Spinning Into Darkness, Spinning into Light

(Insert photo)

**Grade Level:** 3rd grade (2nd grade-6th grade)

**Time Required:** Part 1: 60 minutes

**Group Size:** Whole class and small group recording teams

**Summary:** Why do we have day and night? What makes it so we aren’t in darkness all the time? What causes us to have a sunset and sunrise? How can it be midnight in Beijing, China when it is noon in North Carolina? To find out the answers to these questions students will manipulate their personal Earth they constructed in the last activity *The Earth is Round*. Specifically, they will study the effects on our experience here on Earth of the fact that the Earth spins about its axis from West to East, completing a rotation once a day. They will understand that this causes celestial objects, as viewed by observers on Earth, to appear to be moving around the Earth from East to West. When applied to the Sun, this explains not only the apparent motion of the Sun in the sky that was found in “The Sun Moves in the Sky,” but also the daily cycle of light and darkness – Day and Night.

**Keywords/ Vocabulary:**

**Axis:** an imaginary line connecting the North Pole to the South Pole that the Earth spins around

**East, West, North, South:** the four cardinal directions on the compass

**Spin:** A rotation of an object about its axis. The Earth spins about its axis from West to East, completing a rotation in about 24 hours or 1 day.

**Orbit:** The path taken by an object as it moves in space. The Earth moves in an orbit which is almost precisely a circle with the Sun at its center. Earth completes an orbit, circling the Sun and returning to its starting point, in one year.

NOTE: Much confusion has been created by distinguishing *rotation* (meaning spin) from *revolution* (orbital motion). While this distinction is backed by tradition, it is imprecise (revolution *can* be used as a synonym for rotation); it is also difficult for students to retain. We find the unambiguous *spin* and *orbital motion*, reflecting accepted scientific usage, more intuitively clear.

**Horizon:** The imaginary line along which sky and Earth appear to meet as seen by an observer on Earth. At sea or in flat, featureless terrain, this is a horizontal circle. The line is imaginary in that there are no points at which sky and Earth meet, but it is very real as a collection of *directions* in space.
Sunrise: The time of day when the Sun first appears above the horizon in the East. At any instant the Sun is rising along one line of longitude on Earth.

Sunset: The time of day when the Sun disappears below the horizon in the West.

Noon or Midday: 12:00 midday is the time when PM starts directly after at 12:00:01 and the Sun is near its highest altitude or height in the sky.

Midnight: 12:00 midnight is the time in the night when AM starts immediately after at 12:00:01 people who live in Durham are fully in the earth’s shadow and in darkness.

Clockwise: movement in the same direction as the hands of a clock.

Counterclockwise: movement in the opposite direction as the hands of a clock.

Educational Standards:

- Science:
  - Objective 3.01 Observe that light travels in a straight line until it strikes and object and is reflected and or/absorbed.
  - Objective 3.02 Observe that objects in the sky have patterns of movement including: Sun, Moon, Stars.
  - Objective 3.03 Using shadows, follow and record the apparent movement of the Sun in the sky during the day.
  - Objective 3.06 Observe that patterns of stars in the sky stay the same, although they appear to move across the sky nightly.

- Math:
  - Objective 3.01 Use the appropriate vocabulary to compare, describe, classify two and three-dimensional figures.

Pre-Req Knowledge:

This activity will synthesize understandings from previous lessons. In part, this is where we have been going. The concepts of sunrise, sunset, midday, and midnight and their relation to the location of Earth, Sun, and observer were introduced in “Sunrise and Sunset on a Tilting Plate.” Here, these will be combined with the effects of Earth's shape as discussed in “What's Up, Earth” to understand the apparent motion of the Sun as observed in “The Sun Moves in the Sky.” Combined with our insights on the motion of light and of shadows, from “Light and Darkness in Space,” this will also explain the progression of light and darkness on Earth. Because this activity brings together the insights collected thus far, it is a natural place to stop, assess students' comprehension, and help them to work through surviving misconceptions and confusions.
Learning Objectives

After this activity, students should be able to:

- Describe and display the spinning or rotating movement of the Earth on its vertical axis.
- Describe how day and night is a result of the Earth’s spinning movement on its axis and a person’s position or location on Earth.
- Understand that due to the Earth being a sphere one half of the Earth is always in darkness and one half is always light.
- Explain where sunset, sunrise, noon, midnight is occurring on the globe.
- Demonstrate how light traveling in a straight line or path from the Sun causes day and night on our spinning globe or sphere, Earth.
- Explain how the daily pattern of sunrise, noon, sunset, night, at a particular location on Earth corresponds to the appropriate parts of the 24-hour rotation cycle.
- Explain how stars appear to move along arced paths in the sky, while their relative positions are unchanged so that the patterns we see are constant.

Materials List

Teacher needs:
- Modeling clay
- 4 Golf tees or small object to place in clay
- Globe
- A lamp or light source in the middle of the room with 250 watt bulb

Each student needs:
- 3” Styrofoam Earth model
- Small piece of modeling clay
- 4 golf tees of other small figures to place in clay

Background:

Much of the background for this activity has already been laid out in previous ones. At any given time, exactly one-half of the surface of the Earth is illuminated by the Sun, simply because the other half of the sphere that is Earth is in fact inside the Earth's shadow. People on the dark half cannot see the Sun as they would need to look down to look in its direction, and the Earth lies in the way. Thus also sunlight cannot reach them. As the Earth rotates about its axis a fixed point on Earth is swept into and out of the illuminated half. In this activity, we will hold the Earth so that the axis is vertical, while the direction from Earth to Sun us horizontal. They are thus perpendicular to each other. (This is not quite accurate, as we will see in later activities “Your World is Tilted” and “The Seasons and the Orbit,” but it is a reasonable approximation and...
makes the relevant discussion for this activity a bit simpler.) This means that other than the poles, each point on Earth is in the illuminated half of the sphere precisely one-half of the time. Given our previous experience, it should come as no surprise that our world is dark about half of the time – when we are in the Earth's shadow. That is what we call night. The other half of the time, we are out of the shadow which means we can see the Sun (remember that being in the shadow is the same as not having a line of sight to the light source). That the entire world then seems filled with light is because we are surrounded by objects that reflect or scatter the sunlight. Even the atmosphere, because of impurities like dust, ice crystals, or tiny drops of water, scatters enough light to appear bright blue rather than dark.

This is the essential point. To complete the discussion, we want to make as many connections as possible between the observations students make with the model they manipulate and the experiences of people living on the Earth.

If we follow a fixed point on Earth as it goes through a full rotation, we can reproduce the experience of a person living at that point through a full 24-hour period including a day and a night. Let's begin with the moment in the rotation at which our observer is just entering the illuminated half of the Earth. This is the transition from Night to Day – morning. The Sun is just becoming visible to our observer. On closer inspection, we notice that when the Sun first becomes visible, the line of sight from the observer to the Sun just grazes the Earth. The observer emerging from the shadow will see the Sun emerging from being obscured by the Earth, and visible just above his or her Eastern horizon.

As the Earth rotates, the fixed point with our observer moves deeper into the illuminated half of the Earth's surface. From the point of view of the observer, the Sun is moving higher in the sky, reaching its highest point when the observer is in the middle of the illuminated half, along the line of longitude closest to the Sun. At one point on this line, at the equator, the Sun is directly overhead, while north of the equator it appears to the South and south of the equator to the North. The farther from the equator our observer, the lower the Sun will appear at midday.

As the Earth continues to spin, our observer will be carried toward the Eastern edge of the illuminated half of Earth, and the Sun will approach the horizon in the West, finally disappearing when the observer crosses the line into the dark half.

Following through a rotation we see that the observer spends precisely half of the time (12 hours out of each day) in the dark and the other half in the light, except at the poles where a perennial twilight occurs, with the Sun on the horizon always. Of course this is not the true state of things on Earth; that is due to the tilt of Earth's axis and will be discussed later. But it is the state of things in our current model.

In terms of our study of the apparent motion of stars in various parts of the sky in the previous Activity, the Sun is just one such star (object outside Earth) which lies above the Earth's equator (once more, this is not precisely true, we will correct that later).

Preparation: Getting Ready

- Place the lamp/light source in the middle of the room or some location that everyone has a direct view of its light.
• Make whatever arrangements you have settled on to darken the classroom.
• Have 3” Styrofoam models ready from last activity
• Place your Globe for easy access

Activity:

Part 1: Science Notebook Intro

1. Introduce the activity with the following Motivation / Challenge:
“A second grader came to one of my third graders last year and asked, ‘This weekend on
Saturday at noon or 12 o’clock, right around lunchtime, I was watching the news and they said
they were ‘Live’ from Beijing, China and it was midnight there. Then the TV news went to a
story in Perth, Australia and in Australia it was midnight too. Now how can it be the middle of
the day with the Sun overhead here in North Carolina, USA and it is midnight with the Sun
nowhere in the sky in China and Australia? I think the TV news was trying to trick us. Do you?’”
Talk to your tablemates or partner next to you and draw and write what you know to answer this
question and what the second grader needs to know to figure out why it is midnight in China and
Australia and people are sleeping and here in NC it is noon and people are eating lunch. Allow
the class to brainstorm and record their ideas in their science notebook for 5-7 minutes and then
list their responses on chart paper to be referred to during the activity.

2. Return each student’s Earth model and instruct him or her to use a marker to draw China in the
Northern Hemisphere above the equator and Australia directly below China and the equator in
the Southern Hemisphere as well as place a golf tee with clay on each country. Use your large
globe and white board to demonstrate where students should place China and Australia on their
model. Their drawings don’t have to be perfect but should be in the correct hemisphere. On the
opposite half of the world have the students draw the USA in the Northern Hemisphere and
Brazil directly below us in the Southern Hemisphere and place a golf tee with clay on each
country. Explain to the kids that if they were to dig from China through the center of the Earth
they would come up in the USA and if they dig from Australia through the Earth they would
come up in Brazil.

3. Turn off the classroom lights and turn on the light source in the middle of the room. Ask the
class, “The last couple of activities you’ve learned about the shape of the Earth and the way light
ctravels in space and how we see objects in space, I want you now to work with your partner and
answer the following question: Can everyone on Earth be in sunlight at the same time?
Experiment with your Earth models to discover an answer imagining the light in the center of the
room is the Sun. Keep in mind what the shape of the Earth has to do with who on Earth is in
light or darkness. After you are confident about an answer write and draw an explanation in your
science notebook.” Once everyone is finished review the responses with the class that prove or
disprove what is on the chart paper responses from Step 1. Add any new responses that are
helpful and correct. To develop further understandings ask, “How would your answer be
different if the Earth was a cube?” If you have several cubes in the class hand them out and let
the kids experiment. Ask, “How would your answer be different if the earth was a cone?” Again
if you have geometric solid cones in the class pass them out for experimentation to help answer
the question.
4. Ask each partner group to imagine it’s the middle of the day in NC and when their straw person looks up into space what do they see? The Sun overhead. Have them move their Earth model to the midday position for NC. Ask how they know this position is midday or noon? See if anyone can make the connection to the midday mark on the Sun’s Path Map in the room or the midday shadow tracing of his or her body. Next have them imagine they call someone on the phone in China or Australia. Ask, “What time of day is it for the straw person on your Earth model in Beijing, China’s capital city if it is still midday or noon in NC? How do you know? Now pretend you look up from China or Australia what do you see now?” Take some time to allow students to demonstrate and discuss their answers. After discussion and demonstration of their answers with their models have each student draw the NC midday or noontime and the Beijing midnight position of the Earth and Sun in their science notebook. Additionally, given what they know about the way light travels and the shape of the Earth explain why Beijing, China is at midnight and NC is at noon?

5. Next instruct the class “to imagine that 12 hours have passed and people in China and Australia will be eating lunch at 12 noon, what will your straw person back in NC be doing? Move your Earth model and explain to your partner what people in NC will be doing and prove why you believe this to be true. Also work with your partner to come up with a description of how the Earth moved so that now China and Australia are in light and USA and Brazil are in darkness? Write and draw your explanation in your science notebook.” Once most everyone is finished allow students to read, discuss and demonstrate their explanations.

6. Ask the class to look down on their Earth’s North Pole and imagine their Earth was spinning counterclockwise or opposite the direction of the hands of a clock. Explain this is the direction the Earth is spinning in space and have them spin their Earth in this direction. Ask, “Start with Durham at midnight in total darkness and spin your Earth very slowly and figure out where your NC straw people first gets touched by the Sun’s light. What is the time of day called when we first see the Sun? (Sunrise) Now, work with your partner and see if you can both come to an agreement about where Sunrise is for your NC straw person.” Once everyone finds sunrise explain, “Today the Sunrise time for Durham was ___ AM. Placing your Brazil and USA straws at Sunrise, what position are your straw people in China and Australia at? Are they moving into the Sun’s light or into the Earth’s shadow or darkness? What is that time of day called? Now slowly move your USA & Brazil straws to the sunset position where the straws are getting hit by the last bits of sunlight for the day and moving into nighttime or darkness.

7. Question the class, “How are your Earth model’s position at sunset and sunrise similar to your experiments with the plate’s sunset and sunrise positions?” If you have the plates on hand nearby pass them out and allow partner groups to compare and demonstrate the similarity between the sunset/sunrise positions with the plates and with your model Earths. Next make the connection to the Sun’s position near the horizons at sunrise and sunset on the Sun’s Path map in the class.

8. Instruct the class to draw a picture of the Earth’s position when Durham and Brazil are at Sunset and draw another picture where Durham and Brazil are at Sunrise. Require them to describe what the differences are between the two times and explain what causes these differences.
9. Instruct the class to place their Durham, NC, USA and Brazil golf tee people to midnight and ask, “Instead of looking up and seeing the star we call our Sun, what does the person see out in space?” Their responses should include: stars, planets, airplanes, another galaxy of stars, and constellations. Ask, “Has anyone looked at the stars throughout the night and noticed something about the way they move throughout the night?” Hopefully, someone responds that the stars move across the sky like the Sun and Moon and if not make the connection for them. Explain that just as our closest star, the Sun, rises and sets each day, so too do all of the stars at night and because we are spinning counterclockwise the stars appear to moving clockwise or East to West during the night just like the Sun appears to be during the day. Ask, “If the Sun, our closest star, has a path across our sky that is shaped like an arc or half circle what path do you think the stars have across the night sky? Explain your answer.”

10. You can use your Earth’s Orbit Calendar drawings and have kids draw the appropriate constellations that will be up in the night sky near their birthday drawings. A helpful resource is at http://www.astro.umass.edu/~arny/constel/night_sky_learn.html Ask, “Everyone place Durham in darkness or midnight. Have your Durham straw person look out into space. What do they see? Are there any playground toy or amusement park rides you have been on or any sport or activity you have played where you have spun around and it felt like the Earth was moving and not you?” Students should answer, a merry-go-round, carousel, vortex rides. Explain how we on Earth are spinning as well and believe our friends in space, the stars, are moving just as when you are on the spinning ride your friends or family off the ride seem to be moving despite the fact that they are staying still. The same is true for the Earth and the Stars that seem to be traveling through are playing tricks on you. You feel and think the rest of the world is spinning just like people on Earth are spinning and believe the rest of the space is spinning.

11. Ask, “Are there other stars besides the Sun up during the day?”

(insert photo)

Attachments

Safety Issues

- Warn students never to look at the light source directly – this could temporarily blind or daze them.
- Use caution when setting up the wiring for the central light source, to ensure that students do not trip over the wires in the darkened classroom.
Assessment

Pre-Activity Assessment
In the science notebooks and recorded on your chart paper the students’ responses to the opening Motivation/Challenge.

Activity Assessment
1- Geographical understanding of representing and locating China, USA, Australia and Brazil on their Earth models.
2- Can everyone on Earth be in sunlight all at the same time? What does the shape of the Earth have to do with your answer? Imagine the light in the middle of the room is the Sun and use your model Earth to figure out an answer to the question. After you are confident about an answer write and draw an explanation in your science notebook.
3- Position your globe so that it is midnight in China and Australia and noon or midday in the USA and Brazil. Draw the position of the Earth and Sun in your science notebook and given what you know about the way light travels and the shape of the Earth explain why and how this does happen and is true? Next, imagine that 12 hours have passed and people in China and Australia will be eating lunch at 12 noon and people in the USA or Brazil will be asleep at 12 midnight? How is the Earth moving that now China and Australia are in light and USA and Brazil is in darkness? Write and draw your explanation.
4- Hold your Earth so USA and Brazil is in darkness at midnight. Now spin the Earth slowly so your person (golf tee held on with clay) turns opposite the direction of the hands on the clock or counterclockwise. To be sure you are moving counterclockwise look down on the Earth’s North Pole and imagine the way the hands of the clock move and now spin your globe the opposite direction. Another mnemonic is that we will have all rotational and orbital motions in the Unit be such that we rotate towards our left. So a person standing on the North pole should be turning to their left.

Post-Activity Assessment
Computer generated illustrated model of the Sun’s path with written explanation using computer graphics software (i.e. KidsPix) to illustrate and answer the following questions:
1- Draw the southern horizon with East, South, West and at least 4 landmarks labeled.
2- Illustrate the Sun’s path as it changes position each hour.
3- Describe the Sun’s path’s shape? What is the shape similar to?
4- What do you notice about the Sun’s path’s pattern each hour?
5- What happens to the Sun after it sets? Why can’t we see it?
6- Is the Earth revolving around the Sun or is the Sun revolving around the Earth? How does your data support one way or another? (It’s not necessary for everyone to understand the Earth’s revolution around the Sun but it is helpful for them to start to make the possible connections.)

Activity Extensions
Shadow Tracking: Track the Sun’s movement by tracking a stick’s shadow each hour. Much like the Sun tracking groups each hour have a group track the stick’s size, shape and direction each hour. Check out http://hea-www.harvard.edu/ECT/Stick/stick.html#intro
for a great lesson that helps your students record the smooth arced motion of the Sun across the southern horizon.

References

A helpful site at locating constellations for different times of year is at http://www.astro.umass.edu/~arny/constel/night_sky_learn.html
Students can draw the constellations and place them next to their birthday drawings in the Earth Orbit Calendar. (see Additional Activities section)

Find exact times throughout the world at http://www.timeanddate.com/worldclock/

Find live webcams to prove that it truly is midnight near Beijing, China and near Perth, Australia when it is noon in NC at:
German School in Shanghai, China http://www.ds-shanghai.org.cn/webcam/webcam.html
Adelaide, Australia http://abc.net.au/adelaide/adelwebcam.htm

K-6 Astronomy activities from Harvard-Smithsonian Center for Astrophysics’ Everyday Classroom Tools at http://hea-www.harvard.edu/ECT/

Language arts and Astronomy connections at Stanford’s Solar Center at http://solar-center.stanford.edu/interview/questions.html

Earth, Sun, and Stars Teacher’s Guide by LHS GEMS
Lawrence Hall of Science University Of California at Berkeley