pacific's Project Astro participants. The full activity is described in "Astro Adventures," a publication of the Pacific Science Center. It is also available through the Astronomical Society of the Pacific shop, as part of their *Universe at Your Fingertips* DVD. It is highly recommended that users purchase one of these write-ups for doing a more extensive unit on moon phases and eclipses:
http://www.astrosociety.org/education/the-universe-at-your-fingertips-2-0/
and
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAAahUKEwiTrZ3qlrvHAhVQKYgKHSDkBBM&url=https%3A%2F%2Fwww.pacificsciencecenter.org%2Fwp-content%2Fuploads%2Fastro_adventures_order.pdf&ei=AqDXVZOkA9DSoASgyJOYAQ&usg=AFQjCNGqb_1F-qvHqt0jXCNdBpuR3uDoGA&sig2=EukJnLFQIgyZB-DRn27UYA

Activity Goals:
Participants will learn that:
- The Moon is always half-lit by the Sun.

- Moon phases are caused by observing the half-lit Moon at different times during its orbit of the Earth.
- All people on Earth see the same moon phase at the same time, though those in the southern hemisphere see the moon upside down compared with the northern.
- Solar eclipses are caused by the Moon coming exactly between the Earth and the Sun, blocking all but a small shadow of the Sun's light to the Earth. Only a small number of people can observe a solar eclipse because of the small size of the shadow.
- Lunar eclipses are caused by the Earth coming directly between the Sun and the Moon, casting a shadow on the Moon. Everyone on the night-side of the Earth can observe a lunar eclipse.
- Solar and lunar eclipses do not occur every month because the Moon's orbit is tilted to the Earth's plane of orbit around the Sun. So the Moon, Earth, and Sun rarely line up exactly.

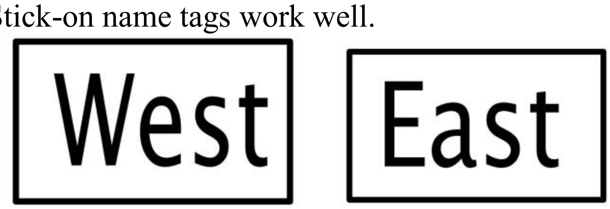
Materials:

- **Light source**: A tall floor lamp with the shade taken off. Or, a light bulb on a stand or clip that can be placed about 1.5-2 meters high. Clear incandescent light bulbs work best. Battery-powered lanterns sometimes work.

- **Small ball**: A white (or light-colored) ~5cm (2”) ball for each participant. These could be made of Smoothfoam™, Styrofoam™, Model Magic™, clay, paper mache, or they could be golf balls, tennis balls, wooden globes, round fruits, whatever. You may need to drill a hole in each ball for the holder to be inserted.

- **Stick**: 1 satay stick, pencil with a sharp point, wooden stick, etc. to serve as a holder. You'll need 1 for each ball. (Avoid very sharp sticks when working with children.)

- **Signs** (optional): A set of small **West** and **East** paper signs for each participant; use tape or pins to attach these to their shoulders (i.e. clothes over shoulders). Stick-on name tags work well.



- **Dark place**: A room that can be darkened, large enough for participants to form a circle around the light bulb, about 1.5 meters (5 feet) away from it. You may need to form 2 circles (and add another light bulb), depending upon the number of participants you have. If you absolutely cannot find a dark room, you can still do the activity by using small flashlights to light the model Moons. See *Drive By Science – Teaching Moon Phases*: http://solar-center.stanford.edu/activities/MoonPhases/Drive-By-Science-Moon-Phases.pdf

Preparation:

Mention that the scale is way off in this activity. Give an example of the real Earth-to-Moon scale, e.g. show a picture of the Earth and Moon to scale, or have a model of an Earth and Moon to scale then mention how far away and how large the Sun would be on that scale.

At this scale, the Sun would be ~4.5 meters in diameter and 1.4 km away.

Lesson Plan:

1. Get Oriented

a. Have participants pin or tape their **East** card on their left shoulder, and **West** card on their right shoulder. When they turn, they should turn towards their left shoulders.

b. Darken the room and gather participants around the light bulb, but do not pass out the Moon balls yet. Tell participants that:
   - The light bulb = Sun
   - Their head = Earth
   - Their nose = current location
   - Their left ear/shoulder = east
   - Their right ear/shoulder = west
   - The ball on a stick will eventually represent the Moon (but don't pass out the balls yet)

c. Ask participants to stand where it is "noon", then midnight, sunrise, sunset. Remember, they should turn towards their left shoulders. When all participants get this right, have them
   - Turn around fully = 1 day
   - Walk around the Sun (counterclockwise) = 1 year
   - Repeat the daily cycle to make sure they "get it"

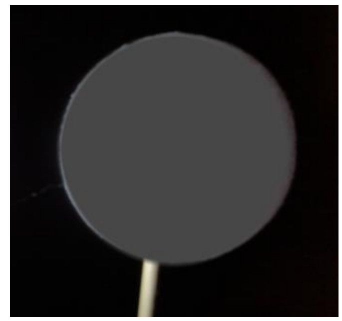
d. Pass out the ball Moons. Tell participants that the ball models represent the Earth's Moon. Ask them how long it takes for the Moon to orbit the Earth [about 1 month ("moonth")].

2. Moon Phases Activity

a. Have participants hold up their Moons.

b. Ask participants where the light on the Moon comes from [the Sun]

c. Have them stand facing the Sun/lamp at "noon" with the Moon between them/Earth and the Sun. What do they see? [New Moon or No Moon or a dark moon] *For now, ignore the fact that they are also viewing a solar eclipse.*

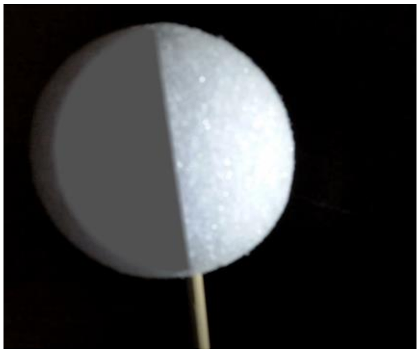


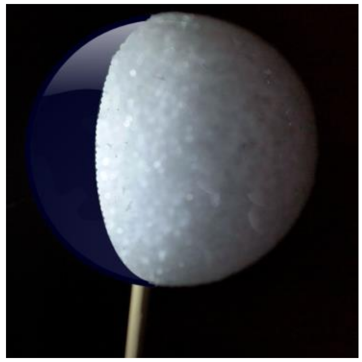
d. Have them stand at midnight, with the Moon opposite the Sun. Make sure people hold their Moon high enough for it to catch the light. What do they see? [Full Moon]

e. Go back to noon (New/No Moon) and move their Moon a bit to the left. What do they see? [small, waxing crescent] On what side of the Moon is the crescent? [right]

f. Have participants continue moving their Moon leftward to first quarter, waxing gibbous, full, waning gibbous, last quarter, and back to new.

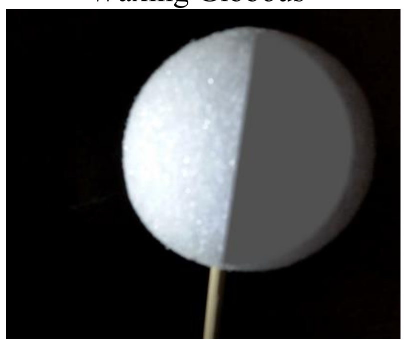
g. Give participants time to experiment with their Moons.


First Quarter


Waxing Gibbous


Full Moon


Waning Gibbous


Last Quarter


Waning Crescent

h. Remind them that, all this time, their head/Earth is spinning through about 29 day-night cycles during the time it takes for one month/*moonth* to go by.

i. Note that there are 2 points during the cycle when the Moon is in a crescent phase (waxing and waning), a gibbous phase (waxing and waning), and a quarter phase (first and last quarter). Ask participants to verbalize what differentiates these [the sides of the Moon which are light or dark; the light part is always "pointing" towards the Sun]

3. Timing

a. Explain to participants that, to determine rising and settings times, they will need to use their periphery vision to determine when the light bub appears over their left/east shoulder and when it "sets" beyond their right/west shoulder.
b. Have participants figure out roughly what time of day the New Moon rises. [sunrise]
c. What time of day does the Full Moon rise? [sunset]
d. What time of day do first quarter and last quarter rise? [1st quarter=noon, last quarter=midnight)
e. What percentage of time is the Moon up during the day? [roughly half the time]

Moon Phases Timing

Day of cycle	*Phase*	*Rise (approximate)*	*High in Sky (approx.)*	*Set (approx.)*
0	New Moon	sunrise	noon	sunset
3.7	Waxing crescent	~ 9 AM	~3 PM	~9 PM
7.4	First Quarter	noon	sunset	midnight
11	Waxing gibbous	~3 PM	~9 PM	~3 AM
14.7	Full Moon	sunset	midnight	sunrise
18.4	Waning gibbous	~9 PM	~3 AM	~9 AM
22	Last Quarter	midnight	sunrise	Noon
25.7	Waning crescent	~3 AM	~9 AM	~3 PM
29.5	*New Moon*	*sunrise*	*noon*	*sunset*

4. General

a. Ask them if all people on Earth see the same phase of the Moon on any given day? [yes]
b. Do the people in the southern hemisphere see the same phase of the Moon as in the northern hemisphere [yes, except that it is upside down]

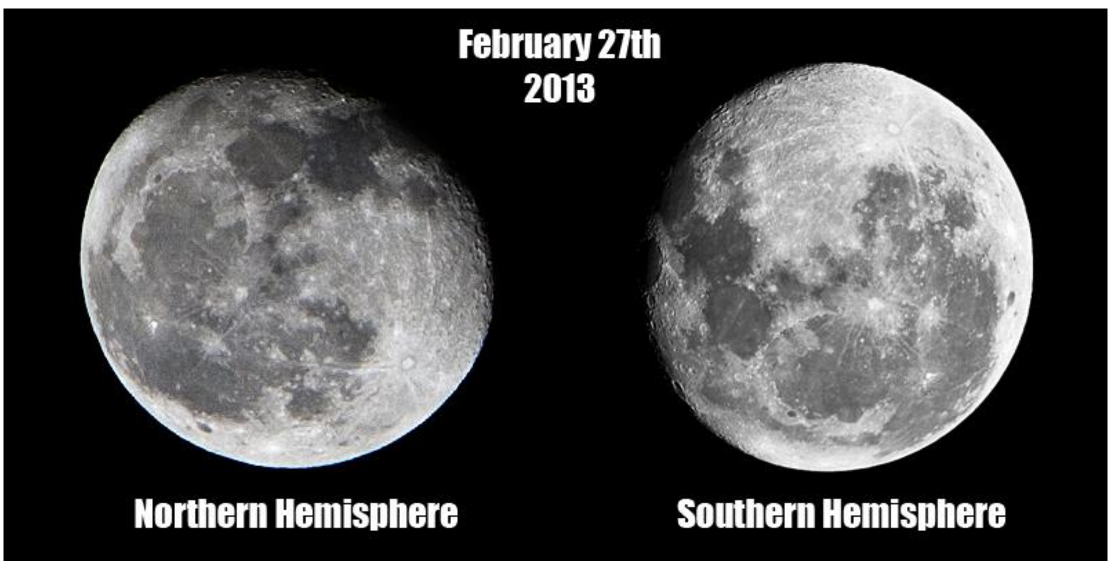


Image credit: *https://www.reddit.com/r/astrophotography/comments/19dx8z/last_nights_moon_from_the_southern_hemisphere/*

5. Eclipses

a. Have participants model a solar eclipse by placing the Moon, at noon, between the Earth & Sun. In what phase is the Moon? [new] [this is also how they observed the New Moon]

b. Model a lunar eclipse by placing the Earth between the Moon and Sun at midnight. This time, they should lower their Moon ball to fall into the Earth's shadow. In what phase is the Moon? [full]

c. How many people on Earth can see a total solar eclipse? Go back to the solar eclipse arrangement and refer to the small shadow that falls on people's faces when they are modeling a solar eclipse. [Only a few people on Earth fall into that shadow, so only a few can see the total solar eclipse.]

d. Go back to the total lunar eclipse. How many people can see a total lunar eclipse? [everyone on the night side, because the shadow covers the entire Moon]

e. Why don't we have solar eclipses and lunar eclipses every month? [the Moon's orbit is tilted so it rarely falls exactly in line with the Sun]

f. If you wish, show participants an image of a total solar eclipse (one is attached). During a solar eclipse, what color is the corona? [white]. Hence what color is the Sun? [white – see http://solar-center.stanford.edu/activities/SunColor/]

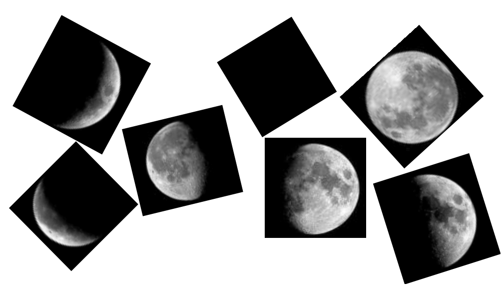
Credit: NASA/Cirtain

g. If you wish, show participants an image of a total lunar eclipse (one is attached). During a lunar eclipse, the Moon is often reddish. Ask your participants if they know why. [light is scattered through the Earth's atmosphere and only the long red & orange waves get through to illuminate the Moon – see http://solar-center.stanford.edu/activities/SunColor/What-Color-is-the-Sun.pdf]

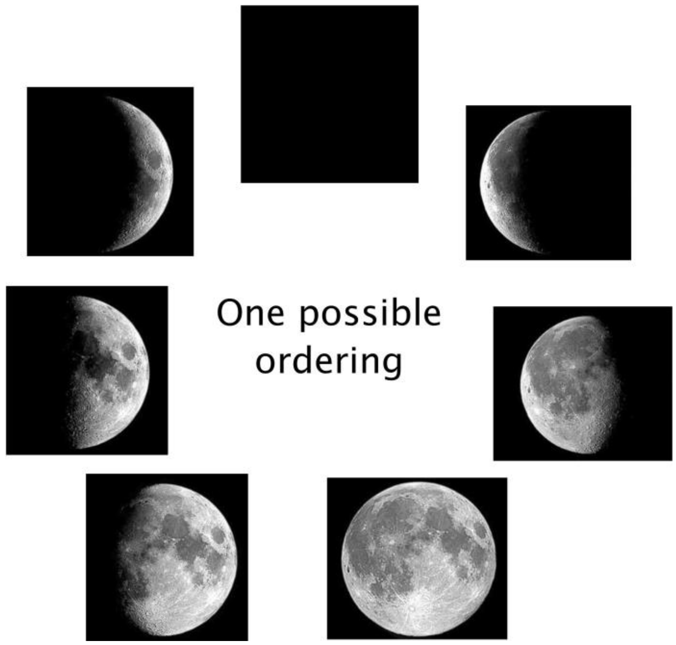
Credit: Heribert Propepper / Associated Press File

6. Firming up the Information (could also be used for assessment) by Ordering Moon Phase Imagery

a. Divide participants into pairs.
b. Copy a sheet of the Ordering Moon Phases imagery (attached) for each pair. Either cut out the images beforehand, or have participants cut them out. If you wish to reuse the cards, you could laminate the sheet before cutting.



c. Ask participants to arrange the imagery in the order of the Moon phase cycle. They may start with any phase they want. It might help if they arrange the imagery in a circle.
d. Have participants discuss order with their pairs and come to a consensus.
e. Have pairs report to the group. Are there different interpretations?



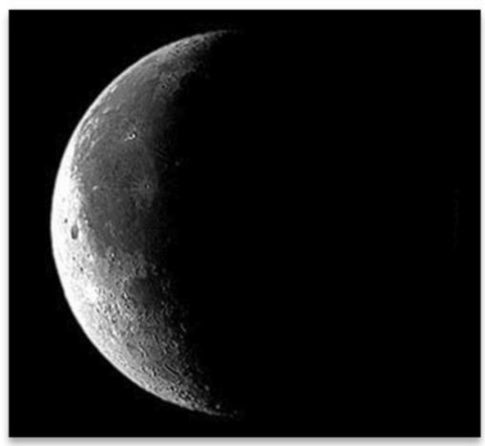
Going Farther:

a. In what season does the Moon get highest in the sky (northern hemisphere)?
b. Where does the Moon rise at the equator? At the poles?
c. Does the Moon rise & set at the same places along the horizon each day? If so, how long does it take for the Moon to go from its most northern rising point to its most southern rising point?

Resources:

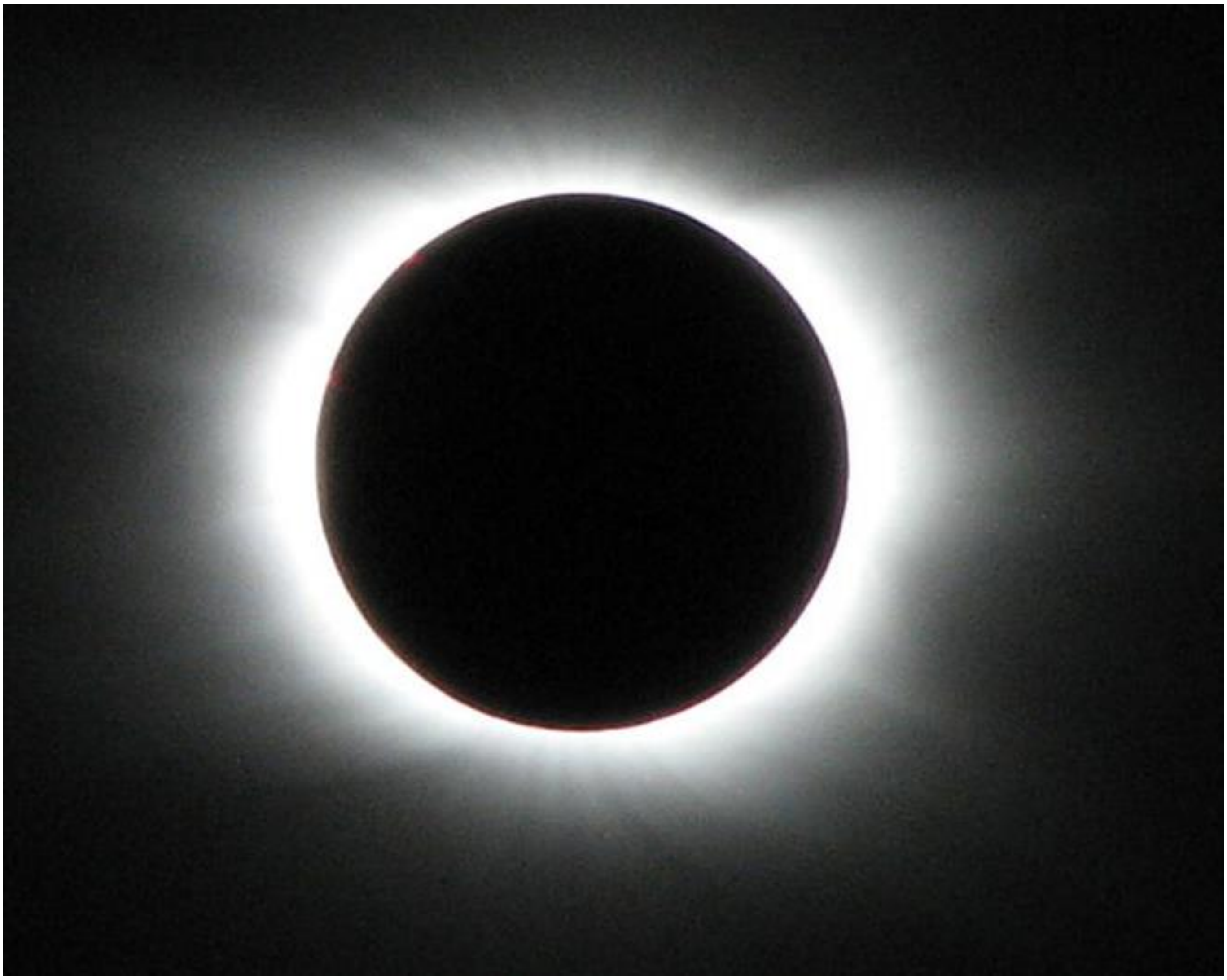
This activity is inspired by one that was taught to a collection of Project Astro participants. It was developed by Dennis Schatz and originally described in “Astro Adventures”, a publication of the Pacific Science Center. It is also available through the Astronomical Society of the Pacific, as part of their *Universe at Your Fingertips* DVD. It is highly recommended that teachers purchase one of these write-ups for doing the complete activities:
http://www.astrosociety.org/education/the-universe-at-your-fingertips-2-0/
or
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAAahUKEwiTrZ3qlrvHAhVQKYgKHSDkBBM&url=https%3A%2F%2Fwww.pacificsciencecenter.org%2Fwp-content%2Fuploads%2Fastro_adventures_order.pdf&ei=AqDXVZOkA9DSoASgyJOYAQ&usg=AFQjCNGqb_1F-qvHqt0jXCNdBpuR3uDoGA&sig2=EukJnLFQIgyZB-DRn27UYA

Ordering Moon Phases



East	West
East	West
East	West
East	West

Total Solar Eclipse

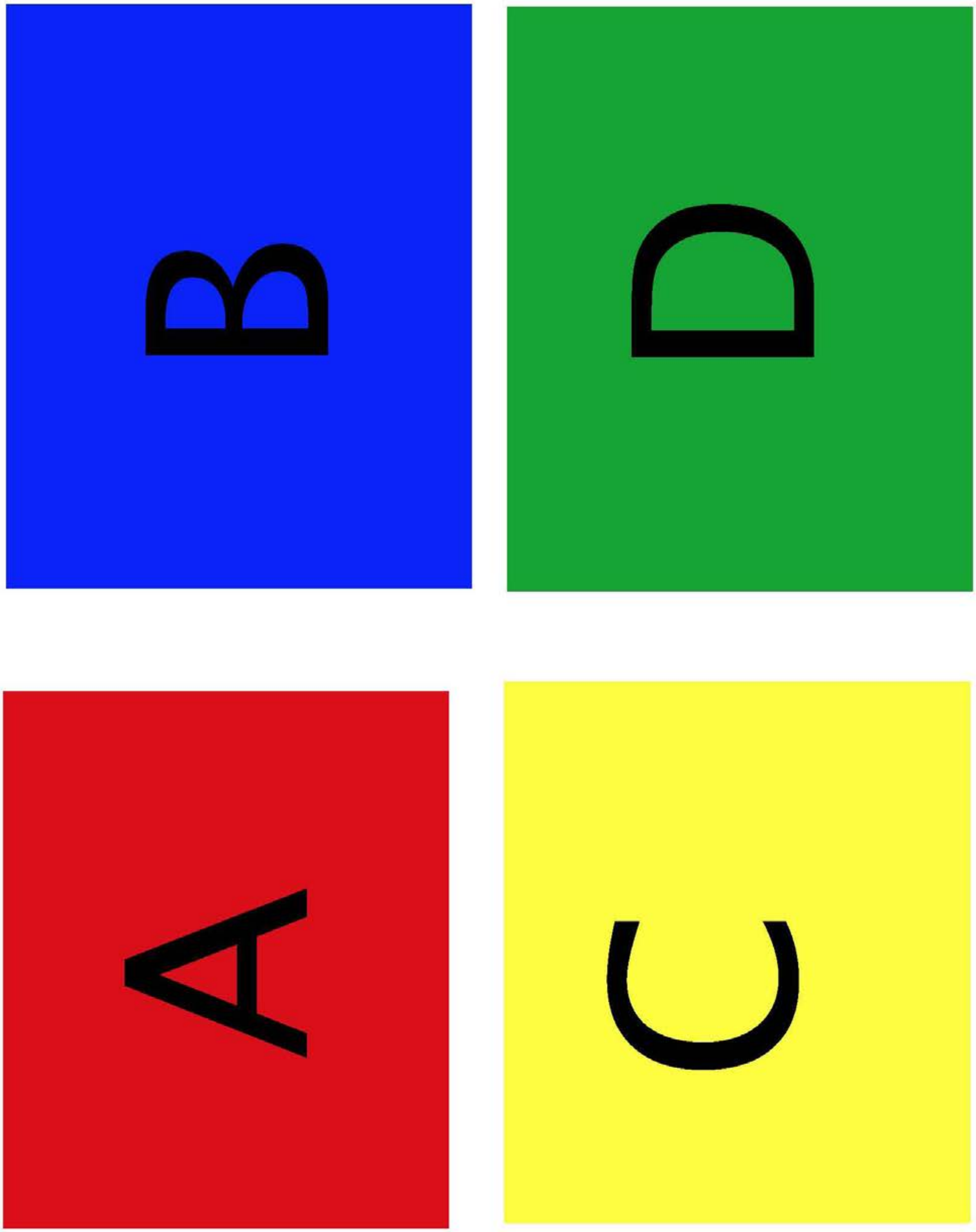


"NH53 - Outer corona (by)" by NH53 - Outer coronaUploaded by ComputerHotline. Licensed under CC BY 2.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:NH53_-_Outer_corona_(by).jpg#/media/File:NH53_-_Outer_corona_(by).jpg

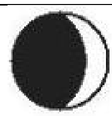
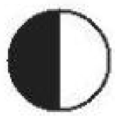
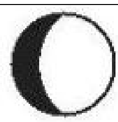
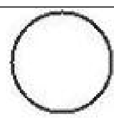
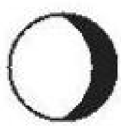
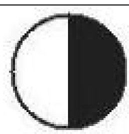
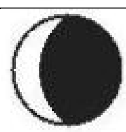
Total Lunar Eclipse

Photo: Wiki commons

Appendix B - Signal Cards



Appendix C - Moon Phase *Approximate* Rise/Set Times

Day of cycle	*Phase*	*Rise (approximate)*	*High in Sky (approx.)*	*Set (approx.)*
0	 New Moon	sunrise	noon	sunset
3.7	 Waxing crescent	~ 9 AM	~3 PM	~9 PM
7.3	 First Quarter	noon	sunset	midnight
11	 Waxing gibbous	~3 PM	~9 PM	~3 AM
14.75	 Full Moon	sunset	midnight	sunrise
18.4	 Waning gibbous	~9 PM	~3 AM	~9 AM
22.1	 Last Quarter	midnight	sunrise	noon
25.8	 Waning crescent	~3 AM	~9 AM	~3 PM
29.5	*New Moon again*	*sunrise*	*noon*	*sunset*

Appendix D – Resources

Universe at Your Fingertips DVD:

This activity is inspired by one that was taught to a collection of Project Astro participants. It was developed by Dennis Schatz and originally described in "Astro Adventures", a publication of the Pacific Science Center. It is also available through the Astronomical Society of the Pacific, as part of their *Universe at Your Fingertips* DVD. It is highly recommended that teachers purchase one of these write-ups for doing the complete activities:
http://www.astrosociety.org/education/the-universe-at-your-fingertips-2-0/
or
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAAahUKEwiTrZ3qlrvHAhVQKYgKHSDkBBM&url=https%3A%2F%2Fwww.pacificsciencecenter.org%2Fwp-content%2Fuploads%2Fastro_adventures_order.pdf&ei=AqDXVZOkA9DSoASgyJOYAQ&usg=AFQjCNGqb_1F-qvHqt0jXCNdBpuR3uDoGA&sig2=EukJnLFQIgyZB-DRn27UYA

Activities and Information about the Moon:

http://nasawavelength.org/ - search on "moon"
http://moon.nasa.gov
http://www.nasa.gov/moon
http://www.nasa.gov/topics/moonmars
http://nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html

NASA Lunar Missions:

http://nssdc.gsfc.nasa.gov/planetary/lunar/lunartimeline.html (All)
http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2013-047A (LADEE)
http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2011-046A (GRAIL)
http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2007-004B (THEMIS-B / ARTEMIS-P1)
http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2009-031A (LRO)
http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2009-031B (LCROSS)