

The Reasons for the Seasons

By Julie Lee Lambert and Suzanne Smith Sundburg

Ask a fifth-grader why he or she believes Earth has seasons, and the answer usually involves a mistaken notion about Earth's distance from the Sun. Not only are elementary students often stumped by the seasons, but adults also commonly misunderstand this concept—even Harvard University graduates (Schneps, Sadler, and Woll 1988).

Children understand that temperature usually fluctuates depending upon one's nearness to a heat source, which gives rise to the false analogy of the Sun's heat and its presumed effect on Earth's seasonal temperature fluctuations. Another explanation for this widespread erroneous impression may lie in the two-dimensional drawings that often depict Earth's orbit around the Sun. Most diagrams emphasize the elliptical nature of Earth's orbit. Although it is technically elliptical, Earth's orbit is a nearly perfect circle, with only a 2% difference between its *apogee* (the point in Earth's orbit at which it is farthest from the Sun's center) during the month of June and its *perigee* (the point in Earth's orbit at which it is closest to the Sun's center) during the month of January. Perigee occurs in January, corresponding with the Northern Hemisphere's winter, and the apogee occurs in June, corresponding with the Northern Hemisphere's summer.

The construction of a three-dimensional model of the changing seasons using simple materials has been successful in correcting students' misinterpretation of the cause of the seasons (Lambert and Ariza 2008).

Like the other planets, the Earth rotates on its axis as it revolves around the Sun. Earth is currently tilted 23.5° on its axis and remains in the same alignment with respect to the background stars throughout its orbit around the Sun, which takes 365.2 days. The North Pole always points toward Polaris or the North Star. We know that Earth is tilted 23.5° because of the geometric relationship between Earth and the Sun. The difference between the angle of the midday Sun on an equinox (September or March)



and a solstice (December or June) is equal to 23.5° .

As Earth revolves around the Sun, its axis remains tilted 23.5° in the same direction. However, the direction of Earth's tilt with respect to the Sun does change, causing the seasons. When the Northern Hemisphere is tilted toward the Sun, that half of the Earth receives more direct sunlight and has summer. At the same time, the Southern Hemisphere is tilted away from the Sun and has winter.

In this lesson, students employ a simple model to learn how Earth's tilt and revolution around the Sun causes our seasons.

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References

- Lambert, J. and E.N. Ariza. 2008. Improving achievement for linguistically and culturally diverse learners through an inquiry-based Earth systems curriculum. *Journal of Elementary Science Education* 20 (4): 61–79.
- Schneps, M.H., P.M. Sadler, and S. Woll. 1988. *A private universe: Misconceptions that block learning* [Videorecording]. Santa Monica, CA: Pyramid Films.



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Explaining Seasons With Tilting Toothpicks

What causes the seasons?

Grade Level: 4–6

Process Skills: observing, modeling, inferring, and communicating

Engage

To assess students' prior knowledge, first each student answered a brief preassessment (see NSTA Connection). The preassessment helped determine whether students thought Earth's changing distance to the Sun causes seasons or whether students thought that the tilt physically changes during different seasons. Additionally, it helped teachers determine if students knew that the Northern and Southern Hemispheres are experiencing opposite seasons when shown a diagram of the Sun's rays and a tilted Earth.

Teams of students were then asked to make a model of the seasons using a small craft light, four Earth models made of Styrofoam, four toothpicks, and a protractor. Students were told that the toothpick represented Earth's axis and to push the toothpick into the ball through the North Pole so that the end would go out at the South Pole. They also were told that each Earth model should represent one season.

Teams were asked to sketch their physical model and to answer a series of questions (the summary of embedded assessments is available online; see NSTA Connection). Each team then presented its model. The initial models revealed students' naïve or alternative conceptions. Most of the teams initially explained the seasons as being the result of Earth's distance to the Sun. Most teams had the tilt of the summer and winter Earth models correct, but they were not sure what to do with the tilt in the spring and fall Earth models. Figure 1 shows a typical model in which the students placed Earth closer to the Sun during the summer season and farther in the winter with the correct tilt, but then made the tilt more vertical for the spring and fall season. Occasionally, a model did not match the verbal explanation. For example, a team may have said that it kept the tilt the same, but the model showed a change in the direction of the tilt (Figure 2).

Explore and Explain

Teams were then asked to read a narrative describing Earth's orbit and its proximity to the Sun throughout

Materials

- Styrofoam circular base (approximately 1 ft. in diameter) and four spheres (approximately 1 in.)
- Toothpicks
- Protractors
- Craft light

Figure 1.

Incorrect student model.



Figure 2.

Tilt inconsistencies.



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the seasons, its tilt on its axis in relation to the Sun, and the amount and angle of direct rays of sunlight that each hemisphere receives during a particular season (see NSTA Connection). Based on the infor-

mation contained in the story, the teams were asked to revise their models accordingly. Each team's revised model was then checked, and the previous explanation was expanded on during a whole-class discussion. Assessment was again embedded (see NSTA Connection).

Each team eventually constructed a correct model of the seasons. One student helped his team understand the changing seasons by using a protractor to place each of the four toothpicks (*without* the Styrofoam Earth spheres) on the base, each at a 23.5° angle and all pointing the same direction. Immediately, students on his team seemed to understand the cause of the seasons. This simple explanation seems to help most students construct a correct model of the seasons.

The lesson highlighted one of the more difficult concepts underlying the cause of the seasons—the idea of direct and indirect light. Students sometimes asked why the Arctic is not warmer when it receives almost 24 hours of daylight during the summer. To help students understand why regions near the equator are warmer, a teacher can hold a flashlight perpendicular to a line drawn on a board. Using a marker, the bright area can be circled. Then the light should be moved so that it shines over the line at an angle, and the marker should again be traced around the bright area. Students will observe that the area was smaller when the light was shone at a perpendicular angle, and therefore the Sun's rays would be spread over less surface area and the area would be much warmer. When Sun's rays strike Earth's surface nearer the equator, the Sun's radiation is spread over a smaller area than at higher latitudes. See the "What Causes the Seasons?" Science 101 column (Robertson 2007) for a detailed explanation of this phenomenon.

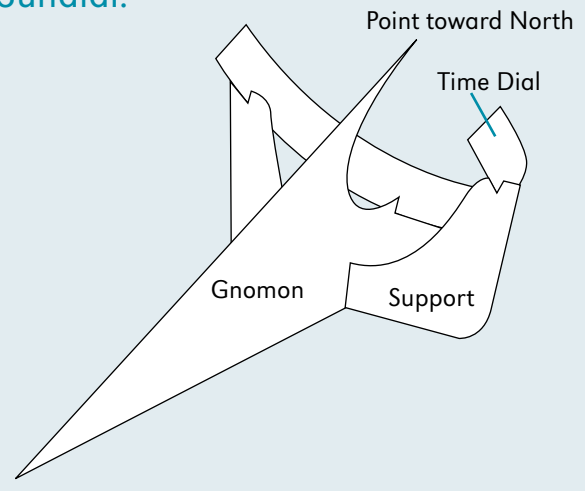
Extend

Students next applied their understanding of the real world by constructing a working sundial to measure the time of day (find directions online; see NSTA Connection). As the Sun shines on the sundial, the shadow of the gnomon's point will cover the current time on the time dial (Figure 3).

Next, we made an *astrolabe*, an instrument used to measure the angle of an object in the sky, such as the Sun or Moon, above the horizon (see NSTA Connection). In Greek, the word *astro* means "star," and *labe* means "to find." Both the sundial and the astrolabe can be used to track the Sun's path across the sky throughout the day or year.

Finally, students compared the number of daylight

Figure 3.
Sundial.



hours and the path of the Sun for each season in cities at different latitudes. Sunrise and sunset times for most cities can be found on the U.S. Naval Observatory's Astronomical Applications website (see Internet Resource).

Reference

Robertson, W. 2007. What Causes the Seasons? (*Science 101*) *Science and Children* 44(5): 54–57.

Internet Resource

U.S. Naval Observatory's Astronomical Applications
<http://aa.usno.navy.mil/data>

NSTA Connection

Download the preassessment, seasons narrative, and a summary of embedded assessments at www/nsta.org/SC1004.



Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996).

Grades 5–8

Standard D: Earth and Space

- Earth in the Solar System

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.