Lunar Phases Curriculum Pack

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The ***Astronomy For Educators Workshop*** will be held on December 2nd (Elliptical Orbits), December 9th (Exploring Lunar Phases), and December 16th (Exploring the Lunar Surface).

The workshop focuses on Dr. Barth's ***Low-Cost Science*** methods for teaching astronomy and space science. The intent of Low-Cost methodology is to enable every school, teacher, and student to enjoy a quality astronomy education without significant expense. Dr. Barth believes that a quality STEM education is the right of every child – and that no one should lack a powerful STEM experience because funding for expensive lab equipment is lacking.

Comments, and reviews of these materials may be posted on social media, or emailed directly to Dr. Barth. Questions about the activities may be addressed to Dr. Barth at: AstronomyForEducators@gmail.com

About the Author:

Dr. Daniel E. Barth is Assistant Professor of STEM Education at the University of Arkansas, USA. Dr. Barth has more than 40 years of experience teaching astronomy and physics at secondary and university levels, and training STEM educators in the United States. Dr. Barth has been a Reagan Scholar, Research Corporation Fellow, and Science is for Kids Foundation Fellow. Dr. Barth's work has been recognized by UNESCO, the Amgen Award for Science Teaching Excellence, the Global Campus Award, and more. Published works include:

Science Texts:

Astronomy for Educators

Observational Astronomy

Teaching Science Through Literature

Fiction:

Maurice on the Moon

The Doomed Colony of Mars

Crisis on the Far Side

Revolt in Volkov Crater

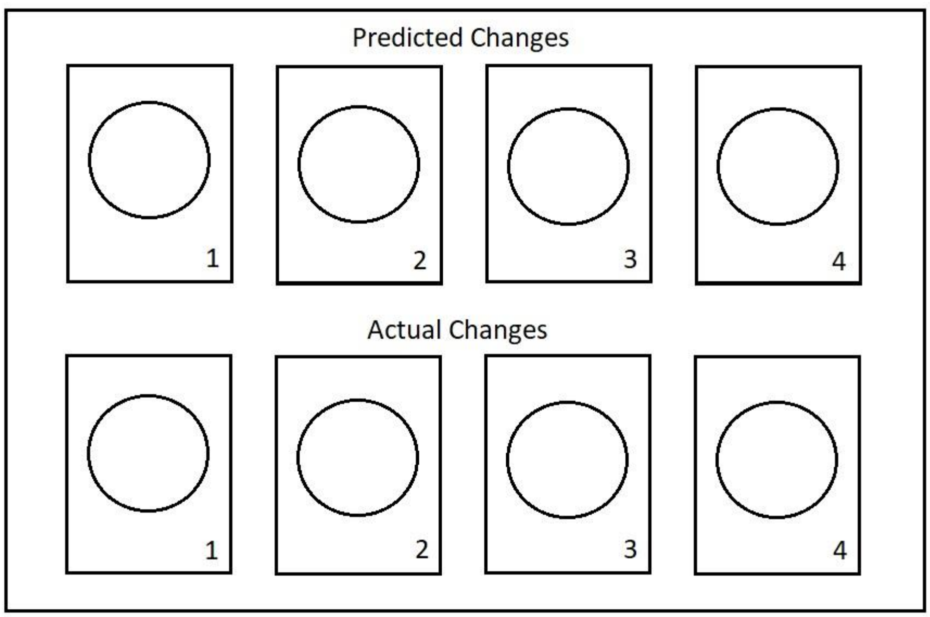
Predicting Lunar Phases

One of the crucial questions that we face as teachers and home school parents is: 'How do I provide high quality science instruction?' This question really breaks down into two parts. First, can we provide quality STEM activities that children (and parents!) can understand? Second, can we afford to do this?

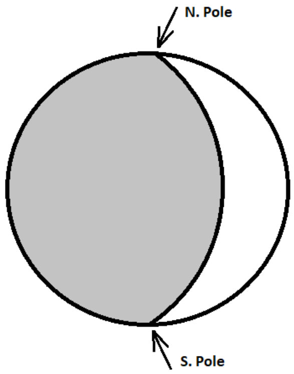
I believe that the answer to both questions is an unequivocal 'Yes!' Let's take a look at a typical assignment a teacher or home school parent might conduct either in general science, or in astronomy and space science curriculum: understanding the lunar phases.

The response of many educators, both face to face (f2f) and remote delivery is to assign a video for students to watch. There are a wide variety of such videos available, some are excellent, many are poor; however discussing the quality of videos misses the point – all are grossly inferior to engaging the child in a hands-on activity and exploration. No matter how we deliver them, we cannot simply throw facts at a child and expect that they will develop a sound, conceptual understanding of anything.

Let's start with some very simple activities that will engage the student in the study of the night sky. This first activity requires just pencil and paper, and is best conducted during the ***waxing moon***, the 2-week period when the Moon grows brighter and more fully illuminated each night. The waxing moon is also visible each night just after sunset, meaning that students don't have to stay up late. (See the end of the article for dates and a printable activity sheet.)



This generally starts with the parent or teacher showing the child what the Moon looks like tonight. The student copies the phase of the Moon by drawing the ***terminator***, the line that separates light and shadow. For our purposes, always draw the terminator starting at the top or 'north pole' of the Moon, and finishing up at the bottom, or 'south pole of the Moon.



Drawing the Moon in its ***waxing crescent phase*** as it appears just 2-3 days after the new moon illustrates several things to the student. It is often easy in the crescent phase to see the entire disk of the Moon. This shows us that the shape of the Moon itself does not change (the Moon is always a sphere), but the amount of the Moon illuminated by sunlight does change.

With careful observation we can see that the ***terminator*** always stretches 180 degrees – from the Moon's north pole to its south pole – no matter how the Moon appears tilted with respect to our horizon.

The next step is to ask the student to draw in the top row of boxes what they think the Moon will look like over the next 7-10 days. I ask my students to do this ***in ink***, so that the prediction cannot be changed. Standards-based education has given students a tremendous fear of 'being wrong'. This is an excellent opportunity to teach students ***about science culture.*** We do not do science to prove ***we are right,*** rather we do science ***to become more right.*** Every student should be praised for their prediction – it is the effort (and the risk!) that must be rewarded here, not a 'correct answer'!

Over the next week or so, the students can go outside every 2-3 days and look at the Moon, sketching the phase that they see in the boxes in the lower row. This process provides several valuable insights to everyone involved. Science is not an instant process; it cannot always be boiled down into a 1-hour activity suitable for a single class period. Students will have to contend with clouds and weather, too; science sometimes proceeds from incomplete data! Although the sky is our laboratory, we do not control it. Our young scientists must plan their observing time and go out when the Moon is visible; the phenomena will not wait for us and there is no redo button!

It is fascinating when the week of observing is over to compare what we thought would happen to what we actually observed. Once again, it is critical at this point for the teacher or parent to emphasize what we have learned about the Moon and its phases instead of looking for easy 'right vs. wrong' answers. Remind the child that in science, ***virtually all first predictions are incorrect!*** Science is an adventure in learning more precisely how the world works!

Modeling Lunar Phases

If you have completed the project ***Predicting Lunar Phases***, the next step is to think about making a model of the entire cycle of lunar phases. This cycle is called a ***lunation***, and it takes just over 29 days to complete. Modeling the lunar phases is a fun activity and can be done with a variety of materials. Modeling clay, salt dough, cookie dough, even chocolate sandwich cookies can be used! I like to work with salt dough because it makes a permanent piece of science art that the child can keep and display.

To make salt dough, you need 1 Cup white flour, ½ Cup table salt, and ½ Cup of tap water.

Measure salt and flour carefully into a large bowl and blend these dry ingredients together with a fork. Next add the water a few teaspoons at a time, mixing well until all the water is added. Knead the dough for 10 minutes until it is smooth and easy to handle (kids love this part!), then let the dough rest in the bowl for 20 minutes.

At this point, the dough is ready to use. If you wish, you can put your dough in an air tight container and save it unrefrigerated for weeks, just remember to knead it a bit before use. I usually roll out the dough on a plastic cutting board until it is no more than ¼-inch thick. I use a round cookie cutter (or water glass) to cut the 8 round shapes I'll need. If you don't have a rolling pin or cookie cutter, you can roll small dough balls about the size of a quarter and then flatten them with the bottom of a water glass. Either way, you should now have 8 salt dough circles.

Now I take a butter knife and cut out my 8 shapes.

Two complete circles for new and full moon.

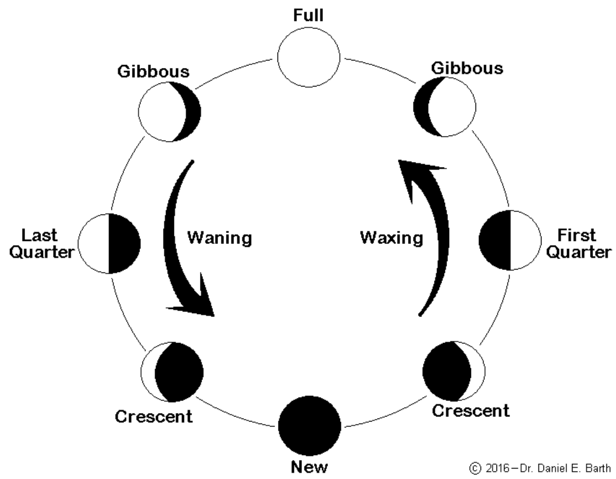
Two crescents (top right in photo), and two gibbous shapes (top left). One circle can be cut in half for the two quarter moons (lower right).

Use a spatula and transfer the shapes to a baking sheet, then preheat your oven to 250° F (120° C) and bake for 2 hours. If the tops still seem soft, you can easily continue to bake them for an additional hour, don't worry – nothing will spoil these and you cannot 'over bake' them!

Once baked hard and cooled, they can be decorated! One full circle should be left white (full moon) and one full circle should be colored dark (new moon). Paints, markers, crayons can all be used here. For the other shapes, you can decorate them as you wish. Older children may wish to look up photos of the full moon and try to draw accurate maria and craters on their moons with a permanent marker.

The decorated shapes can then be mounted to a square of cardboard - the top of a pizza box works wonderfully for this! Place a plate on your cardboard and trace a complete circle, draw arrows in an anti-clockwise direction (the Moon seen from space, high above the Earth's north pole, would orbit the

Earth in this direction!) Glue each phase shape onto your cardboard so that it matches the drawing below:



With the full moon at the top and the new moon at the bottom, glue each phase shape down. You can use a generous coating of white glue, but you will find that a stronger adhesive such as silicone glue or construction adhesive like Liquid Nails® works better.

As you look at your finished lunar phase diagram, notice that the ***terminator*** starts on the eastern edge of the Moon and moves gradually across to the west as you go from new moon to full.

Once you reach full moon, the terminator line again crosses the Moon from east to west. The terminator line is actually the sunrise line during waxing moon. It shows how far the sunlight has moved across the lunar surface. As the line crosses each area, that location experiences sunrise! During waxing moon, the situation is the opposite – as the line crosses each location on the lunar surface, that crater, mountain, or maria experiences sunset, and then darkness.

This model of lunar phases shows us ***one lunar day***. As we look at the model from new phase around the circle, we see the sunlight reaching across the lunar surface until the entire hemisphere is illuminated, then we see the sunset line (the terminator) continue from east to west until the entire hemisphere is in darkness again!

You can do more with your model – use sticky notes to indicate what day of the current month that you can see each phase! Your model has now become a lunar calendar that can be updated from month to month throughout the year.

This model is fun to make and fascinating to explore, but we're not done yet! One thing you may have noticed is that this lunar phase calendar helps us ***predict what happens next*** in the night sky, and when we will be able to see a particular moon phase. The problem with our model is that it does not help us understand ***how the lunar phases work!***

Next time, we will build another model that will help us understand how the Sun, Earth, and Moon combine with the Moon's motion around the Earth all work together to produce the lunar phases we see in the night sky!

Modeling the Earth-Moon System

If you have completed the activities in the previous articles, you should now have a pretty good idea of ***what happens next*** in the sky. You can look at the lunar phases on night, and know with certainty what will happen to the lunar phase over the coming days and weeks. Even so, these models have a major weakness – they do not tell us ***how the lunar phases work!*** Our next project will help us understand how the lunar phases work, and what causes them to appear as they do.

To complete this next model, I use ping-pong balls, black spray paint, colored markers and a few other items. Some parents (and teachers!) have noted that it may be difficult for them to get three ping pong balls per student or group, and that they have reservations about using spray paint. This is perfectly understandable! Any ball will do! You could use plastic golf balls, rubber balls, base balls – any light-colored ball will do fine. You can even make balls out of modeling clay, air-dry clay, or salt dough – try to make them as round as you can, but having a perfect round shape isn't necessary!

I begin with a ping pong ball and some wide blue painter's tape. Cut a piece of tape and wrap it carefully around the equator of the ball. (Tip: if there is a logo on the ball, make sure it is visible <u>above</u> the tape!)

With the ball wrapped, you are now ready to paint one side. I use a stick, even a pencil or a ruler and stick the wrapped ball to one end. This lets me paint without getting paint on my hands or clothes. Be sure to paint outside in the fresh air! A thin coat of flat black paint works best and dries in just 10 minutes.

If you are preparing a number of these balls for a class (2 per student), you can tape them all, then place them inside a cardboard box and spray the paint down inside. This paints all the balls at once, and you don't have to trust your students with cans of spray paint! Of course, if you do not want to use paint or do not have it available, you can use black marker, even crayons, as long as one side of the ball is uniformly dark. (Tip: Always use permanent markers! Water based marker will come off on everyone's hands and make a mess!)

With two balls painted, you can now use markers to draw on the features of your planet and moon. Don't worry about the 'art' aspect. You can draw very realistic models of our Earth and Moon, but that is not necessary! Any planet with random oceans, continents, polar caps, etc. will work just fine. For your moon, shade in maria (dark regions), highlands (bright regions), some craters, etc. If your students have 'art anxiety', tell them to make up their own planet. Have them make up names for oceans, continents, and lunar features – even name their planet and its moon!

Once you glue your planet and moon models onto a base, they will be ready to use. We often use plastic bottle caps for bases, coins, poker chips and the like also work well. Teachers: if you use plastic poker chips for the base of the model, you can glue a strong magnet to the bottom which will allow you to display your models on a white board where everyone can see them! For students to be able to see how the models are arranged on the whiteboard is often a great help in the classroom! Some models such as the ones you see here can be very accurate. One of these shows the new world with north and south America, the other shows the south Pacific with Australia, the Indonesian archipelago, and eastern Asia! (Tip: clouds and storm systems were added using a white correcting pen!)

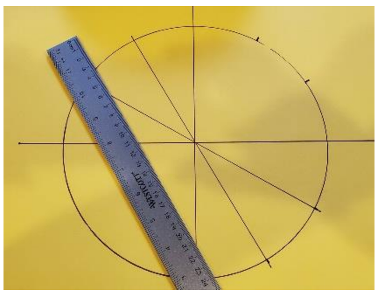
You may wish to expand your model solar system! You can add a solid yellow model for the Sun, a plain, half-black, half-white model for cloud-shrouded Venus. You can even add an outer planet such as Mars, Jupiter, or even Saturn with an index card cut out to make the ring system!

There are many ways to explore our solar system with these models including, seeing how the lunar phases work, why inferior planets (closer to the Sun than us) show phases while superior planets (farther from the Sun than Earth) do not. You can even prove that the old ***Geocentric*** (Earth-centered) model of the solar system doesn't work, but the ***Heliocentric*** (Sun-centered) model does. We will look at modeling the lunar phases, and touch on these other ideas next time!

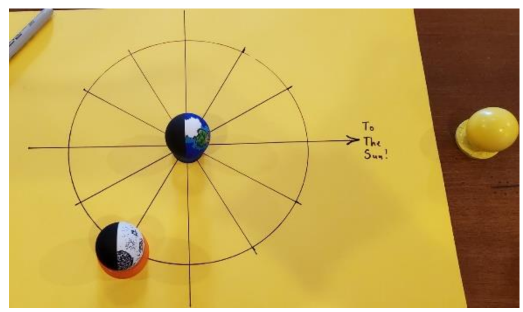
Exploring how the Lunar Phases Work

Last time, we created lovely models of planets and moons! This activity has been a favorite with my students for more than 30 years! If your children and students are like mine, once they mastered making a single planet and moon, they were hardly satisfied – my classroom often became filled, worlds without end, and models as far as the eye could see! Let's see how we can use these models to show children how the lunar phases actually work.

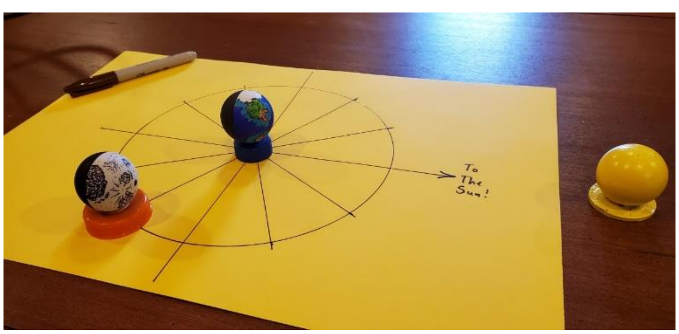
With your models made, all you need now is some construction paper (bigger sheets work better), and a few markers. We'll start by using a plate or a compass to draw a large circle on our paper. Once we have the circle, use a ruler to divide it up into 8 pieces, just like you might cut up a pizza! I used an old clock to draw my circle, the hours provided nice marks to precisely divide my circle into 12 even parts. You can easily do 8 parts by drawing a vertical and horizontal line through the circle, then evenly divide diagonally into 8 parts.



Once I had the circle drawn, I used a ruler to draw my lines, being sure to pass through the center each time. If you are working with younger children, don't be too fussy! Even if the circle is a bit off center or the circle isn't evenly divided into equal parts, this model will still work fine. The design is very forgiving!



With the circle now drawn and divided on our construction paper, draw an arrow to the right and label it 'To the Sun!' Whether or not you have made a Sun model, it is important to know where your Sun is supposed to be. This is important because the Sun acts like a 'distant candle' that illuminates exactly half of each planet or moon (the day time side!) and leaves half of each body in darkness (the night time side!) It is critical to make sure that the lighted half of your planet and moon ***always point directly in the Sun's direction!*** If your planet and moon are not pointed correctly, you will not see the lunar phases as they appear in the night sky!



One thing to point out to students here, is that as we look at the model, we do not really see phases as such. Have the students play with the model for a bit, and ask them to see if they can get the model to show phases just as we diagramed them using our salt-dough models. Chances are, the students will not be able to do this (most adults can't solve this puzzle, either!) So, how is it done?

Our model shows the Sun, Earth, and Moon, as well as the Moon's orbit around the Earth; so why can't we see the phases of the Moon as they appear in our diagram, and in the correct order? The answer is

really rather simple – so simple in fact, that most people overlook it. We haven't put ourselves into the model! As human beings, we stand on the Earth's surface and look out into the night sky! It is this unique point of view, standing on the Earth and looking up, that gives us our perspective of the lunar phases in the night sky! I've added a little figurine here to illustrate this point.

For us to be able to see the Moon as it appears from the Earth, we have to put our head down on the table with our eye looking just over the Earth at the Moon. When we put our eye into the model in the same position as we ourselves occupy on the Earth, then we immediately see the lunar phases just as we would in the night time sky! All we need to do now is to look, and draw each phase of the Moon as we see it.

To do this, begin with the Earth in the center and the Moon at the 3 o'clock position - be sure both lighted faces are pointing ***to the Sun!*** Place your eye down near the Earth and you should see the ***new moon phase*** – you will only see the night time side of the Moon. Draw a small circle and sketch in the moon phase as you see it. Continue to move the moon model to each new position, moving anti-clockwise around the circle. Each time, put your eye down and make a sketch of the phase you see!

When you are done with this, you should have a chart of the lunar phases that is very similar in all important respects to the one we made with salt dough earlier. It shows the phases in their correct order. It shows the terminator, the line of sunrise and sunset sweeping across the Moon's surface from east to west. It shows how the Earth, Sun, and Moon work together along with the Moon's orbital motion around the Earth – and our special place on the Earth's surface looking out into space all create the lunar phases that we see in the night sky!