Closer but colder

CLASSROOM SCIENCE ACTIVITY TO
SUPPORT STUDENT ENQUIRY-BASED LEARNING

This classroom-tested teaching plan uses the four innovations of the TEMI project, as detailed in the Teaching the TEMI Way (TEMI, 2015).

You should read this companion book to get the most from your teaching. The **TEMI** techniques used in this teaching plan are: **1)** productive science mysteries, **2)** the **5E model** for engaged learning, **3)** the use of presentation skills to engage your students, and **4)** the apprenticeship model for learning through gradual release of responsibility. You might also wish to use the hypothesiser lifeline sheet (available on the **TEMI** website) to help your students document their ideas and discoveries as they work.

To know more about **TEMI** and find more resources **www.teachingmysteries.eu**

This research project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 321403.

teachingmysteries.eu

FP7-Science-in-Society-2012-1, Grant Agreement N. 321403

Co-funded by the Seventh Framework Program of the European Union

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What's the mystery?

Because of the shape of the Earth's orbit around the Sun, it is farther away from the Sun in July than it is in January. Still, we have colder days in January than in July. How is this possible?

Through this mystery, students will investigate the orbit of the Earth around the Sun and its influence on solar energy here on Earth. This will lead them to a deeper understanding of the seasons on Earth.

DOMAIN(S)

Physics, mathematics, earth sciences, astronomy.

SUBDOMAIN KEYWORDS

» Physics:
(Radiative) energy

» Mathematics:
(Spherical) geometry

» Earth sciences:
Seasons

» Astronomy:
Solar radiation
Celestial mechanics

AGE GROUP

12 to **16** years old.

EXPECTED TIME FOR THE MYSTERY

Approximate time for teacher preparation:
15 min.

Approximate time in classroom:
Two 45 min. lessons.

SAFETY/SUPERVISION

No need.

Disclaimer: the authors of this teaching material will not be held responsible for any injury or damage to persons or properties that might occur in its use.

PREPARATION AND LIST OF MATERIALS

The teacher should watch the following videos, which explain the reason for the seasons. TEMI Youtube Channel:
www.goo.gl/tUDaq5
playlist> Earth's Tilt 1
playlist> Earth's Tilt 2

Materials:

» Terrestrial globe

» Lamp/flashlight

» Protractor (optional: the universe awareness Earth ball).

LEARNING OBJECTIVES

» Learn why there are seasons.

» Learn about solar energy on Earth and its dependence on the orbit of the Earth around the Sun.

Guidance notes for teachers

THE 5E MODEL

Engage

CAPTURE STUDENTS' ATTENTION

Ask the students the following questions:

1. What season are we in right now?
2. Do you think that the Earth is now closer or farther away from the Sun?

In the summer months of the Northern Hemisphere, the most likely response from the students on question (2) will be that they think the Earth is closer, whereas in winter months they will most likely think the Earth is further away from the Sun. The fact is, however, that in July (summer month on Northern Hemisphere) the Earth is farther away from the Sun than in January. For students who live in the Northern Hemisphere, this will most likely be counterintuitive.

In this mystery we will learn how seasons work, how the Sun warms up the Earth and gain more knowledge and understanding about the orbit of the Earth around the Sun.

Explore

COLLECT DATA FROM EXPERIMENTS

To help the students explore this mystery, the teacher can guide the students through the following questions:

1. How does the Earth orbit the Sun? What is the shape of that orbit?

Answer for teacher: the Earth travels around the Sun in an elliptical orbit. Look at **IMAGE 1** on the next page for more information on the Earth's orbit.

Let the students draw the Earth's orbit on a sheet of paper.

2. Can you describe how an ellipse differs from a circle?

Answer for teacher: instead of one *centre point*, an ellipse has two *focal points*. The ellipse is shaped so that every point on the ellipse has the same summed distance to both focal points (see **IMAGE 2**). On the internet you can find several great resources that demonstrate how to easily draw an ellipse using a string, pins and a pencil.

In the next section, the students will explore the properties of the intensity of light, using a flashlight, paper and a pen/pencil.

3. How does the intensity of a flashlight depend on its angle?

Answer for teacher: the total energy output of the flashlight is always the same. If the students shine light on the paper surface at an angle that positions the light beam perpendicular to the surface, the light circle will be small and intense. The energy density (amount of energy per area) on the surface will be higher than when the students shine the beam along an acute angle.

Let the students play with this. Let them hold the flashlight at different angles: have them measure and document the angle and draw a circle (or ellipse!) around the resulting flashlight beam. They will notice that the light intensity of the projected beam will be lower when they hold the flashlight at sharper angles. By doing this, they can notice that the energy density is inversely proportional to the projected area.

4. Did you know that the Earth's rotation axis is tilted? What is the angle of the Earth's axis with respect to its orbital plane? Can you determine what is the angle of this tilt of the Earth's axis?

Answer for teacher: 23.5 degrees. Students can actually find this out by looking at a terrestrial globe, which is (almost) always tilted at a 23.5 degree angle. The students can use the protractor to measure the tilt of the terrestrial globe.

The students can now use their protractor to tilt the inflatable universe awareness Earth ball by 23.5 degrees.

The students can now move their tilted Earth ball/terrestrial globe in an orbit around a lamp to simulate the Earth orbiting the Sun. Using the knowledge they gained by exploring question (1) through (4), the students should now be able to deduce why seasons exist.

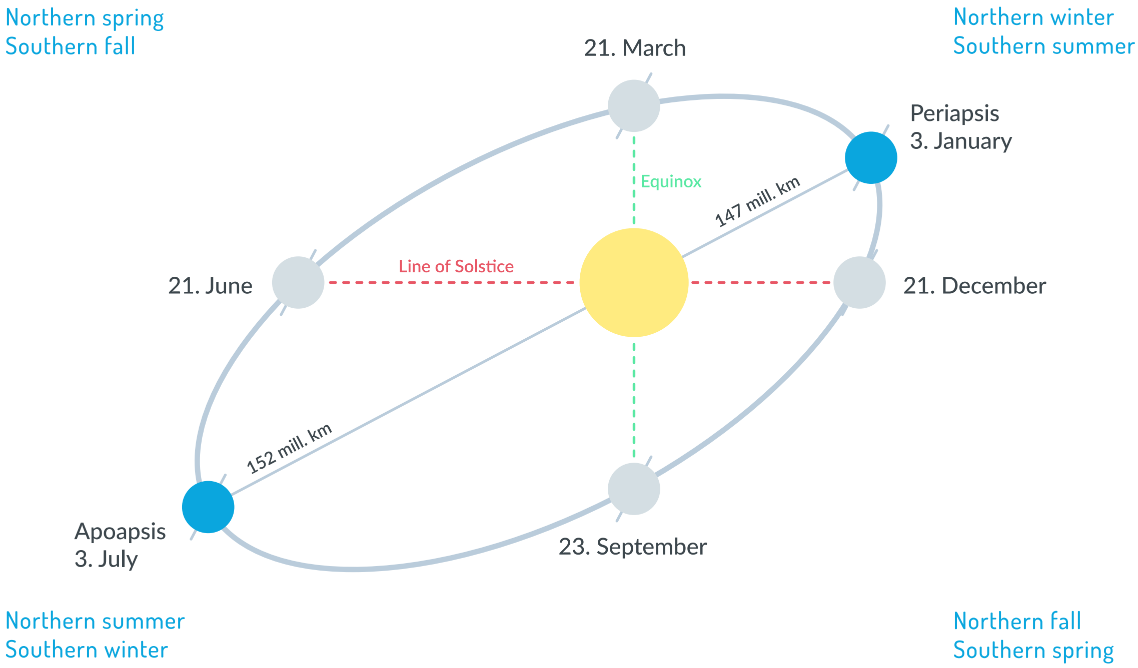

IMAGE 1. THE EARTH'S ORBIT AROUND THE SUN.
(Note that the relative sizes and distances of the Earth/Sun are not to the correct scale)

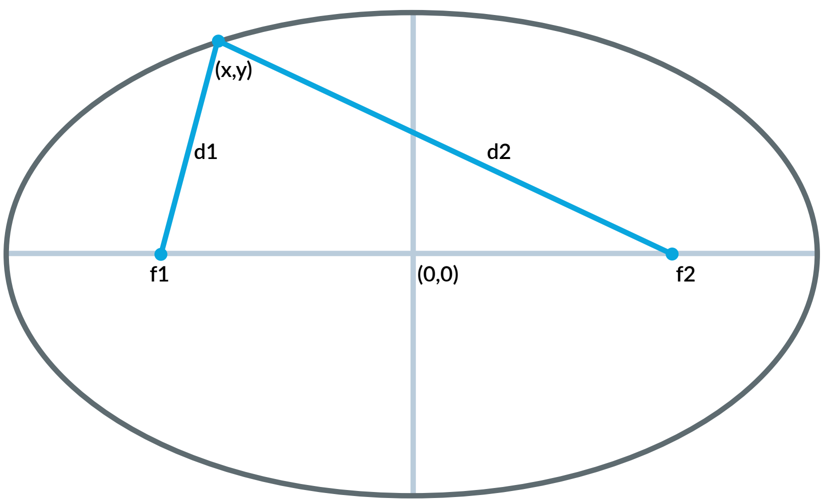

IMAGE 2. AN ELLIPSE. HERE THE SUM OF THE DISTANCES D1 + D2 IS CONSTANT FOR EVERY POINT ON THE ELLIPSE.

PHYSICS

Explain

WHAT'S THE SCIENCE BEHIND THE MYSTERY?

At the beginning of this section, the teacher can hand to the students the diagram of the Earth's orbit around the Sun (**IMAGE 1**). It is up to the teacher to decide whether to show the students the different steps towards the explanation or to guide them through the steps.

1. The teacher/students rotate a tilted model of the Earth around a lamp and look at when the light has the highest impact on the northern hemisphere.

2. What percentage of the average distance between the Earth and Sun is the difference in distance between aphelion (apoapsis) and perihelion (periapsis)?

Answer for the teacher: About three per cent. The average distance between the Earth and the Sun is 149.5 million km while the difference between aphelion and perihelion is 5 million km.

Note for the teacher: the teacher can challenge older/more advanced students by making the the mystery more mathematically challenging. They can ask the students to calculate the difference in energy density (e.g. per m^2) between the aphelion and the perihelion. For this, the students need to use the formula for the surface area of a sphere: $A=4\pi r^2$ (where r is the radius of the sphere).

3. Hold the Earth model at a certain distance from the lamp and then add this percentage to the distance. Can you see a difference in intensity of the light shining on the Earth?
   There should be no noticeable difference.

4. Hold the Earth model tilted 23.5 degrees with the northern hemisphere facing the lamp and then pointing away from the lamp. Can you see a difference in the intensity of the light shining on the Earth?
   The students should notice a difference.

5. So what has the most impact on the temperature in Europe? The distance to the Sun or the tilt of the Earth's axis?
   Answer for the teacher: tilt of the Earth's axis. The northern hemisphere faces the Sun at a sharper angle in January than in July; therefore, the energy density on the northern hemisphere is lower in January than it is in July. This is the reason why it is warmer in the northern hemisphere in July than in January. The distance to the Sun has an insignificant effect on the temperature.

When the students have finished exploring for themselves, they can watch this video that explains it all. TEMI Youtube Channel:
www.goo.gl/tUDaq5
playlist> Earth's Tilt 1

Extend

WHAT OTHER RELATED AREAS CAN BE EXPLORED?

Now that the students understand the reason for seasons and the physics behind it, they can extend their knowledge and understanding.

For example, the students can extend this mystery by calculating the position of the second focal point in the elliptical orbit of the Earth around the Sun *(at five million km from the Sun, towards the aphelion point of the Earth's orbit).*

Another way to extend the mystery is for the students to look at the length of the days in the northern hemisphere at each part of the orbit. Which month has the longest days? (June). So at which point in the orbit should the Earth be tilted, with the northern hemisphere pointing towards the Sun? *(At the summer solstice, close to June).*

The students can explore the reason why the Sun shines both day and night during the summer north of the Arctic Circle but doesn't rise during the day (or night) south of the Antarctic Circle at that time. They can explore this with the globe and flashlight.

As a follow-up exercise, you can show this video. TEMI Youtube Channel:
www.goo.gl/tUDaq5
playlist> Earth's Tilt 2

Evaluate

CHECK THE LEVEL OF STUDENT SCIENTIFIC UNDERSTANDING

Let the students explain in pairs how the seasons work. They can use the globe/flashlight or build their own model with colour paper (like in the YouTube video).

Showmanship

TIPS ON HOW TO TEACH AND PRESENT THIS MYSTERY

Although this seems like an obvious mystery, it is not as easy at it seems at first. It's best to let the students explore with the globe and flashlight so they can see for themselves how the tilt in the Earth's axis causes certain effects.

GRR

TEACHING SKILLS USING GRADUAL RELEASE OF RESPONSIBILITY

Setting up the mystery: ask the students what they know about the seasons, the orbit of the Earth around the Sun, etc.

Demonstrated enquiry (level 0): show the class how the Earth is tilted at an angle of 23.5 degrees when rotating the Sun. Show them what an elliptical orbit is. Watch both videos together. Let the students explain what they have learnt.

Structured enquiry (level 1): 'we do it'. Students then use their hypothesiser lifeline sheet to record their own alternative ideas about how the seasons work and to record their tests and conclusions regarding these other explanations.

Resources

The teacher can use the following YouTube videos for more information about the seasons:
TEMI Youtube Channel:
www.goo.gl/tUDaq5

A playful video explaining the reason for the seasons. It demonstrates how it can be summer in the northern hemisphere while it is winter in the southern hemisphere (and vice versa).
playlist> Earth's Tilt 1

A video explaining why the Sun will never rise above the horizon north of the Arctic Circle in January while it will never go under the horizon south of the Antarctic Circle (and vice versa in July).
playlist> Earth's Tilt 2

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STUDENT WORKSHEET

With this mystery, we will learn about the orbit of the Earth around the Sun and about the energy density of light. We will use these to deduce the reason for seasons.

Engage

WHAT'S INTERESTING?

Task 1: Do you know the dates that mark the start of each of the seasons? If not, find out!

Task 2: What season are we in right now?

Task 3: Do you think that the Earth currently is closer or further from the Sun than it will be half a year from now?

Explore

WHAT'S HAPPENING?

Task 1: How does the Earth orbit the Sun? What is the shape of that orbit?

Task 2: Draw a circle on a piece of paper. Now draw an ellipse next to it. Can you describe how an ellipse differs from a circle?

Task 3: By using a flashlight and a piece of paper, find out how the intensity of a flashlight depends on its angle. At what angle is the energy density of the light beam on the paper at its maximum?

Task 4: Did you know that the rotation axis of the Earth is tilted? Can you determine what is the angle of this tilt of the Earth's axis?

Task 5: Now move your tilted Earth model (terrestrial globe or inflatable Earth ball) in an orbit around the Sun (the lamp). When is the energy density of the lamp on the northern hemisphere the highest? At that point, what is the energy density of the lamp on the southern hemisphere?

And when is the energy density of the lamp on the northern hemisphere at its lowest?

Explain

WHAT'S CAUSING IT?

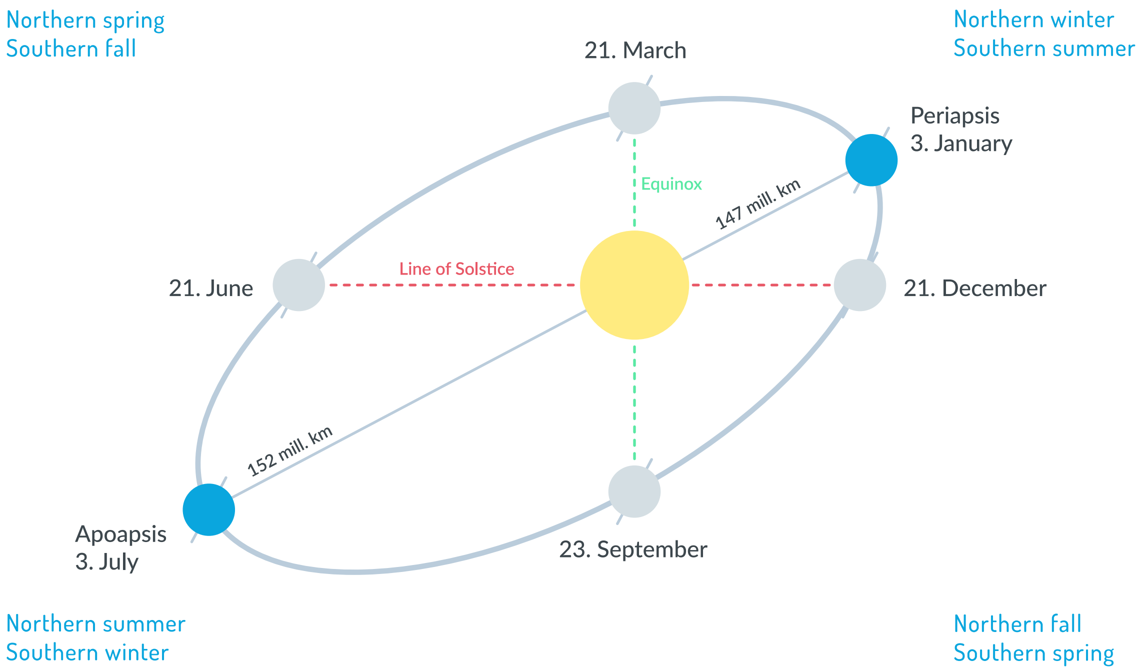
Task 1: Rotate a tilted Earth model around a lamp and look at when the light has the most impact on the northern hemisphere.

Task 2: What percentage of the average distance between the Earth and Sun is the difference in distance between aphelion (apoapsis) and perihelion (periapsis)?

Task 3: Hold the Earth model at a certain distance from the lamp and then add this percentage on to the distance. Can you see a difference in the intensity of the light shining on the Earth?

Task 4: Hold the Earth model tilted 23.5 degrees with the Northern Hemisphere facing the lamp, and then pointing away from the lamp. Can you see a difference in intensity of the light shining on the Earth?

Task 5: So what has the most impact on the temperature in Europe? The distance to the Sun or the tilt of the Earth's axis?



Extend

WHAT'S SIMILAR?

Task 1: Calculate the position of the second focal point in the elliptical orbit of the Earth around the Sun.

Task 2: Using the terrestrial globe, the flashlight, and the diagram of the Earth's orbit around the Sun, look at the length of the days in the northern hemisphere at each part of the orbit. Which month has the longest days?

Task 3: Explore the reason why the Sun shines during the night at the North Pole when it is summer in the northern hemisphere and why the Sun won't come up during the day at the South Pole. Explore this with the globe and the flashlight.

Evaluate

WHAT'S MY UNDERSTANDING?

Task: Explain what you have learnt to your classmates. Think about a good way of presenting this. For example, you can use the flashlight and globe or make your own model with coloured paper.