Physics > Big idea PES: Earth in space> Topic PES1: Solar System and beyond

Key concept (age 11-14)
PES1.1: Planets and the Solar System

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.

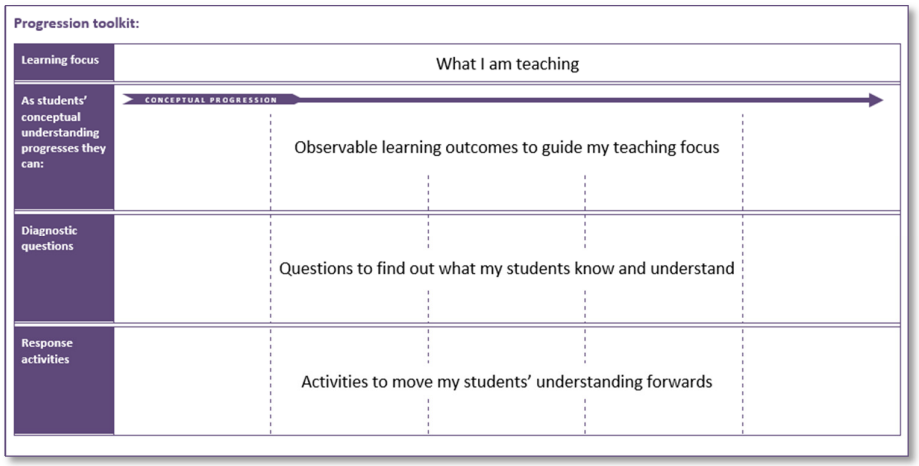
How does this key concept develop understanding of the big idea?

This key concept develops the big idea by building on the ideas of how the Earth orbits the Sun and the Moon orbits the Earth, to establish a clear physical model for the Solar System that can explain everyday observations.

The conceptual progression starts by checking understanding of the Earth as a sphere. It then supports the development of a scientific model that explains days and years in order to enable understanding of the nature and scale of the Solar System.

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: Planets and the Solar System

Learning focus	In the Solar System: eight planets orbit a star called the Sun; moons orbit most of the planets; and the planets spin on their axes. We live on the Earth where: a year is defined as the time for the Earth to orbit the Sun; a day as the time it takes the Earth to spin on its axis; and the Moon orbits in about 28 days. The planets are very small compared to the huge distances between them.				
As students' conceptual understanding progresses they can:	CONCEPTUAL PROGRESSION Identify that we live on the surface of the Earth which is a sphere P	Describe how the Earth spins on its axis and explain what a day is P	Describe how the Earth orbits the Sun and explain what a year is P	Describe how the Moon orbits the Earth and explain what a lunar month is P	Describe the sizes of the Sun, Moon, Earth and other planets, and the distances between them
Diagnostic questions	The Earth	Day and night	Sun, Moon and Earth		The size of space
Response activities	Modelling the Earth			Modelling the Moon	The Solar System

Key:

P Prior understanding from earlier stages of learning

What's the science story?

The Earth is a sphere. It appears locally flat because it is very big. Day and night, and the apparent motions of Sun, Moon and stars are due to the rotation of the Earth on its axis. 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.

The Sun is also a sphere. It is very hot. It (emits radiation that) illuminates and warms the Earth. Solar radiation illuminates the half of the Earth's surface that is facing towards the Sun. The Sun is many times bigger than the Earth and looks small because it is far away.

The Earth orbits the Sun once every year (365¼ days), which means it moves around the Sun in (roughly) a circle.

The Moon is a cold rocky sphere that does not produce its own light. The moon is much smaller than the Earth (its diameter is 4.6 times smaller). The Sun lights up the half of the Moon that is facing towards it.

The Earth is a planet. There are seven other planets orbiting the Sun. In order of increasing distance from Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. Most of these planets have moons that orbit them. (Pluto is a one of several dwarf-planets that are known, and there are thought to be many more, further out from the Sun in the Oort Cloud.)

The Sun, planets and other orbiting objects are collectively known as the Solar System.

What does the research say?

It can be tempting to keep work on the Solar System 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. In the sky the Sun appears to be smaller than the Earth but in fact is much bigger and very far away. The Moon looks to be the same size as the Sun, but is much, much smaller and also much closer. For similar reasons stars appear to be tiny and therefore very different to the Sun.

It is also easy to assume that students understand more than they do. Research has shown that the majority of young children aged 8-10 have a naïve understanding of the Earth as being flat. By age 12 most understand the Earth to be spherical, although for many correct ideas about gravity tend to develop later (Nussbaum, 1985; Driver et al., 1994; Baxter, 1989). Just 20% of 16-year-olds interviewed in a study held the accepted science view that gravity pulls objects near to surface of the Earth towards the *centre* of the Earth (Baxter, 1989).

A study of thirty-two Tasmanian students identified a progression in students' thinking from a model with the Earth at the centre, which was held by about three-quarters of the 9- and 10-year-olds, to a model with the Sun at the centre that is understood by the majority of the 11- and 12-year-olds (Jones, Lynch

and Reesink, 1987). To correctly explain observable phenomena that are caused by movement of the Earth, Sun and Moon students need to understand the correct scientific model. If they are using a model that is incorrect students are likely to form further misunderstandings and about a quarter of 11- and 12-year-olds are using incorrect models.

In a study (n=25 for each age range) about half of students aged 11-12 thought that night and day were caused by the movement of the Sun with just 20% giving the correct explanation; by age 13 or 14 about half could explain how day and night are caused by the Earth spinning on its axis (Baxter, 1989). It may be that by keeping work on the Solar System simple and descriptive students are allowed to maintain their misunderstandings. One of the key findings of Lelliott and Rollnick's (2009) review of astronomy education research (1974-2008) was the need for teachers to use physical models both to scaffold learning and to challenge misunderstanding.

One problem with models of the Solar System is the difficulty of scale. If the Earth is modelled as the size of a soccer ball, the Moon would be the size of a tennis ball orbiting at 6.6m from the Earth, and on the same scale the Sun would be the size of a (spherical) ten storey building about 2.6 kilometres away. Diagrams of the Solar System in books and on posters are often poorly drawn and not to scale which can lead to persistent misunderstandings (Taylor, Barker and Jones, 2003). There is evidence that students typically have a poor understanding of the scale of space and it is recommend that there is a greater focus on the teaching of distance and size to help explain astronomical phenomena more clearly (Lelliott and Rollnick, 2009).

Only about half of 10- and 11-year-olds realise that the Sun is a star (Sharp, 1996). This misunderstanding, that the Sun is different to the stars, is persistent and just 55% of adults identify the Sun as a star (Lightman, Miller and Leadbetter, 1989).

The progression toolkit for Planets and the Solar System reminds students that we live on the surface of the planet Earth which a solid sphere. By using models to describe the motion of the Earth as spinning on its axis and orbiting the Sun, students are given the opportunity to develop a scientific understanding of days and years. Adding the Moon to the model allows them to consider why the scientific model of the Sun, Moon and Earth is correct when other models, that could explain days and years, are not. Thinking about the relative sizes of the Earth, Sun and Moon and the distances between them allows students to interpret models and pictures of the Solar System and introduces them to the sheer enormity of space.

Guidance notes

Seasons and eclipses are very challenging ideas that have been deliberately left out of this key concept. They are tackled at a later stage of learning in the topic PES2: Earth, Moon and Sun.

Scale models of the Solar System

Searching on the internet for ‘Solar System model scale calculator’ will find several websites that can be used to calculate scales in the Solar System. If you want to make a 3-D scale model, then expanded polystyrene balls of a wide range of sizes can be bought on the internet. The larger planets can be made from paper-mache using a balloon as a mould. If this is done then ‘punch-balloons’ give a rounder shape than regular ones.

There is a very good video of a scale model of the Solar System on the Channel 4 (UK) programme: 'Scientific Eye Space' (about 12 minutes from the start). This uses the full length of the runway at Leeds-Bradford airport, in the north of England with students dropped off along the runway holding scale models of each planet. On this scale the Earth is the size of a blackcurrant and 76 m away from a beach-ball sized Sun. Please note if you use this video that it was made when Pluto was still considered a planet and Pluto is included in the model.

References

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

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

Jones, B. L., Lynch, P. P. and Reesink, C. (1987). Children's conception of the Earth, Sun and Moon. *International Journal of Science Education,* 9(1)**,** 43-53.

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.

Lightman, A. P., Miller, J. D. and Leadbetter, J. B. (1989). Contemporary cosmological beliefs. *Second International Seminar: Misconceptions and Educational Strategies in Science and Mathematics.* Cornell University, Ithaca, N.Y.

Nussbaum, J. (1985). The Earth as a cosmic body. In Driver, R., Guesne, E. & Tiberghien, A. (eds.) *Children's Ideas In Science.* Milton Keynes: Open University Press.

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.

Taylor, I., Barker, M. and Jones, A. (2003). Promoting mental model building in astronomy education. *International Journal of Science Education,* 25:10**,** 1205-1225.