Lesson 1: Images of the Moon

Everyone has a mental image of the Moon. Often this is a single image, like the full Moon. This activity is a pre-assessment of students' existing knowledge of the Moon's appearance that will make their observations in the following lessons more meaningful.

Concepts

Students share their prior understanding and beliefs about the Moon and its phases.

Objectives

Students will:

- draw their mental image of the Moon;
- analyze images drawn by different students;
- predict the sequence of the Moon's phases based upon prior knowledge using lunar photos;
- recognize that the Moon's appearance changes; and,
- question how and why the Moon's appearance changes.

Materials

- Blank paper
- Lunar photographs (Set #1)
- Scissors
- Tape or glue
- Astronomy Notebook

Procedures

1. Distribute one blank sheet of paper per student. Ask the students to close their eyes and create a mental picture of what the Moon looks like to them. Have them draw this mental image on their blank papers.

2. In small groups of three or four, have students compare their pictures. Discuss why the pictures vary (if they do).

   Teacher's Note: You and other students should not judge the appropriateness of each drawing or the student's reasons for his or her drawing. Use the drawings and discussion as clues to student preconceptions about the Moon.

3. Have students post their drawings in the front of the room so all students can view them. Through an open discussion comparing the drawings, ask students "What questions do you have about the Moon?" Guide students to pose questions they might be able to answer through observing the Moon over several weeks.

Some of the questions that might be brought forth are:

- Does the Moon have different shapes?
- Why does the Moon's appearance change?
- What causes its changing shapes?
- How long does it take to change?
- When can you see the Moon's different shapes?
- Is there a pattern to the changing shapes?
- Does the face of the Moon always have the same features?

4. Once it has been established that the Moon changes shape or has phases, distribute copies of the lunar photographs, tape or glue, scissors and a blank sheet of paper to each work group. Their goal is to place the photographs on the sheet of paper in the order they think they would see them if they observed the Moon throughout several weeks. Allow 10 to 15 minutes for discussion and decision making.

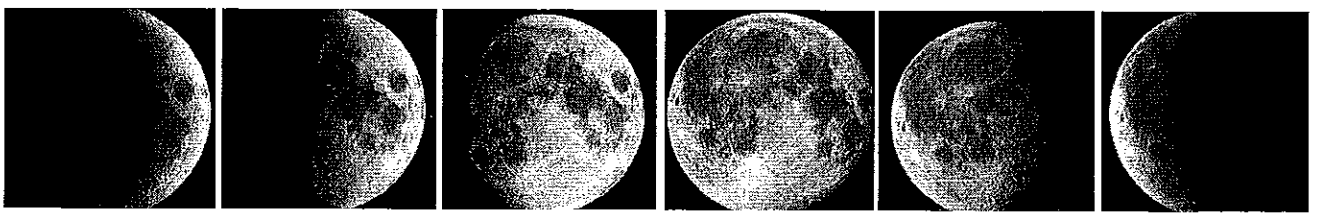
5. Once each group is satisfied with the order of the photos, students should tape or glue them to the blank sheet of paper. Number the pictures from one to six in the order each would be seen. Be sure to indicate which way is up.

6. When all of the groups have completed their photo sequences, have them move around the room to see the predictions of other groups. Ask work groups to explain their reasoning for choosing the sequence they used. These reasons should not be judged for appropriateness since the students are only presenting their best guess. During the post-assessment using this activity (Lesson 3), students should have a much better grasp of the order of the photos and the reasons for that order.

7. The students' predictions should be posted on a wall of the room for ongoing reference during Lesson 2. Alternately, one member of each work group can keep the team's photo sheet in his or her Astronomy Notebook for later reference.

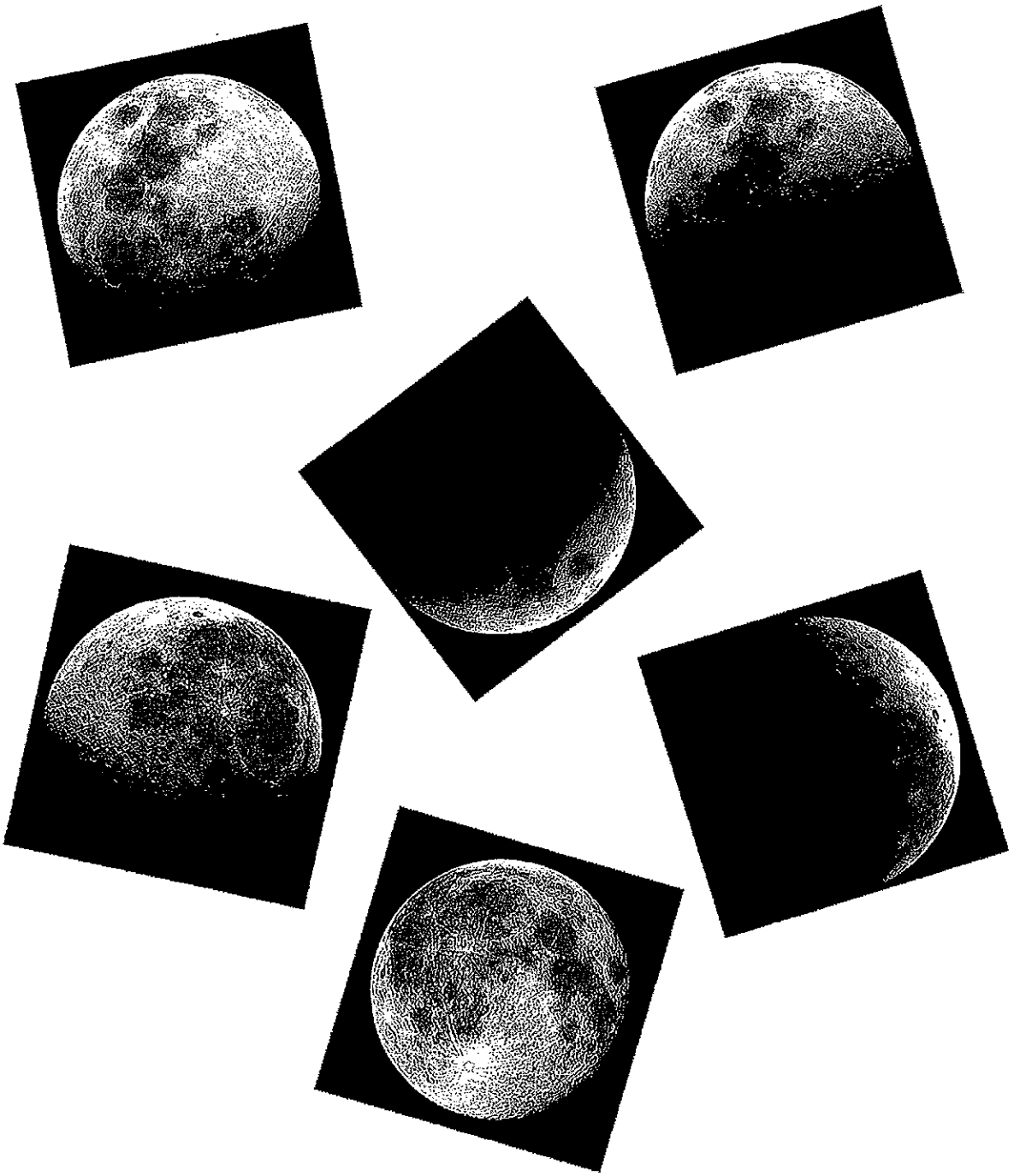
Teacher's Note: Students will want to know the "right" answer to sequencing the Moon photographs and also will want to discover the answers to some of the questions raised during the class discussion. It is important not to share the right answer at this point, but to use Lesson 2 as a means for students to discover the correct order of the photographs.

Set #1 — One Possible Order of Moon Phase Photos



Lunar Photographs – Set #1

Cut out each picture. Arrange them in the order you would expect to see the Moon during the next several weeks.



Lesson 2: Observing Phases and Features

Lesson 1 gave insight to student images of the Moon and the variations perceived by different students. These differences provide motivation to explore this phenomenon in depth. In this activity, students are challenged to investigate firsthand the phases of the Moon. Students also learn more about the features we can observe on the surface of the Moon. Students will observe the Moon over a one-month period and record their observations. The Lunar Observing Record Chart in this activity helps students keep track of their observations.

Concepts

The Moon follows a specific pattern of phases that can be observed and recorded.

Objectives

Students will:

- make a daily record of Moon observations;
- use their observations to begin developing an understanding of the sequence of lunar phases; and,
- use their observations to understand that we always see the same Moon features from Earth.

Materials

- Lunar Observing Record Chart (Each student will need two charts for the 4 weeks of observations.)
- Pencil
- Binoculars (optional)
- Clipboard or other firm writing surface
- Astronomy Notebook

Procedure

Advanced Preparation

Make copies of the Lunar Observing Record Chart. Look in an almanac, daily newspaper, on the Internet or on a calendar to determine when the first quarter Moon will be visible for the month in which you are planning to do this activity. It is best to start this activity two or three days before the first quarter, when the Moon will be in the western sky in the afternoon and evening. This will allow you to take students outside near the end of the school day to make your first observation together. It may be started at any time, but certain phases work better for making observations during times when students are outside or awake.

1. Plan to begin this activity on a clear day when you can see the Moon in the sky. The first quarter Moon is visible in the afternoon. Students may not realize that the Moon is often visible in the daytime as well as at night. This will allow you to help students do some daytime observations during the early part of this activity. With your assistance, students will be able to use their skills to make nighttime observations in the coming weeks when the Moon is not visible in the daytime sky.

2. Distribute copies of the Lunar Observing Record Chart. Tell the students they have an opportunity to explore some of the questions they asked in Lesson 1 by observing the Moon over the next two to four weeks.

   Teacher's Note: If time constraints or the weather do not allow the students to observe the Moon for a full month, they should be able to begin determining the pattern of the phases after about 10 observations. When the weather is a problem, students can use resources (newspapers, the Internet, computer simulations) to complete their observation charts. You can choose to have students do research about the phases or use a computer simulation program to develop an understanding of the phases, but having the students actually make the observations themselves is a much more powerful learning experience.

3. Explain how the Lunar Observing Record Chart is used:
   - Go outside as a group and locate the Moon. Record the date, time of the observation, the Moon's location in the sky and its shape.
   - Have students go out every clear day and repeat their observations. After the first observation, make a class activity of predicting what phase the Moon will be in before the next observation.
   - It is helpful to summarize daily observations on a classroom copy of the Lunar Observing Record Chart that can be posted on a wall. An alternative to this is to have one student each day draw a picture on construction paper of the class's observations for the previous day. These could be posted daily in consecutive order to allow the students to see the pattern of the phases emerge throughout the activity.

4. Students can work independently during the two to four weeks of observing, but brief teacher checks should be made on how their observations are progressing.

5. Since you want students to include the surface features of the Moon in their observations, this is a good time to introduce the vocabulary for the different features visible, such as craters, maria and rays. You also should introduce the vocabulary that is used to describe the different phases. These would include new, full, waxing crescent, waning crescent, third quarter, first quarter, waning gibbous and waxing gibbous. This terminology is detailed in the diagram below and in the background material. An overhead or copies can be made of the labeled picture of the full Moon found at the end of this unit to help students learn the terminology. It is not recommended that students be required to learn the names of specific features found in the picture.

New | Full | Waxing Crescent | Waning Crescent | Third Quarter | First Quarter | Waning Gibbous | Waxing Gibbous

Lunar Observing Record Chart

Directions: Find the Moon in the sky. Record the date, time, location in the sky and any observable features. Shade the circle to show the Moon's appearance.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____
Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____	Date_____ Time_____

Lesson 3: What Did We See?

Students have now seen the Moon change its shape over time and have observed some of the features on the surface of the Moon. This lesson is an embedded assessment of students' understanding and interpretation of what they have observed. By challenging them to explain what they think causes the phases, students must again explore their own theories.

Concepts

The Moon follows a specific pattern of phases. Observable characteristics can be used to identify features of the lunar surface.

Objectives

Students will:

- infer the sequence of the Moon's phases using lunar photos based upon their observations; and,
- make predictions about the cause of the Moon's phases.

Materials

- Lunar photographs (Set #2)
- Scissors
- Pencil
- Tape or glue
- Sheets of blank paper
- Astronomy Notebook

Procedure

Advanced Preparation

Make copies of the lunar photographs – one for each student and one for each group of two or three students. They will be doing the activity first individually and then in small groups. Take down any posted records of the daily observations from Lesson 2 or the predictions from Lesson 1.

1. Distribute copies of the lunar photographs, tape or glue, scissors and a sheet of blank paper to each student. Have students cut out the photographs. Their goal is to place them on the sheet of paper in the order they think they would see them if they observed the Moon throughout several weeks. Allow 5 to 10 minutes for them to work with the photographs. They should work individually.

   Teacher's Note: This exercise is an assessment of your students' data interpretation. They have already done this activity with a different set of photos in Lesson 1. Students should now be able to order the photographs from their lunar observations. If students have difficulty, ask questions to find out why they are having difficulty. This will help you determine the additional work students might need in making, recording and interpreting their observations.

2. Once each student is satisfied with the order of the photos, they should tape or glue them to the blank sheet of paper. Have them number the pictures from one through six in the order each would be seen. Be sure to have them indicate which way is up.

3. Have students get together in small groups and compare their sequencing and orientation of the pictures. Encourage discussion of whether one sequence is more appropriate than another. Their reasoning should be based on their class observations of the Moon over the past four weeks.

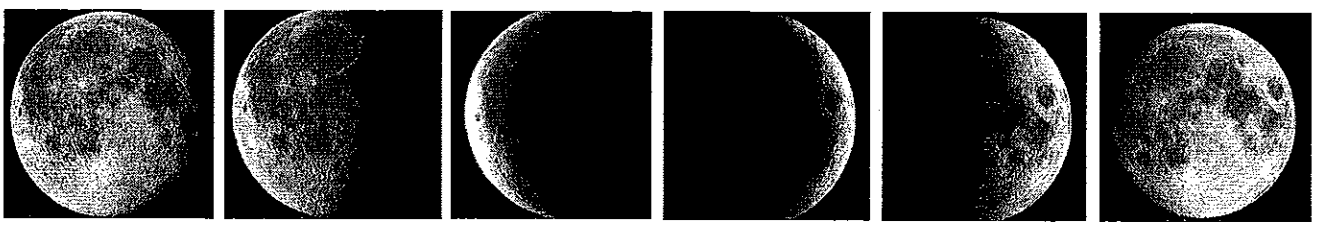
   Teacher's Note: Students may begin to notice details of the features of the Moon that they did not notice when they were making their observations of the Moon. There is no one correct beginning to the sequence of pictures since the phases occur in a cyclical pattern. Many students will probably put the pictures in the order in which the Moon observations were made, but you can start anywhere in the cycle for placing the pictures in order.

4. Give each group another page of photos and a blank piece of paper. Have them come to a group consensus about the sequence and orientation of the pictures. Once they agree, they should glue the pictures onto their blank sheet of paper. One representative from the group can present the group's ideas to the class and the group picture sets can be posted. Have students periodically review the photographs during Lesson 4 to determine whether they want to revise their predictions.

5. In their Astronomy Notebooks, have students individually write what they think causes the phases of the Moon. Encourage diagrams if that helps, but there also should be a written explanation. Groups of students may then discuss their conjectures or a class discussion can be held.

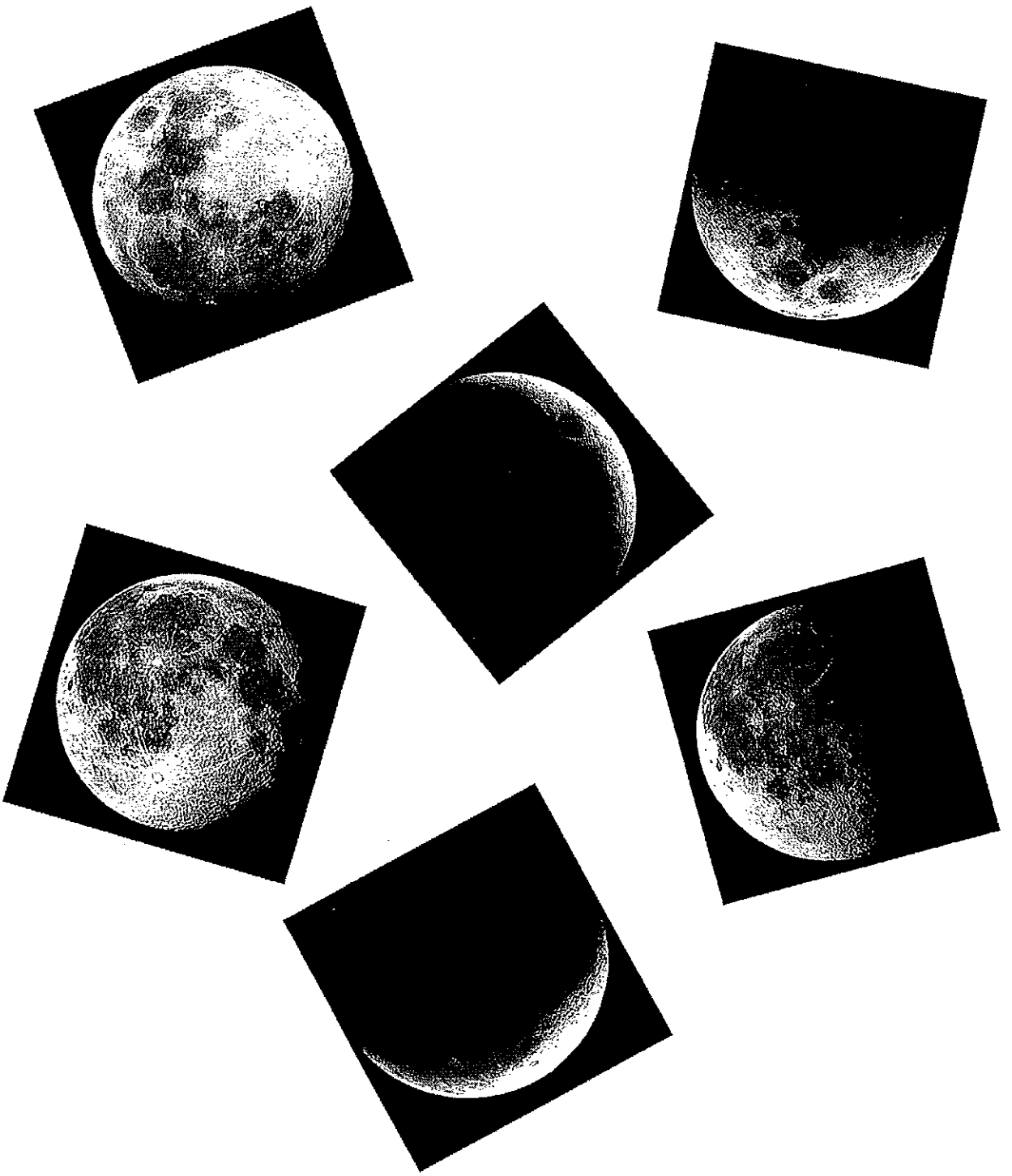
   Teacher Note: Students should be encouraged not to be critical of other students' ideas of what causes the phases of the Moon. No one in the class has any firsthand knowledge at this point to say exactly what causes the phases. All conjectures are legitimate. This final exercise is an embedded pre-assessment for the next lesson. Through these explanations you will be able to identify the types of theories held by your students. With this knowledge you will be able to direct your questions in the next activity to challenge each student's thinking.

Set #2 — One Possible Order of Moon Phase Photos



Lunar Photographs – Set #2

Cut out each picture. Arrange them in the order you would expect to see the Moon during the next several weeks.



Lesson 4: Modeling Moon Phases

This activity allows students to use models of the Sun, Earth and Moon to discover why Moon phases occur.

Concept

The observed phase of the Moon is determined by the Moon's position relative to Earth and the Sun.

Objectives

Students will:

- be able to state the order of the Moon's phases from one full Moon to the next; and,
- demonstrate how the Moon's position around Earth creates the phases.

Materials

- Light bulb on a stand or clamp (or a lamp with its shade removed)
- Extension cord
- One Styrofoam ball or light-colored sphere for each student (as a model Moon)
- Pencil and paper
- Darkened room
- Copies of the Moon Phases Activity Sheet (one per student)

Procedure

Advanced Preparation

Be sure that there is plenty of space for students to stand and move about as they work through this activity. Check that the lamp or light bulb for the model Sun works properly and that it can be placed high in the front of the room where everyone can see it. The room will need to be completely dark for this activity.

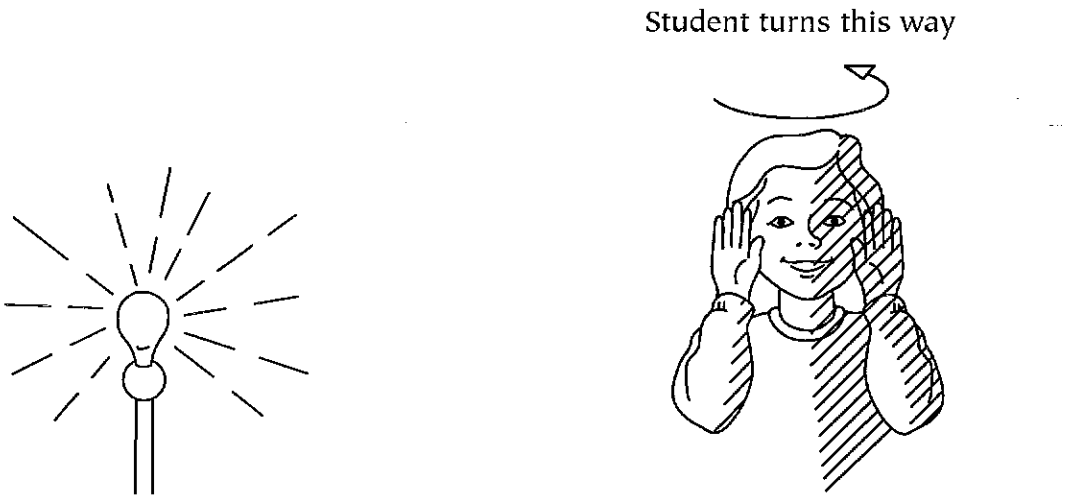
1. Review the results of Lessons 2 and 3, which showed that the Moon goes through a sequence of phases. Work with the students to review the order of the phases from one full Moon to the next. Discuss some of the students' predictions about what causes the phases of the Moon.

2. Since we cannot go into outer space to observe the Moon orbiting Earth and the phase changes, we will be using a model to learn what causes the Moon phases. Place the lamp in front of the room. Remind students of safety near the hot light bulb and electrical cord. Have students stand in a semicircle facing the lamp. Spread them out enough so the light from the lamp reaches each student. Remind students that this activity will be an extension of the Earth-Sun system that was investigated in the previous unit. As with the prior unit, the lamp represents the Sun and their heads represents Earth with their noses being the students' hometown.

3. Review the model developed in the Sun Watching Unit. Ask students to stand so it is noon in their hometown (noses at noon.) If disagreement occurs as to what position this would be, have students discuss it until it is agreed that noon is when their nose is pointed toward the "Sun." You may want to explain the term "high noon." Next, ask them to stand so it is midnight at their noses. They should turn so that they face away from the Sun.

   Students should recall which way Earth rotates on its axis from the Sun Watching unit. If students do not remember, you will need to review a few things. Determine which way is north, south, east and west for their Earth-heads. If their hometown/nose is in the Northern Hemisphere, north is the top of their heads, south will be their chins, east will be to their left and west to their right. From prior knowledge and their Moon observations, they should know that the Sun rises in the East. Have the students place their open hands on the sides of their heads, acting as horizon blinders. Have them determine which way Earth rotates so that the Sun rises over their left (eastern) hand. After some trial and error, they will be able to determine that Earth rotates from right to left in their model, with their right shoulder moving forward. (See illustration below.)

   Ask students to stand so it is sunrise and sunset. Practice the ideas of sunrise, noon, midnight and sunset until you feel that the students have a good understanding of these relative positions. Spending time to develop this part of the model is very important. You can evaluate the students' understanding by asking for odd times of the day or night. For example, ask them to turn so it is 3 a.m. or 3 p.m. Reinforce the knowledge that as students turn through 24 hours they will make one complete circle. This will be important for them to keep in mind during the next activity. The revolution of the Moon in its orbit of Earth takes about 29 days. This means for us to see all of the Moon's phases will also take about 29 days. During this same time period Earth has spun 29 full turns.



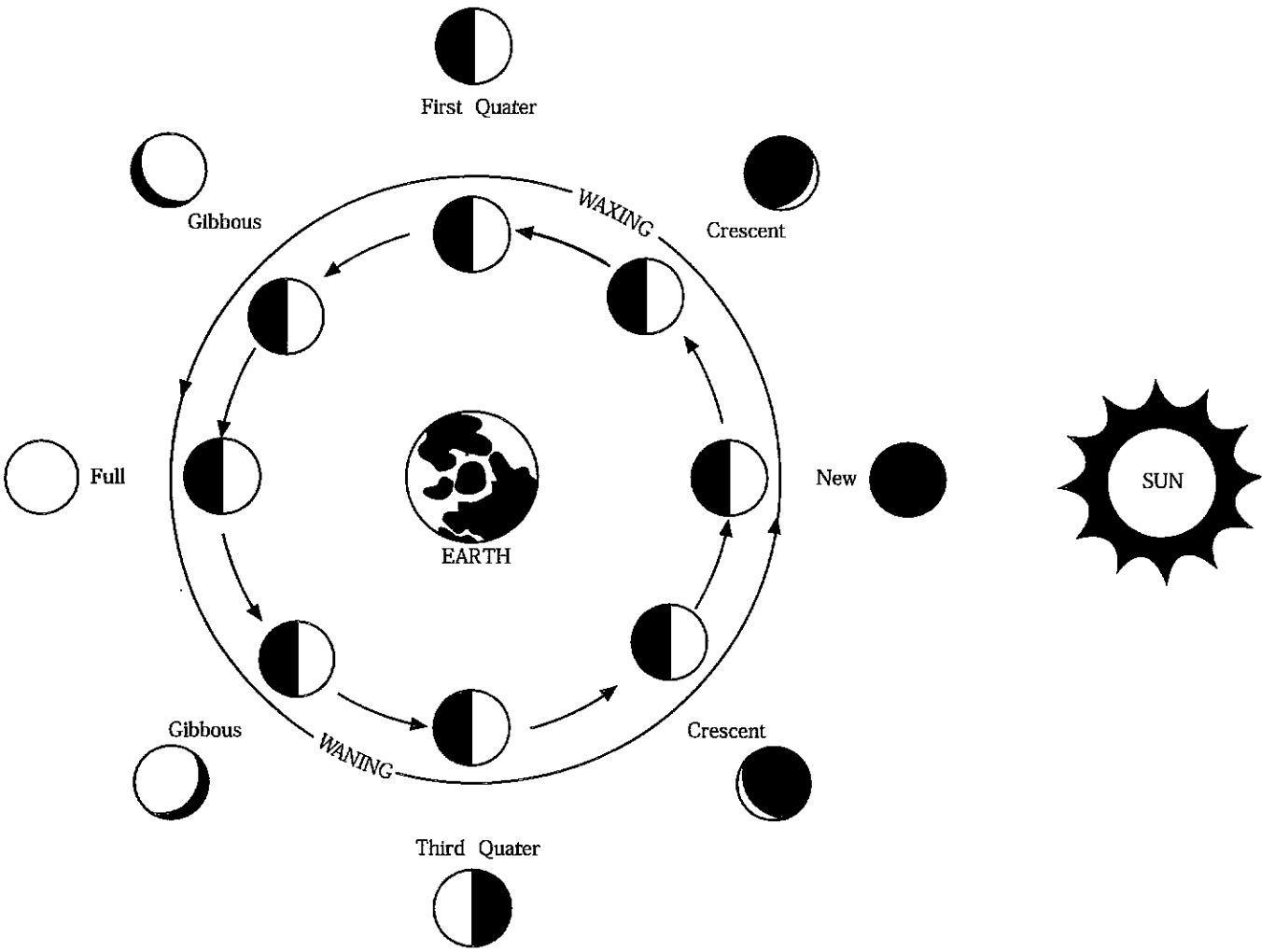
Light bulb represents the Sun. Student's head represents Earth. Hands are "horizon" blinders to help see sunrise and sunset. Local (nose) time for the child in this model is around 6 p.m.

4. Distribute one Styrofoam-ball "Moon" to each student. Stick a pencil into the ball to make it easier to hold and to observe the phases of the Moon model. Have students hold the model Moon at arm's length. Allow time for students to explore how the Sun's light reflects off the model as they place their Moons in different positions around their Earth/head. Help students find a few of the phases of the Moon with which they are already familiar, such as a full Moon, a new Moon and first and third quarters. A new Moon occurs when the Earth, Moon and Sun are aligned with the Moon between Earth and the Sun. A full Moon occurs when the three bodies are aligned but Earth is between the Moon and the Sun. See the diagrams that follow for a visual representation of the proper positions for the different phases.

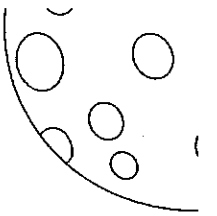
   Students need to develop the notion of the path of the Moon as it orbits Earth. There is a common misconception that Earth's shadow causes the phases. Students who are trying to produce the different phases by hiding parts of the Moon with their head's shadow need to address this. They will come to recognize, possibly with some assistance, that they cannot generate the exact shape of the different phases by using the shadow of Earth. They will need to determine through discussion and modeling that the Moon takes about 29 days to complete one orbit. During these 29 days each phase will be visible for approximately one 24-hour period.

Moon Phases Diagram

The inner sequence shows the Moon's relative position to Earth and the Sun as viewed from outer space, above the solar system. Students are asked to produce this diagram on the "Moon Phase Activity Sheet."



The outer sequence shows the Moon as seen from Earth. For example, you would see the waning crescent (lower right) as a small slice of the Moon illuminated on the left side. A waxing crescent, upper right, would have the right side of the Moon illuminated.



Teacher's Note: Students will have many questions as they explore. Try not to answer their questions directly—encourage them to explore using the model. One question that usually comes up and must be addressed early is how high the model Moon should be held. If it is held at head height there will be an eclipse (instead of a full Moon) during each orbit of the Moon around the student's head. Help the students develop the idea that they did not observe a lunar eclipse during Lesson 2 and generally people make a big deal about eclipses. Therefore they probably do not occur every month. Students should then decide they have to hold the Moon balls up high so the Moon balls are exposed to the Sun's light throughout their orbit around Earth. (The phenomenon of eclipses is an advanced topic. It is recommended that elementary students explore the phenomenon, but they will not be able to construct a complete understanding of how often eclipses occur until middle school or beyond.)

6. After students explore finding the phases, choose one lunar phase and ask the students to determine what position in the Moon's orbit they must place their Moon in order to achieve that particular phase. Full Moon is a good phase with which to start. Encourage students to compare their positions and discuss differences. Ask one student who has the correct position to state why it is correct. As the teacher, you can check for understanding by seeing if all of the students are holding their Moons in the same position. When looking at other peoples' Moon models, students should notice that at all times one-half of the Moon is illuminated by the Sun.

7. Have students model other phases; for example, first quarter, third quarter and new Moon. Use the terminology introduced in Lesson 2 when requesting a particular phase, such as waning gibbous, third quarter, etc.

8. Allow time for students to experiment with the movement of the Moon. They can observe their own model as well as other students' models. This activity is very powerful and can answer many questions that the students generate about the Moon.

   Teacher's Note: Students may find it helpful to change the model slightly to answer certain questions. If one student holds the Moon ball and another student "plays" Earth, they can more easily see Earth spinning on its axis while the Moon is barely moving in its orbit. How much of a circle does the Moon move each 24 hours? About $1/29^{th}$ of a circle. So everyone on Earth basically sees the same phase on the same night.

9. Have students work together to complete the Moon Phases Activity Sheet. The goal of completing the sheet is to produce a diagram similar to the one on the preceding page. These drawings should be kept in their Astronomy Notebooks.

10. After completing the diagrams, ask students to write down in their Astronomy Notebook the causes of the changing Moon phases. (The spinning Earth—your head—makes the Moon rise and set each day, but this does not affect the phase of the Moon. Movement of the Moon around Earth and the relative positions of the Sun, Earth and Moon cause the phases.) Encourage them to use diagrams in their explanations.

11. Check student diagrams and explanations for the causes of phases. Ask students if they are sure that their observations and the model support their diagrams and statements. If discrepancies arise, have students go back to the model to further clarify the concepts.

Going Further

Advanced students may want to consider how their observations of the Moon would vary if they lived in the Southern Hemisphere, for example, in Australia. This is a difficult problem for elementary level students, but a nice one that will encourage open-ended study.

Moon Phase Activity Sheet

This diagram represents a view you would see when looking down from above at your head when you are modeling the Moon orbiting Earth. Darken the areas on each Moon that are not illuminated by the Sun. Then label each Moon phase as you would see it when your nose (on Earth) is pointed directly at it.

Moon Phase Terms: New Moon, Full Moon, First Quarter, Third Quarter, Waxing Crescent, Waning Crescent, Waxing Gibbous and Waning Gibbous.