Activity 1.1 Sun and Seasons

Teacher Background

For people living in the middle latitudes, the progression of the changing seasons sets the stage for some of nature's most beautiful sights, from the colorful blossoms of spring to the rich shades of autumn. The changing seasons are accompanied by the annual migration of many animals, variations in the length of daylight and the rising or falling of temperatures. While we're very familiar with these natural cycles, many people have a basic misunderstanding of their underlying causes.

In the classic documentary film "A Private Universe," (see URL below and Resources) several students graduating from Harvard are questioned about some basic science concepts, including an explanation for the changing seasons. Many incorrectly state that the seasons change because of variations in the distance between Earth and the Sun. This misconception is widely shared by many adults and children without the benefit of an Ivy League education. It would surely surprise them to learn that our Sun is actually *closer* to the Earth during a northern hemisphere winter than during the northern hemisphere summer!

Earth orbits the Sun once every 365 1/4 days. (That's why we need a leap year every 4 years to keep the calendar straight.) While Earth's orbit is slightly elliptical (not perfectly circular), variations in the distance between the Earth and the Sun are not enough to cause the seasonal changes. Instead it is the 23.5 degree tilt of the Earth's axis that is the primary reason for the changing seasons. When the northern hemisphere is tilted towards the Sun, those living on this part of the Earth enjoy summer—longer hours of daylight and warmer temperatures—while those in the southern hemisphere experience winter. When the northern hemisphere is tilted away from the Sun, the opposite occurs—winter is celebrated north of the equator and summer south of the equator. It's only when the Sun is positioned above the equatorial latitudes, at the equinoxes, that both hemispheres experience the spring and autumn seasons.

It may also surprise your students to learn that *every* spot on Earth receives the *same* amount of daylight over the course of a year. Shorter winter days are balanced by longer summer days. However, not every part of the Earth receives the same *intensity* of sunlight, one of the primary reasons for the existence of different climatic zones, such as the tropical and temperate regions. This is primarily due to the curvature of the Earth. In latitudes near the equator, sunlight falls more intensely on a smaller area. The sunlight also travels through less atmosphere than at higher latitudes. The same amount of sunlight is spread over a wider area and passes through more of the atmosphere at the higher latitudes, resulting in less heat per square meter of land surface. During summer, the Sun appears higher in the sky, its radiational heating is more intense, and daylight hours are longer. Winter brings shorter daylight hours, a lower position of the Sun in the sky, and less intense radiational heating.

This Activity models the relative positions of Sun and Earth throughout the year and allows students to observe for themselves the fundamental but often misunderstood astronomical relationships that are the most important driver of our planet's weather and climate.

Objectives

Students will participate in a demonstration showing that the tilt of the Earth is the primary cause for the changing of the seasons and explain the seasons in their own words.

Students will observe a demonstration showing how the intensity of radiational heating varies due to the curvature of the Earth and the amount of atmosphere through which it must pass.

Vocabulary

axis
elliptical
equinox
orbit
pole of rotation
radiational
revolution
rotation
solstice

Materials

Earth globe
incandescent light bulb (soft white variety)
lamp fixture
string
tape measure
strong flashlight and cardboard baffle with 3 cm, 1", circle cut out
Worksheet 1.1 (either made into an overhead or copied for individual student reference)
WEATHERlogs

LFSTORM Standards Correlation sheet (for teacher reference)

Engage

Ask your students to describe as many visible signs of seasonal change as possible. (Answers might include observing migrating birds, flowers blooming and leaves changing color—or the Super Bowl and/or the World Series.) Do they have a favorite season of the year? Ask them to explain the reasons for the changing seasons. (The fixed tilt of the Earth on its axis in relation to its orbital path around the Sun.) Be prepared for some surprising answers!

Share some extreme state-by-state records for high and low temperatures. A relatively current listing of such information can be found in "The Weather Book" by USA TODAY weather editor, Jack Williams. (Note: since weather just keeps on happening, a few "records" have in the 1997 edition now been surpassed. For the very latest data see http://www.usatoday.com/weather/wcstates.htm and http://www.usatoday.com/weather/wheat7.htm) If all locations on Earth receive the same amount of daylight over the course of a year, why do different parts of the country (Miami, FL and International Falls, MN) and the planet experience such a wide range in temperature? (The curvature of the Earth leads to variations in the angle of the sunlight, the length of daylight, and the amount of atmosphere through which the rays must pass.)

Procedure

Place a lamp fixture in a central location of your classroom. Secure the electric cord to the floor to keep students from tripping over it. Remove the lamp shade and place a large soft white bulb in the lamp. Turn on the lamp and turn off the classroom lights. Ensure there's enough ambient light for students to record what they are about to observe in their WEATHERlogs. Ask them to write down exactly what they see and specifically where light and shadow fall on the Earth globe.

Have a student volunteer hold the globe and walk around the lamp (which, of course, represents the Sun) modeling the orbital path of the Earth. Have students describe what the orbit should be, allowing the point to be made—by them or you—that the orbit is in reality an ellipse, but that at this scale a rough circle will suffice. Be sure that the student is holding the globe tilted at approximately 23.5 degrees: if possible, a straw or stick might be placed on the North Pole/South Pole axis to make the tilt more apparent. Be sure the student does not change the orientation of the axis while orbiting the model Sun. If viewed from above, the student should be walking in a counterclockwise direction. (You might wish to use Worksheet 1.1, side 1, to further explain the demonstration or to distribute copies later to students to help them explain what they have observed.) Encourage students to observe carefully and point out changes in how the globe is illuminated by the lamp at different locations in its orbit. Have students record their observations in their WEATHERlogs while the demonstration is under way.

Ask the students to identify the positions in the orbit which represent each of the four seasons of the northern hemisphere. Have them note in their logs exactly what they see happening with each hemisphere and how much light it receives. Encourage (polite) discussion until a consensus has been reached (around the correct answer). Mark the classroom floor with the dates of the spring and fall equinoxes and the summer and winter solstices.

(Note: the following can be done as either a teacher demonstration or you can recruit and carefully direct 3 students to hold the globe, baffle and flashlight as you talk through the procedure.) Next, turn off the lamp and turn on the flashlight which now represents the Sun. Hold the globe about one meter (3 feet) away from the flashlight and place the cardboard baffle with the 3 cm (one inch) hole between the flashlight and the globe. Adjust the distances so as to shine a 3 cm (one inch) beam of light directly onto the globe at the equator. Have a student measure the size of the beam of light falling on the globe. Slowly change the position of the flashlight and cardboard so that the light beam moves away from the equator and towards either one of the poles. Be careful not to change the relative positions of the cardboard and the flashlight. Have another student measure the size of the light beam in its new position close to the pole. While the new locations receive the same amount of light (the flashlight and its position have not changed), have students hypothesize what happens to the light's *intensity* at any one point. Where on the globe is the light beam most intense?

Expand/Adapt/Connect

While spring officially begins on the vernal equinox and fall on the autumnal equinox, signs of the changing seasons can be observed earlier or later based on latitude. Use the globe/lamp/flashlight models to demonstrate why signs of spring arrive earlier in the southern states and why deciduous leaves begin to fall earlier in northern parts of the country.

After demonstrating the orbital path of the Earth around the Sun, select various objects located along the walls of the classroom (clock, bulletin board, posters, etc.) to represent stars and constellations in space. (An option would be to place real or simulated constellations, perhaps using luminescent stars if you can dim your room lights sufficiently to make them glow, on the walls to make this extension even more engaging.) Have a student face away from the lamp while carrying the globe around the model Sun and call out the names of these objects as they come into his/her view. Through this simple procedure it should become clear why we see different stars and constellations along the horizon throughout the course of a year.

Suggested URLs

http://radar.metr.ou.edu/OK1/meteorology/Seasons.html

Good diagrams showing the relationship between the Sun and the Earth and how sunlight varies by latitude at the equinox and solstice.

http://www.learner.org/teacherslab/pup/

Copies of the "Private Universe" video can be ordered by going to "Additional Resources." Students can also try to answer the first 2 survey questions (with online answers) to see if they really understand the "reasons for the seasons."

http://www.rspac.ivv.nasa.gov/nasa/earth/seasons/seasons1.html

If you've got the bandwidth, an interesting animated explanation (Shockwave and Java) of the seasons.