How Do You Know? – Episode #1: What Shape is the Moon?

One of the persistent problems with standards-based STEM curriculum is the emphasis upon the ***Learn, Believe, Repeat*** methodology that trains students to pass multiple choice tests rather than to think scientifically and participate in discovery oriented activities.

The result of this *successful test* emphasis, as opposed to a *successful student* emphasis, is that students have no understanding of the origin of their knowledge. This *feature creep* problem results in expanding lists of standards that teacher need to teach – and students' questions tend to be quashed. "We don't have time for that!" becomes a common response from the overtaxed teacher. The end result is that students possess facts, but without understanding. This activity, indeed the entire ***Astronomy For Educators*** program, is intended to help you fight this trend and help students discover, and value, what they learn in your class.

Facts You Need to Know:

1. Every planetary (and lunar) surface has been reshaped by ***impactors***, pieces of metal and stone crashing into the surface at ***orbital velocities*** (15 – 75,000 kph.)
2. Almost all impacts form ***circular craters***[1]. It takes a very low angle impact (less than 5 degrees) to form an elongated crater.
3. Impactors strike planetary and lunar surfaces ***randomly***. Every location from pole to pole is equally subject to impacts. All planetary surfaces collect evidence of impacts through their entire history[2].

Teaching and Pedagogy:

We have all been taught that the Earth and Moon are ***spherical***, essentially great balls of rock spinning through space. Almost everyone if asked, will tell you "the Moon is round." If pushed a bit, people will specify

[1] We will seek to prove this through observations of our Moon.

[2] *Geologically Active* planets such as Earth erase crater evidence over time due to an active weather cycle and plate tectonics.

that the Moon is "round like a ball, not like a coin" indicating that they know that planets and moons are generally spherical.

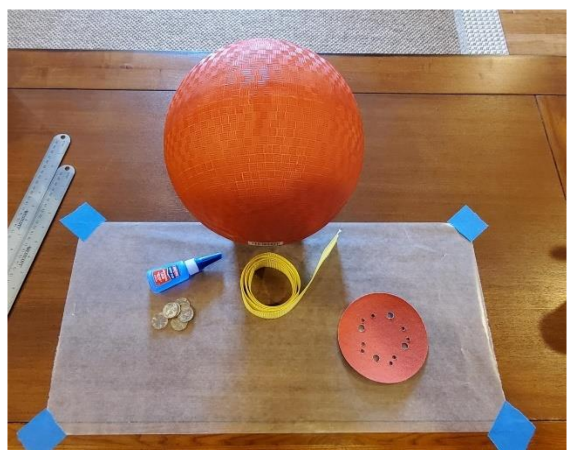
The ***clock stopper***[3] question comes when we ask someone, "How do you *know* that the Moon is a sphere?" I use the clock stopper questions to literally stop a student's mental processes; it is surprising how vigorously students will defend a statement of fact rather than explore a new idea!

Most people, if pushed quite hard, will admit that they do not ***know*** that the Moon is a sphere, they can cite no evidence for this at all. In fact, the students ***believe*** that the Moon is a sphere because they have been told, or sometimes because they have read this in a book or on a website.

Few, if any students, have actually ***discovered that the Moon is a sphere.*** That discovery is the goal of this activity!

Building the Lunar Model:

<u>Materials</u>:

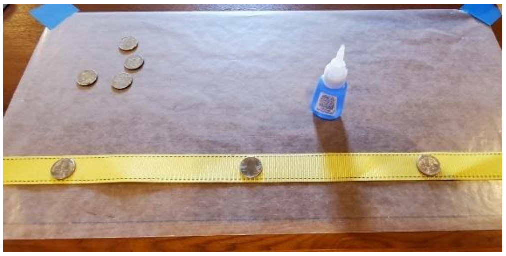


1. 1 meter of nylon web strapping (I cut mine from an automotive cinch strap.)
2. Seven 25 mm coins or similar (I used quarters, poker chips, washers, etc. can also be used.) The coins will represent impact craters in our model.
3. One 30 cm ball (An inflatable vinyl ball, soccer ball, basket ball etc. can be used.) This will represent the Moon in our activity.
4. One 15 cm circle cut from paper or cardboard (I used circle cut from a paper plate.)

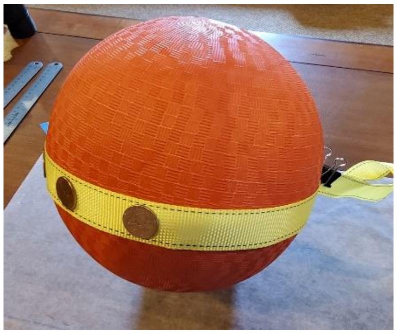
[3] The term ***clock stopper*** comes from bomb disposal teams in WWII. They would call for a giant magnet – a clock stopper – that would literally stop everything happening inside a bomb so they could disarm it safely. I want questions that will *stop mental processes* so that we can teach successfully!

Instructions:

1. Find the center of your nylon strap. Mark this point with a marker.
2. Wrap your strap around your ball, note the position of the mark you made in step 1. Mark your strap 90 degrees to the right and left of the center mark with your permanent marker.
3. Lay the strap flat on a table and use super glue to attach a coin on each of the three marked places. Allow to dry completely (10 – 15 min). Note: you may wish to rub the coins lightly with sand paper – a rough surface holds the glue better!



4. Evenly space and glue two coins to the right and left of the center coin. You should now have seven coins glued to the strap, all evenly spaced. These coins will stretch across the entire hemisphere of your ball.
5. Optional: You can attach some Velcro strips to your Nylon strap once the coins are attached so that the strap and its coins can be quickly attached to your ball. Alternatively, you can use a large binder clip to hold the strap in place while you are working.



Exploring the Model:

Hold the model at arm's length with the center coin facing you. As you examine the shape of the quarters that you see, you will notice that the coin directly facing you appears perfectly ***circular***, while the coins that are farther from the center appear ***elliptical***.

This apparent change in shape is not caused by the coins being deformed in any way, it is simply that we are now viewing them from an angle instead of straight on.

Move the ball from side to side to see how the appearance of the coins changes as the ball moves. Each time a coin rotates with the ball and moves away from the center – it appears more elliptical. Each time a coin moves toward the center, it becomes more circular in appearance.

The Moon actually tilts a bit on its axis this way. Although we see only one side of the Moon from Earth, our satellite companion wobbles a bit – we call this ***lunar libration.*** The libration of the Moon actually allows us to see about 59% of the near side surface rather than just the 50% you would expect if the Moon remained perfectly still.

Observation Time!

Now that you have tested an idea with your model, it is time to spend some time looking at the real Moon. Ideally, the best way to do this is with a small telescope. If you do not have a telescope, you can examine photos of the Moon on the internet; however, if you find a local astronomy club in your area, they will be happy to welcome you and show you the Moon (and lots more!) with the equipment members bring to regular ***Star Parties.***

Any small telescope, even an inexpensive department store model or garage sale find should be suitable for this task. You need to observe the Moon at 50 – 100x. Higher power will get you a better view of craters, but higher power can make it more challenging to keep the Moon in view with your telescope. Astronomers refer to this as ***tracking*** a celestial object.

It works best if you start with the lowest power magnification available to you. Look for the eyepiece with the largest number on it (probably 20 – 30 mm). This will give you the widest field of view and make it easy to center the Moon in your view.

Once you have the Moon in view, change eyepieces to the next smaller number, this will get you a closer view, but zooming in like this will make keeping the Moon centered in your view more challenging. Practice a bit until you feel comfortable. If you "lose the Moon"? Not to worry, just switch back to the lower power eyepiece and start again.

It may work best to get the Moon in view, then let go of the telescope and watch it slowly pass by as the Earth rotates! Look for craters and see how their apparent shape changes as you move from the center of the Moon out toward the edge in any direction.

Does the apparent shape of craters change as you move toward the edge? You should notice that craters become distinctly elliptical in appearance as you move closer to the edge or ***limb*** of the Moon.

Healthy Skepticism:

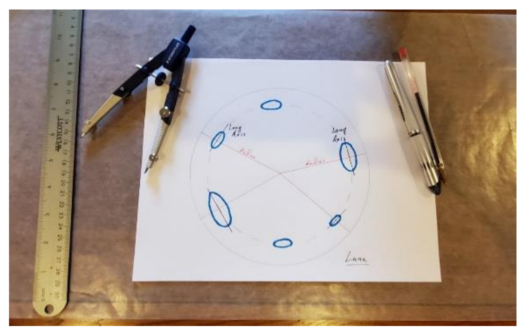
But what about random elliptical craters? Could these be fooling us?

This is a fine and legitimate question! NASA scientists and independent physicists have found that it takes a very low angle impact (under 10 degrees) to make an elliptical crater. In fact, NASA, JAXA, ESA, RosCosmos and other space agencies have found only a handful of true elliptical craters on the Moon.

We believe that is because when an impactor strikes, most of the energy goes into the interior of a planetary surface, then explodes outward in a circle as you would expect with any explosion. In fact, elliptical craters are impossible on Earth, any impactor striking at such a low angle would either burn up, or bounce off our atmosphere![4]

The essential thing about impactors is that they are essentially random. Where they land, the direction from which the strike, all these things are quite random, just as you would expect.

If there were enough random elliptical impacts to *fool us into thinking the Moon is a sphere*, these elliptical craters would appear ***all over the lunar surface.*** The first test then is to see if you can find a true elliptical crater anywhere across the center third of the lunar surface. Go ahead and check, we'll wait!



The second test is to look at the ***long axis*** of the elliptical craters on the Moon. If these are just ***apparent ellipses*** caused by the curved surface of the Lunar sphere – ***they will all be concentrically oriented.*** You can see from the diagram shown here that if the change is crater shape is really just ***how circular craters appear based on their location***, then each crater's long axis will be perpendicular to the radius of the Moon. In other words, all the long axes will be concentric.

No random pattern of impactor strikes occurring randomly over billions of years could create this mathematically perfect pattern!

Congratulations! You have now discovered – and proved – that the Moon is a spherical body!

Now you know – ***How You Know!***

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[4] Search YouTube for "Russian Meteor" or "Chelyabinsk Meteor" to see video of a large, low-angle impactor that struck and exploded above a Russian city in 2013.

For More Information:

The activities and materials provided free for the ***How Do You Know?*** program are based upon Dr. Barth's award-winning book: ***Astronomy For Educators.***

This book is used as a resource in more than 3700 schools across the United States and in more than 40 countries world wide. The book is published as an *Open Educational Resource Text* by the University of Arkansas Library Press.

You are welcome to download a free copy! If you would like to help Dr. Barth, please take our 5-minute survey! All responses are anonymous and information is used in STEM education research and in planning upcoming books in this series.

THANK YOU FOR PARTICIPATING!

Download ***Astronomy For Educators*** for free:

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Astronomy For Educators Survey:

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