3.2: Exploring the Moon's Orbit

The Moon's orbit is wonderfully complex, and yet the youngest child in your classroom can understand the essentials of how the Moon moves through space. One of the essential skills of successful STEM teaching is to be able to break down complex things into small components that are simple to understand. Once your students complete these simple activities, they will be building the pieces of a conceptual model of the Moon and its orbital motion around the Earth.

Academic Standards

Science and Engineering Practices

- Asking questions and defining problems.
- Developing and using models.
- Using mathematics.
- Obtain, evaluate, and communicate information.

Crosscutting Concepts

- Scale, proportion, and quantity.
- Systems and system models.

Next Generation Science Standards

- Space systems (K-5, 6-8, 9-12).
- The Earth-Moon system (6-8, 9-12).
- Gravitation and orbits (6-8, 9-12).

For the Educator

Facts you need to know

1. The Moon's diameter is ¼ that of the Earth, about the same ratio as a small marble to a baseball. The Moon is a much smaller world than Earth is!
2. The Moon's orbit is 60 times wider than the Earth itself. This 60:1 ratio demonstrates the vastness of space, but obviously makes it difficult (but not impossible!) to show an accurate model in the classroom.
3. The Moon orbits the Earth approximately every 28 days (moon and month are related words!) Each week the Moon travels ¼ the way around its orbit.

Teaching and Pedagogy

Now that we have built and decorated our Earth-Moon system model, let's have some fun with it! These next four mini-activities can each be done in 20-30 minutes, perfect for a single class period. Because the model is so large (sixty feet in diameter!), these will obviously be outdoor activities. I strongly suggest that you try them on a paved playground area where you can use sidewalk chalk to mark things out. The distance scale we are working with is something that really has to be experienced directly to allow students to gain a substantive cognitive understanding. One can talk about dinosaurs for days and look at all the photos on the internet you like, but there is no substitute for going to a museum and standing next to a life-size model or a real fossilized skeleton to give one an appreciation of the size of the creature.

These activities strike to the very core of constructivist pedagogy. During these activities, students construct their own meaning and create their own (hopefully accurate!) mental models of the Earth-Moon system. You may see this as simply "play time" rather than real science – don't be fooled! The cognitive work the students are doing as they play with these models is substantial! Your students are constructing mental models and maps of things like size, scale, orbits, planetary motion, rotation and revolution, space travel, and much more. We will be building on these ideas as we continue to build and refine scientific models throughout this book!

Conducting the Activity

Mini-Activity #1

Take your Earth-Moon model outside to the playground with some sidewalk chalk. Use the model as a giant string-compass and draw the lunar orbit out in chalk. Use chalk to draw in the Earth and Moon in their correct sizes on your diagram. Draw the student's attention to the sheer size of the Earth-Moon system compared to the relatively small sizes of the Earth and Moon themselves! Interestingly, the planet Saturn and its ring system would just fit inside the distance between the Earth and the Moon!

Try and use some sidewalk chalk to draw Saturn and its rings on the playground. The planet is a circle ten feet in diameter, the outermost rings make a circle fifteen feet in diameter! The great difference in scale between the tiniest and largest planets is one of the things that makes modeling the solar system so challenging.

How about the Sun in our model? To be in scale, our Sun would be a 100-ft ball (as large as a ten-story building.) We would have to place this giant Sun model 2.1 miles away; from that distance, it would appear to be almost exactly the size of our T-ball moon!

Mini-Activity #2

Ask the students to try drawing their model Moon while standing in the Earth's position. The apparent size of the 4-inch rubber ball from 30 feet is about the same size as the Moon appears in the night sky! Although our Moon looks large because it is a bright object on a dark background, it is really quite small! If you have decorated your Moon with maria and craters with rays, ask students if they can make them out when standing where the Earth is. If they cannot, this is an excellent time to offer them a chance to try out a pair of binoculars if you have one. Students will quickly see that binoculars do bring things closer, but holding them steady and drawing what you see in the eyepiece is still quite challenging!

Mini-Activity #3

Use the 6'-10" measuring cord to mark out the distance that the Moon moves each day. Number these daily positions of the Moon for one entire orbit. How many days does it take for the Moon to orbit the Earth? Surprise! It takes about 28 days (one month) for the Moon to orbit the Earth. Use your sidewalk chalk to draw in the lunar phases as we see them from Earth around your lunar orbit. Use your Lunar phase map from Activity #1 to help you!

Mini-Activity #4

Try for a moon shot! Use marbles or ping-pong balls as 'spacecraft' and try to roll your craft all the way from the Earth to the Moon! Alternatively, have everyone make a paper airplane and try 'flying' to the Moon as someone walks slowly around the lunar orbit representing the orbital motion. Getting from the Earth to the Moon is hard!

Discussion Questions

Now that your students have had a chance to play with this model of the Earth-Moon system, they should have a much better cognitive grasp of how large the system is, and what the relative size of the two bodies are and how they are related in space. Almost all drawings and illustrations from textbooks or internet sites are horribly distorted in this way. Artists invariably show the Moon being far too close to the Earth, and often much larger than it actually is in comparison to the Earth. There are good reasons for this of course, try to draw an accurate scale picture and most of the space on the page is not only empty, but the Earth and especially the Moon are really too small to show any detail at all! Never-the-less, these drawings encourage gross misconceptions about our planet and its nearest companion in space.

1. Show your students a drawing or illustration of the Earth and Moon in orbit taken from any textbook or website. Ask them what is wrong with this drawing as a scientific model?
   - **Answer** There are likely to be a great many things wrong with these illustrations! The relative size of Earth and Moon and the scale of the distance between them just for starters!
2. Ask your students to hold up their drawings of the Moon made from inside the circle at Earth's position. Ask them why observing and drawing the Moon is so difficult!
   - **Answer:** This question will help you see how far your students – and their cognitive models of the Earth-Moon system – have progressed. No doubt they will now realize that drawing small features on a small lunar globe from very far away is quite challenging – even when they originally drew the features themselves and know just what they look like!
3. Show a photo or some video of the Apollo astronauts flying to, and landing on the Moon. Ask your students what they think of these explorers and the journey that they made!
   - **Answer:** To understand an achievement, you must first know something about the challenge that it represents. If I told you I had built and learned to play a Theremin, this might not mean much to you unless you first knew that a Theremin is an

electronic musical instrument that one plays *without touching it*. Your students are likely to find the Apollo voyages much more exciting now that they understand a bit more about the Earth-Moon system!

Supplemental Materials

Going Deeper

The average distance to the Moon is 385,000 kilometers – compare this to a trip from New York City to Los Angeles which is just 4490 km! That trip would take you 41 hours by car (without stopping for gas of food!) The Moon is about 90 times farther away than our imaginary cross-country trip!

Apollo astronauts traveled at an average speed of 5500 kilometers per hour (kph). Imagine you were going to travel this great distance – 770,000 km, all the way to the Moon and back – in a very small car with two of your best friends. Remember that this is a spacecraft and that you ***cannotstop or get out!*** Work together with your two traveling companions to answer these questions.

1. How long would this journey take you? (Show your work!)
2. What things would you want to take with you? Space is very limited, so divide your items up into a ***Must Have*** and ***Want to Have*** lists.
3. Being in the car for this long without being able to stop or even open a window presents some very special problems; eating, washing, and going to the bathroom come to mind! What would you do to handle living in this very compact space for so long?
4. If your compact car got very good mileage, say 65 km per gallon, how much fuel would you need for the entire trip? Find a 5-gallon gas can and measure it; use this to estimate the size of fuel tank you would need for this trip!

Being an Astronomer

Observing the Moon's ***apparent motion*** is much easier than observing its ***orbital motion*** around the Earth – but both take some patience and clear weather! The best time to do this is in the two weeks after ***New Moon***. With your teacher or parent's help, use the internet to find the date for the next new moon, your observations will begin about 3 days after this.

Three days after the new moon, you should see a thin ***crescent moon*** in the western sky just after sunset as the sky gets dark. Watch the Moon for an hour or so starting at sunset and notice the motion of the Moon as it sinks into the west. If the weather is nice, a good way to do this is to have a Moon Picnic in the back yard with your parents and eat dinner as you watch the Moon! This ***east to west*** motion that you see is the Moon's ***apparent motion.*** What we are really watching is ***the Earth spinning on its axis***.

Being a Scientist

The Moon's ***orbital motion*** is harder to see, and you must watch the Moon carefully several days in a row to see it. Begin by going out on a clear night about three days after new moon. Look for the crescent moon low in the western sky right at sunset and make a note of the Moon's position. An easy way to do this is to notice where the Moon is compared to trees or buildings in your back yard. Take careful notes of what you see!

For the next 3-4 nights, go out again just at sunset and notice the Moon's position. You will notice that the Moon appears ***farther east*** each night. This ***west to east motion*** is the Moon's true orbital motion. We don't notice it on one night because the Moon takes 29 days to make a complete revolution around the Earth – it doesn't move much in just an hour or two!

Calculate the ***circumference*** of the Moon's orbit. Circumference = $2 \pi r$ (your teacher can help you with this!) The ***radius*** of the Moon's orbit is just the distance between the Earth and the Moon – 385,000 km. Use what you have learned to answer these questions:

1. How far does the Moon travel in each orbit?
2. How far does the Moon travel in just one day?
3. How fast is the Moon moving in orbit in kph?

Following Up

Think about how challenging space travel is! To be an astronaut and travel to the Moon requires great planning, scientific knowledge, and tremendous courage! We will explore these ideas further in later activities in this book.
