*Physics > Big idea PES: Earth in space > Topic PES2: Earth and Sun*

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| **Key concept (age 11-14)** |
| **PES2.1: Days and seasons** |

**What’s the big idea?**

A big idea in physics is of Earth in space. This is important because we live on the Earth and it is the only planet that we know to have abundant and complex life. Understanding how the Earth and space systems interact, how they affect us, and how we affect them is vital for our survival. Exploring our origins and our place in the universe feeds the intrinsic curiosity of humans and develops a sense of wonder.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by building on observations of changes through a day and differences between seasons, to understand how the Earth-Sun model can explain changes to the length of day and the heating effect of the Sun through a year.

****The conceptual progression starts by checking understanding of how the Sun moves through the sky each day. It then supports the development of the Earth-sun model with the Earth’s axis tilted in order to enable understanding of why days are longer and the Sun higher in the sky during summer, and how these factors increase the average temperature during summer.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Days and seasons**

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| **Learning focus** | The temperature is higher in the summer because the tilt of the spinning Earth increases the length of a day *and* increases the heating effect of the Sun’s radiation. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Describe the apparent movement of the Sun during the day.  **P** | Describe the effect of seasons on temperature, day length and the apparent movement of the Sun.  **P** | Explain why days are longer in summer and shorter in winter. | Explain why the angle of the Sun changes the effect of its heating. | Explain why average temperature is higher in summer and lower in winter. |
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| **Diagnostic questions** | Changing Sun | Changing seasons | Summer days | Heating the towel | Hot summer days |
|  |  |  |  |  |  |
| **Response**  **activities** | Long days of summer | | | Getting warm | Explaining summer |
|  |  | Which season? |  |  |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning |  |  |

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| --- | --- | --- | --- | --- |
| **Changing Sun** | **Changing seasons** | **Summer days** | **Heating the towel** | **Hot summer days** |
|  |  |  |  |  |
| Two-tier multiple choice | Confidence grid | Two-tier multiple choice | Two-tier multiple choice | Confidence grid |
| **Long days of summer** | **Which season?** | **Getting warm** | **Explaining summer** |  |
|  |  |  |  |  |
| Critiquing a representation | Confidence grid | Predict, explain; observe, explain | Explanation story |  |

**What’s the science story?**

*Day and night*

The Earth is rotating about an axis that defines the (geographic) North and South Poles and Equator. As it rotates, different parts of its surface are illuminated. One complete rotation of Earth = 1 day.

We experience daylight everywhere on the half of Earth's surface that is illuminated by the sun. Night occurs everywhere in the half that is not illuminated.

As Earth rotates, we see the Sun in different positions in the sky. The Sun comes into view (rises) in the east, is seen to travel E-W in an arc across the sky, (E-S-W in the northern hemisphere, E-N-W in the S hemisphere) and disappears (sets) in the west.

*Seasons*

The Earth moves round the Sun in an approximately circular orbit. The Earth's own rotation axis is tilted (at about 23°) relative to the axis of its orbit.

The direction of the tilt remains constant in space as Earth travels round the Sun. So the Earth's rotation axis not (usually) at right-angles to a line drawn between Earth and Sun. If it was, all parts of Earth would always get equal periods of daylight and night.

When the North Pole is tilted towards the Sun, daylight lasts for more than 12 hours in the northern hemisphere and less than 12 hours in the southern hemisphere; it is summer in the northern hemisphere and winter in the southern hemisphere. Similarly, at the opposite side of the orbit, when the South Pole is tilted towards the Sun, it is winter in the northern hemisphere (less than 12 hours daylight) and summer in the southern hemisphere. Mid way between these two extremes, Earth's rotation axis *is* at right-angles to a line drawn between Earth and Sun. At these times, (the equinoxes: 'equal night') all parts of Earth get equal periods of daylight and night.

One complete orbit around the Sun = 1 year ≈ 365.25 days

In winter, at any given time of day the Sun is lower in the sky than it is in summer; solar radiation meets the Earth's surface at a more oblique angle so it is less intense (= spread out over a greater area) and so feels less hot. The radiation has also travelled through a greater depth of atmosphere (compared to when the Sun is higher in the sky) so more is absorbed en route before reaching the surface. And the shorter period of daytime in winter means that a given location is warmed for a shorter time in winter than in summer. All of these factors lead to the Earth's surface at any given location being colder in winter than in summer. The first two also explain why the equator is hotter than the poles.

*At the equinoxes, the Sun is overhead at midday on the Equator, and at the poles it moves around the horizon.*

*When it is midsummer in the northern hemisphere, the sun is overhead at midday at a latitude of 23oN (Tropic of Cancer); further north than latitude 67oN (Arctic Circle) the Sun is always above the horizon (it never sets); and south of latitude 67oS (Antarctic Circle) the Sun never rises.*

**What does the research say?**

For a scientific understanding of the causes of seasons, students need to understand and combine thinking about the causes of night and day; how the tilt of the Earth affects the length of day and the height of the Sun in the sky; and also the heating effect of thermal radiation falling on the Earth’s surface from different angles.

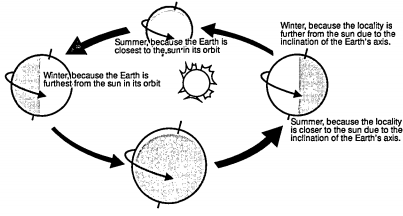
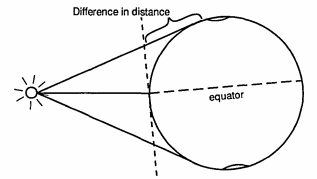
Students often learn about the cause of day and night in primary school at ages 9-11 (Department for Education, 2013) and it can be tempting to keep this work simple and descriptive when in fact it is conceptually demanding (Osborne, 2011). The scientific explanations for simple observations such as the Sun moving across the sky each day are not obvious and sometimes counter intuitive. The Sun’s ‘movement’ across the sky happens not because the Sun is moving, which is the most obvious explanation, but because the Earth is spinning on its axis.

At age 11-14 most students understand the Earth to be a sphere and describe the cause of day and night in terms of the movement of astronomical bodies (Driver et al., 1994; Baxter, 1989; Bakas and Mikropoulos, 2003; Brewer and Vosniadou, 1994; Sharp, 1996). Baxter (1989) found that the proportion of students’ holding the scientific understanding of the cause of day and night declines over time. Further studies (Sharp, 1996; Kikas, 1998) support this finding, which suggests many students learn this idea by rote without understanding, or that they are unable to integrate teaching with their earlier preconceptions. Typically after teaching, about 60% of 10- and 11-year-olds are able to explain night and day (Sharp, 1996; Kikas, 1998), but this ‘understanding’ can be short lived. In her study, Kikas found that after four years only 20% of the students from the original sample still maintained the correct scientific understanding.

In order to build and consolidate students’ understanding of day and night, the use of physical models has been shown to be an effective strategy (Bakas and Mikropoulos, 2003; Lelliott and Rollnick, 2009). Models can be used to explain day and night and why the tilt of the Earth alters the length of the day at different times of the year.

Seasons

In text book diagrams, rays representing radiation from the Sun reaching the poles appear significantly longer than those reaching the equator. Such diagrams can reinforce the misunderstanding that it is warmer in the summer because we are closer to the Sun. When students encounter these diagrams for the first time they often do not have an accurate understanding of scale and do not realise that the differences in distances here are too small to make a noticeable difference to temperature (Ojala, 1992; Ojala, 1997). Ojala also found that the common practice of showing all four seasons on one diagram caused confusion and suggested using a separate diagram for each season.



Ojala (1997)

The most common reason students (wrongly) give for why it is warmer in the summer is the Earth being closer to the Sun at that time (Allen, 2014; Driver et al., 1994; Baxter, 1989). Bakas and Mikropoulos (2003) found that Greek students aged 11-13 (n=102) were more likely to explain that higher temperatures in summer are caused by the Sun being higher in the sky, or because the days are longer, but without explaining the cause of these phenomena.

In the summer one reason temperatures are higher is because the part of the Earth experiencing summer is tilted towards the Sun. This means the Sun is higher in the sky and the radiation from it is spread out over a smaller area of land giving a bigger heating effect. Ojala (1992) suggested representing the uneven distribution of the Sun’s radiation over the Earth’s surface with a diagram that shows how equal amounts of radiation spread. Küçüközer (2008) used a computer simulation to show what proportion of all radiation reaching the Earth fell above or below the equator during the summer and the winter.

Summer in the Northern hemisphere

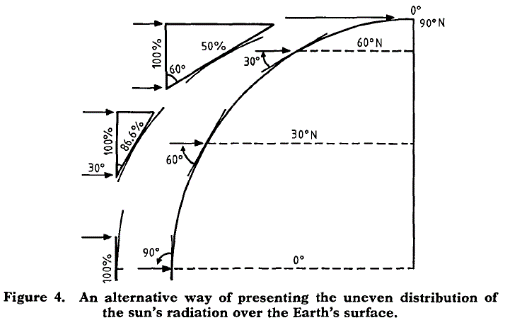
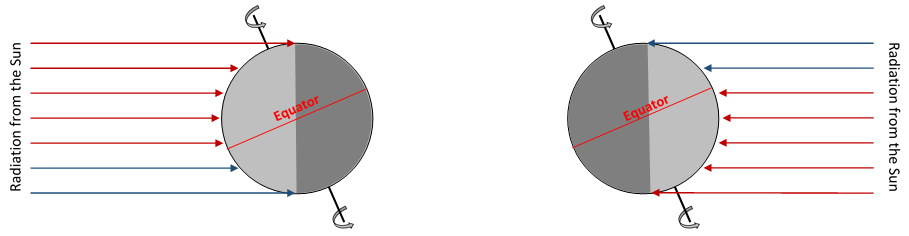
Most radiation falls north of the Equator.

Winter in the Northern hemisphere

*Earth has moved round to the other side of the Sun*

Most radiation falls north of the Equator.

Küçüközer (2008)



Areas of land that each receive the same amount of radiation from the Sun

Ojala (1992)

A second consequence of the Earth tilting towards the Sun in summer is the increase in the length of the day. Depending at which latitude students live, they are likely to have different perceptions of changes to day length. In Greece, Bakas and Mikropoulos (2003) found just 17% (n=102) of 11- to 13-year-olds realised day lengths changed through the year, whereas the phenomena would be obvious to students in Scandinavia. Students are often able to suggest that this is caused by the tilt of the Earth, without being able to explain the mechanism (Baxter, 1989; Dunlop, 2000; Lelliott and Rollnick, 2009). A small proportion of 10- to 11-year-olds believe the Sun moves more slowly through the sky in summer (Sharp, 1996).

Constructivist teaching strategies that challenge student misunderstandings were shown to significantly improve knowledge about the causes of seasons (Trumper, 2006) and elicit longer retention of the scientific concepts (Tsai and Chang, 2005).

**Guidance notes**

This progression toolkit reminds students of how the Sun moves through the sky in an arc which can be explained by the Earth spinning on its axis. It could also be explained *consistently but wrongly* by the Sun orbiting the Earth each day. The Earth-Sun model introduced in the key concept: *PES1.1 Planets and the Solar System* is used to model the spinning Earth, and this model is extended to demonstrate how the tilt of the Earth can explain changes to the length of a day as the Earth orbits the Sun each year. Further evidence to support this model is that it can explain changes of seasons in countries away from the Equator. Seasons cannot be explained by a model of the Sun orbiting the Earth.

A further consequence of the Earth’s tilt is that the angle between each part of the globe’s surface and the Sun changes through each year. A classroom investigation can show how the angle at which a surface faces a heat source changes the rate at which the temperature of surface increases. This evidence added to changes to the length of day explains why it is warmer in the summer compared to winter. Comparing when seasons in the northern and southern hemispheres take place gives evidence that the Earth’s distance to the Sun.

It may be helpful to refer to summer (or any other season) as *northern summer* or *southern summer* to indicate that it is never summer everywhere at the same time.

**References**

Allen, M. (2014). *Misconceptions in Primary Science, 2nd* ednBerkshire, UK: Open University Press.

Bakas, C. and Mikropoulos, T. (2003). Design of virtual environments for the comprehension of planetary phenomena based on students' ideas. *International Journal of Science Education,* 25:8**,** 949-967.

Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education,* 11 (Special Issue)**,** 502-13.

Brewer, W. and Vosniadou, S. (1994). Mental Models of the Daylight Cycle. *Cognitive Science,* 18**,** 123-183.

Department for Education (2013). *Science programmes of study: key stages 1 and 2 - National curriculum in England (DFE-00182-2013),* London, UK.

Driver, R., et al. (1994). *Making Sense of Secondary Science: Research into Children's Ideas,* London, UK: Routledge.

Dunlop, J. (2000). How children observe the Universe. *Publications of the Astronomical Society of Australia,* 17**,** 194-206.

Kikas, E. (1998). The impact of teaching on students' definitions and explanations of astronomical phenomena. *Learning and Instruction,* 8:5**,** 439-454.

Kucukozer, H. (2008). The effects of 3D computer modelling on conceptual change about seasons and phases of the Moon. *Physics Education,* 43(6)**,** 632-636.

Lelliott, A. and Rollnick, M. (2009). Big Ideas: A review of astronomy education research 1974-2008. *International Journal of Science Education,* 32:13**,** 1771-1799.

Ojala, J. (1992). The third planet. *International Journal of Science Education,* 14:2**,** 191-200.

Ojala, J. (1997). Lost in space? The concepts of planetary phenomena held by trainee primary school teachers. *International Research in Geographical & Environmental Education,* 6:3**,** 183-203.

Osborne, J. (2011). Earth in Space. In Sang, D. (ed.) *Teaching Secondary Physics.* London: Hodder Education.

Sharp, J. G. (1996). Children's astronomical beliefs: a preliminary study of Year 6 children in south-west England. *International Journal of Science Education,* 18(6)**,** 685-712.

Trumper, R. (2006). Teaching future teachers basic astronomy concepts-seasonal changes-at a time of reform in science education. *Journal of Research in Science Teaching,* 43(9)**,** 879-906.

Tsai, C. and Chang, C. (2005). Lasting effects of instruction guided by the conflict map: Experimental study of learning about the causes of the seasons. *Journal of Research in Science Teaching,* 42(10)**,** 1089-1111.