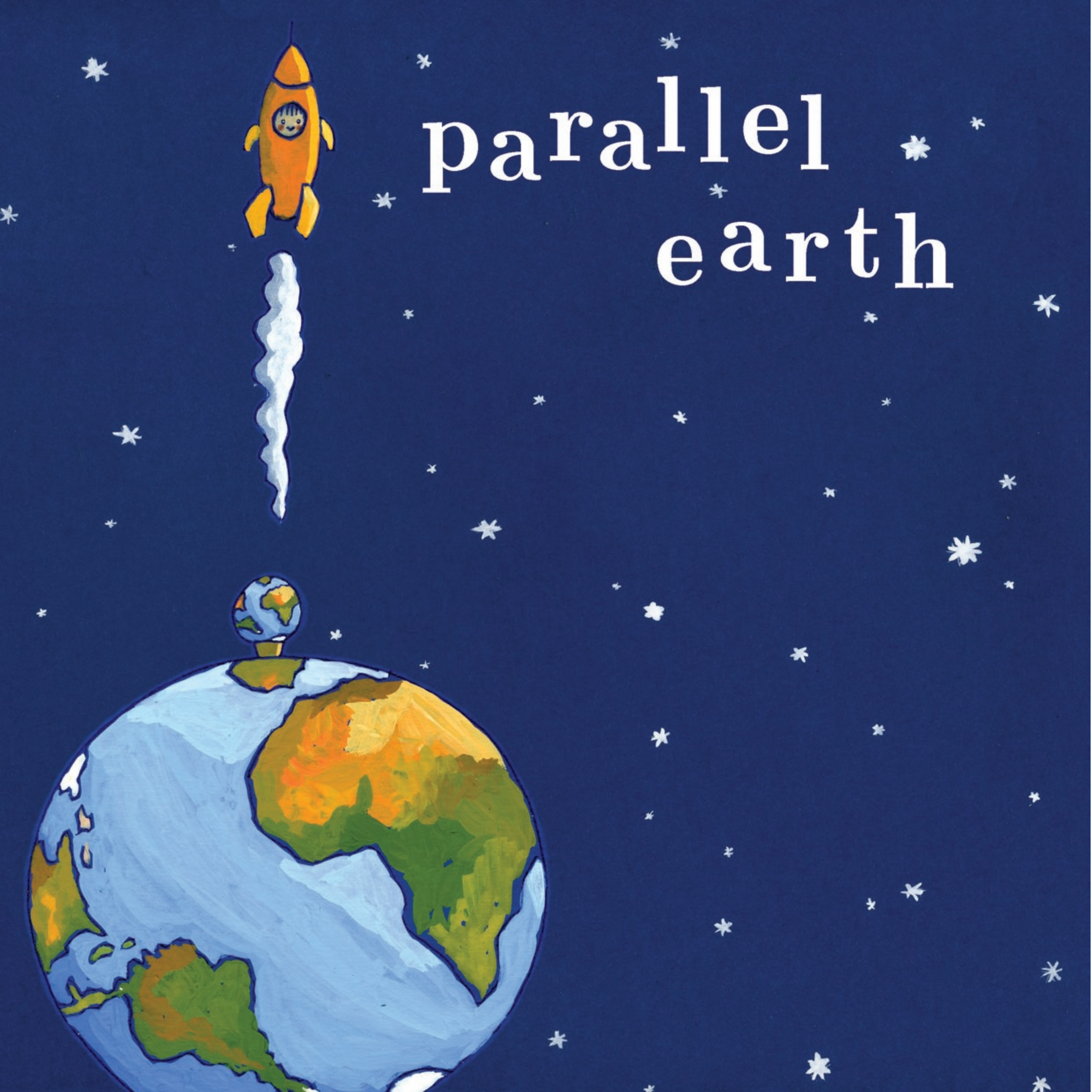
parallel earth



First Edition: December 2012

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Acknowledgements (translation): Heather Andrews, Libby McKearney and Mark Bailey

The book “Parallel Earth” was funded through the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 263325.

Legal Deposit: B-34002-2012
Printed in the EU
ISBN: 978-84-615-9748-2

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EU-UNAWE, 2012

The Spanish National Research Council (CSIC) is the largest public institution in Spain devoted to scientific research and technological development. It aims to encourage, develop and disseminate scientific and technological research in order to contribute to the advancement of knowledge and to the economic, social and cultural development. The CSIC is an institution which promotes science education and supports the work of UNAWE and EU-UNAWE programmes, which are especiallydesigned for young people from all Spanish-speaking countries.

www.csic.es

EU-UNAWE is an educational project of the European Union, based on the UNAWE programme. Both projects use the beauty and grandeur of the Universe to encourage young children, particularly those from underprivileged communities, to take an interest in science and technology and to foster their sense of global citizenship from an early age. Although UNAWE was founded only five years ago, it is already active in over 40 countries and comprises a global network of more than 500 astronomers, teachers and educators.

From 2011 to 2013, EU-UNAWE will implement activities to raise awareness about our universe in six countries: Germany, Italy, Netherlands, Spain, United Kingdom and South Africa. The project includes organizing teacher training workshops and developing learning resources for children. In the long term, EU-UNAWE will help produce the next generation of engineers and scientists. This programme also encourages children from underprivileged areas to realize that they are part of a much larger global community.

es.unawe.org

Introduction

'Parallel Earth' shows us how to use a simple model of the Earth to teach children to visualise our planet as if we were outside it. This allows us to understand a number of phenomena that are difficult to grasp when making observations from the Earth's surface.

The main component of the model is an inflatable Earthball or an Earth globe that can be taken out of its support. This allows us to orient it correctly, with respect to our location on Earth. Such globes are usually available in any school. Once the Earth globe has been appropriately positioned, we have an image of the Earth aligned parallel to where we are located. At different latitudes and longitudes, we can observe a number of phenomena arising from the position of the Earth with respect to the Sun, such as day and night as well as the seasons.

Figure 1: The part of the coloured ball illuminated by the Sun is the same as that illuminated on the Earth globe model. The illumination on the surface of the Earth globe also corresponds to that on our real Earth when the globe is placed parallel to Earth, with the same orientation. We cannot perceive this because we are 'stuck' on the Earth's surface and cannot move away far enough to see it as a whole.

Method

For the Earth model, we use a conventional globe available in any store. Note that the inclination of the fixed support of these globes coincides with the inclination of the axis that goes through the poles. This position is always the same, regardless of our location on Earth. We are so accustomed to seeing a globe with an inclined axis that we normally do not question the frame of reference used for this. Thus, we fail to make the most of the information that an Earth model can provide.

The plane of support of an Earth globe coincides with the ecliptic, i.e. the plane in which the Earth revolves around the Sun while rotating on its own axis. The terrestrial Equator is inclined at 23° 27′ to the plane of the ecliptic, and therefore, the Earth's axis is not perpendicular to the plane of the support or to the ecliptic. In the Northern Hemisphere, this axis is directed towards a point close to the North Star (figure 2).

As observers, we are located at a specific place on Earth. If we would like to use the terrestrial sphere in relation to the Sun, it is essential to orient the model so that our present location is at the top of the sphere. That is, if we position ourselves on the sphere, our location will be the highest point, irrespective of where we are on Earth. Therefore, the sphere representing the Earth must not have a fixed support: we must be able to orient it according to the place of observation. We will therefore use the globe by placing it on a vase, a bucket or a bowl, which can serve as the support (figure 3).

Figure 2: Earth globe with standard support. The axis is oriented towards a point close to the North Star.

Figure 3: Earth globe placed on a bowl. The location of the observer is at the top.

Figure 4: 'Parallel Earth' with its axis aligned with the North–South plane, indicated by the line marked on the ground using a string.

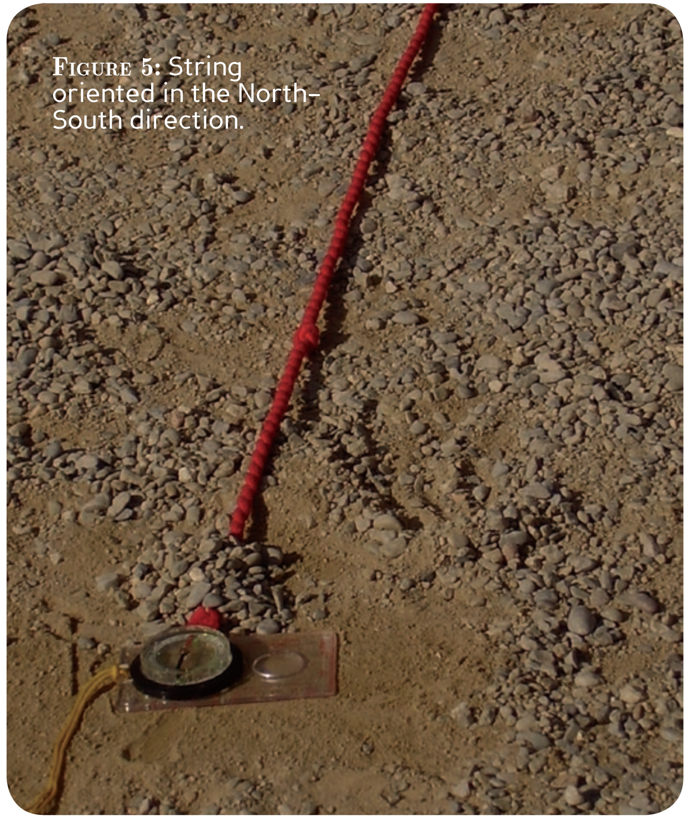


Figure 5: String oriented in the North–South direction.

Observations

We place the model outdoors in a sunny area.

We make sure that our current location on 'parallel Earth' is parallel to the ground beneath our feet and the rotation axis of the terrestrial sphere, i.e. the 'parallel Earth', is aligned with the North–South plane.

We use a compass to find the North–South direction. Although the magnetic North–South direction does not coincide with the geographic one, it is close enough for our purpose.

We mark the direction on the ground with a string and place the sphere above the line (figures 4 and 5).

We ensure that the projection of the Earth model's rotation axis on the ground corresponds as closely as possible to the North–South direction indicated by the string.

When orienting the sphere, it is crucial that our current location, i.e. our town, is at the top of the sphere.

Next, we ensure that our location and its

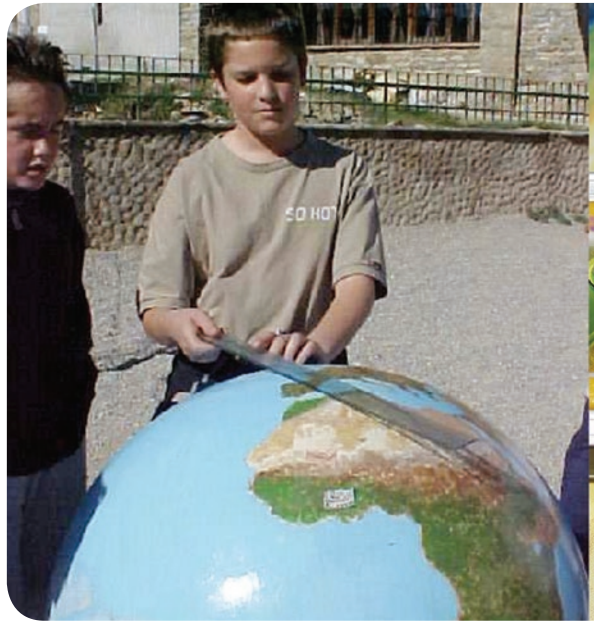


Figure 6: Aligning 'parallel Earth' with the help of a ruler.

Figure 7: Arranging 'parallel Earth' with the help of a spirit level.

representation on the Earth model are parallel (the two are always at the highest point of the sphere) using a ruler, as shown in figure 6.

We place the ruler on our location on Earth such that it is parallel to the ground.

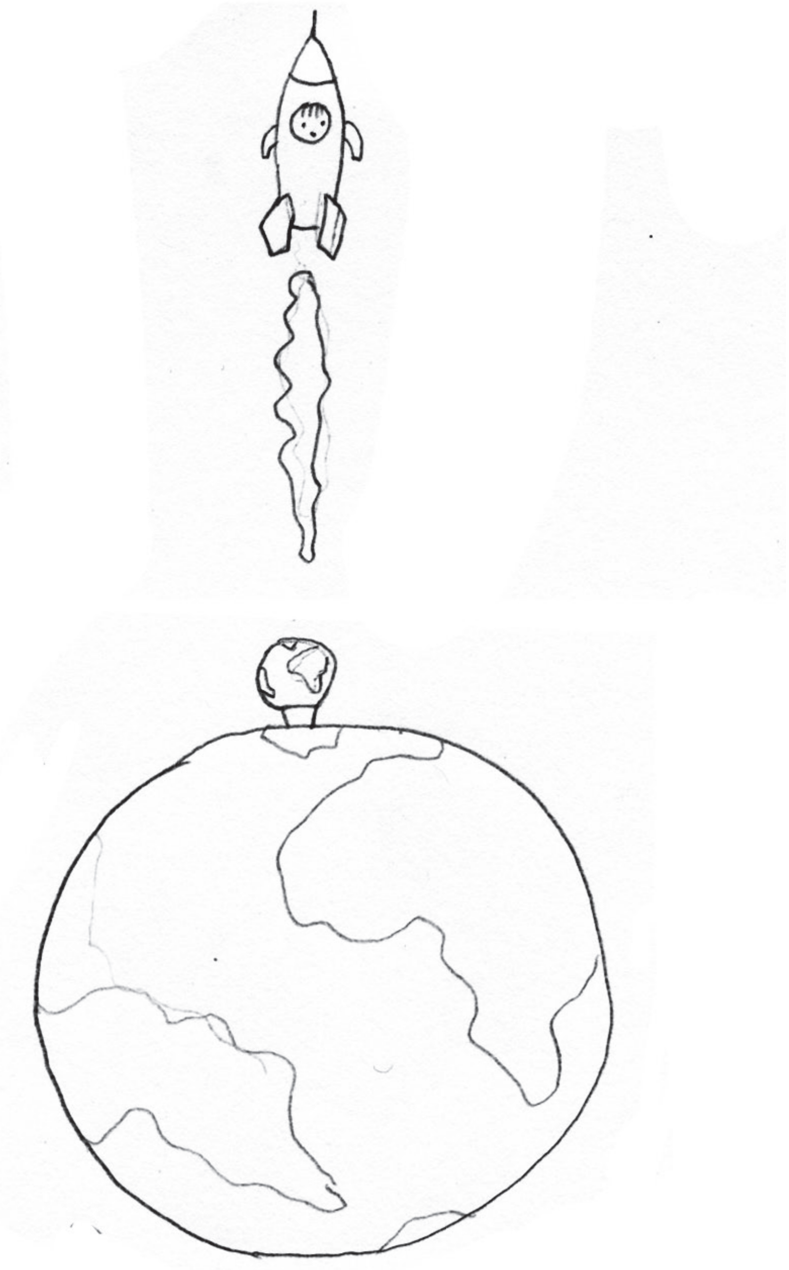
If the ruler is balanced over the entire surface of the sphere, it is correctly positioned. We can check this with a spirit level. Otherwise, we move it until our location reaches the highest point of the model.

Once correctly oriented, our parallel Earth model is ready to use.

Experiments

Let us imagine taking off vertically on a trip into space. We first see the place that we left, for example our school, becoming smaller; next we see our village or town appearing smaller, then our region, our country, our continent, and so on. Eventually, we see the Earth as a small sphere floating in space, a sphere just like our model, partially illuminated by the Sun.

Since our 'parallel Earth' rotates on its axis exactly like the real Earth, we can observe on its surface all the phenomena of light and shadow caused by the Sun and its movement with respect to Earth.



By looking at the 'parallel Earth' for a few hours or a whole day we can infer the number of hours of day and night

When our 'parallel Earth' is placed in a sunny spot, we notice the following:

- Some areas are illuminated by the Sun while others are not. This implies that we experience the same phenomena on Earth; therefore, it is day in some areas on Earth and night at others.
- If we keep looking at our 'parallel Earth' for a few hours, we notice that the shadow separating day from night advances from East to West. Since what we notice is a relative movement, this implies that the Earth turns the other way, i.e. from West to East.
- We also notice that when it is noon in our town or village, the Sun lies close to our South, while in countries situated more to the West the Sun is rising and in countries located more to the East it is setting.

FIGURE 8: Areas of daytime and night time stand out on our 'parallel Earth'.

By looking at our 'parallel Earth' throughout the year we can infer the seasons

Our little sphere oriented parallel to the real Earth turns out to be equally useful if we observe it throughout the year.

- When it is winter in the Northern Hemisphere, we notice that no sunlight reaches the North Pole (figure 9). The days are much shorter. Since there are fewer hours of sunshine, the average temperature is lower and it is cooler. In addition, the Sun lies closer to the real horizon and the rays are spread over a much larger area of the Earth. The feeling of heat on the skin is reduced.

- When it is summer in the Northern Hemisphere, the North Pole is fully illuminated (figure 10) and there are more daylight hours in the Northern Hemisphere as the Sun is much higher on the horizon and the Sun takes longer to complete its apparent daily path across our sky. Moreover, when the Sun reaches higher above the horizon, the rays fall at a steeper angle to the surface, resulting in a higher average temperature. We can easily notice that the Sun 'burns' our skin more in summer than in winter by spending just a little time in the Sun in both seasons.

- It is always day in one half of the Earth and night in the other, but sometimes one hemisphere is more illuminated than the other depending on whether it is summer or winter. Twice a year, the shadow that separates day and night passes exactly through the Earth's rotation axis (figure 11). On these two days, the length of the day is equal to that of night in both hemispheres. For this reason these days are called equinoxes. On these days, the rotation axis of the Earth lies exactly in the plane that separates the two halves.

- When it is summer in the Northern Hemisphere (figure 10), we see that it is winter in the Southern Hemisphere because the South Pole is not illuminated. Obviously the opposite happens when it is winter in the Northern Hemisphere, i.e. it is summer in the Southern Hemisphere. Therefore, one hemisphere is always more illuminated than the other, except during the equinoxes. In the hemisphere where there is more sunshine it will be summer as there are more hours of sunshine and the Sun falls at a steeper angle onto the surface.

Figure 9: The North Pole area falls within the area of night, so in the Northern Hemisphere it is winter.

Figure 10: The North Pole area falls within the illuminated area, so in the Northern Hemisphere it is summer. We see the phenomenon of the Midnight Sun in this figure.

Figure 11: The plane separating day and night coincides with the rotation axis of the Earth at the two equinoxes.

In order to understand that the seasons are caused by the orbital motion of the Earth around the Sun and the inclined rotation axis, it is useful to combine the 'parallel Earth' observation with a Sun–Earth model (figures 12, 13, 14 and 15). For a basic model, we need a light bulb, a pen and a ball of expanded polystyrene.

Figure 12: The North Pole area falls within the illuminated area: in the Northern Hemisphere it is summer.

Figure 13: The two hemispheres are equally illuminated: it is an equinox.

Figure 14: The North Pole area falls outside the illuminated area: in the Northern Hemisphere it is winter.

Figure 15: The two hemispheres are equally illuminated.

If we draw the line of the Equator, we can calculate the rotational motion of the Earth and the time in different countries

With a permanent marker draw the line of the Equator and then a few meridians on the 'parallel Earth'; for example, we can draw six meridians that allow us to divide the area into several segments. That is, of the 360° which corresponds to the whole Equator, each slice corresponds to 60°. It is convenient to draw divisions corresponding to 10° on the Equator. If we focus on how the day-night dividing line runs across the Equator, we can easily infer, with the help of the divisions that we have drawn, that the night's shadow line advances by 15° every hour. Comparing this with the time in our country, we can work out what time it is in different places on Earth.

It should also be noted that if the shadow progresses by 15° every hour, it is enough to divide 360° by 15° to calculate the duration of the day, and we can obtain 24 hours of rotational motion through this experiment.

Figure 16: 'Parallel Earth' with the Equator line.

If we place small gnomons along the same meridian, we can observe the evolution of shadows in different places

Simply fix small gnomons, the shadow-casting part of a sundial, on the surface of our 'parallel Earth' (these can be pieces of toothpicks of equal size, fastened with small balls of clay) to observe the evolution of the shadow at different places on Earth, at various times during the day and year.

The 'parallel Earth' has the six meridians that we have drawn. We place a series of small gnomons along one of the meridians.

We then notice that:

- All the shadows cast by the gnomons, at the same time of day, fall on the same side but point in different directions depending on their position on the meridian, i.e. depending on their latitude.
- If you live in the Northern Hemisphere the shadows point to the West in the morning, to the North at noon and to the East in the afternoon. But if you live in the Southern Hemisphere, they point to the West in the morning, to the South at noon and to the East in the afternoon.

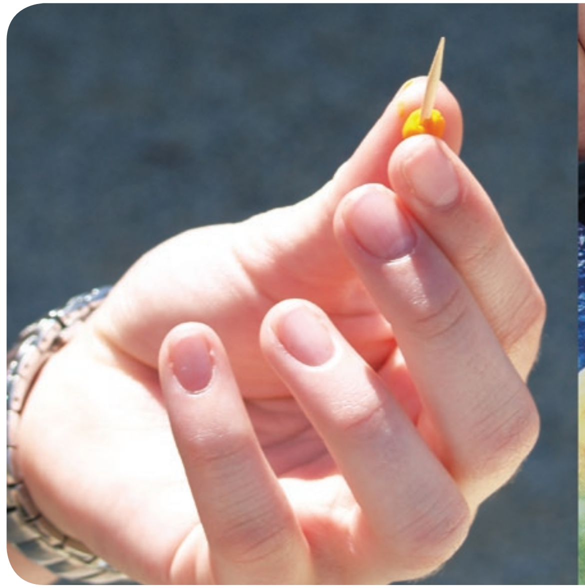


Figure 17: The gnomons can be fixed with a piece of toothpick and a small ball of clay.

Figure 18: We start by placing the first toothpick at our current location.

Figure 19: The gnomons near the poles cast longer shadows; the closer they are to the Equator, the shorter their shadows become.

- At noon, the shadows point in the direction of the meridian line.
- Shadows are very long early in the morning and late in the afternoon and they are shorter at noon.

From all these observations we draw the following conclusions:

At places along the same meridian, it is always the same time.

The closer a place is to the poles, the more obliquely the rays fall and therefore we have the feeling that it is less warm.

The closer we are to the Equator, the more perpendicular to the surface the rays fall and therefore it is warmer.

We use a small torch to see that if we place the torch perpendicular to a surface, the area it illuminates is round (figure 20) and the light is more intense than if we illuminate the same area by placing the torch obliquely. In this case, the illuminated area is elliptical and much larger than before (figure 21) and the light's intensity is lower because the same energy was distributed over a much larger area. If the torch's intensity is strong enough, you can even do the test on the skin's surface. If the light falls perpendicularly you perceive more heat than when it falls obliquely.

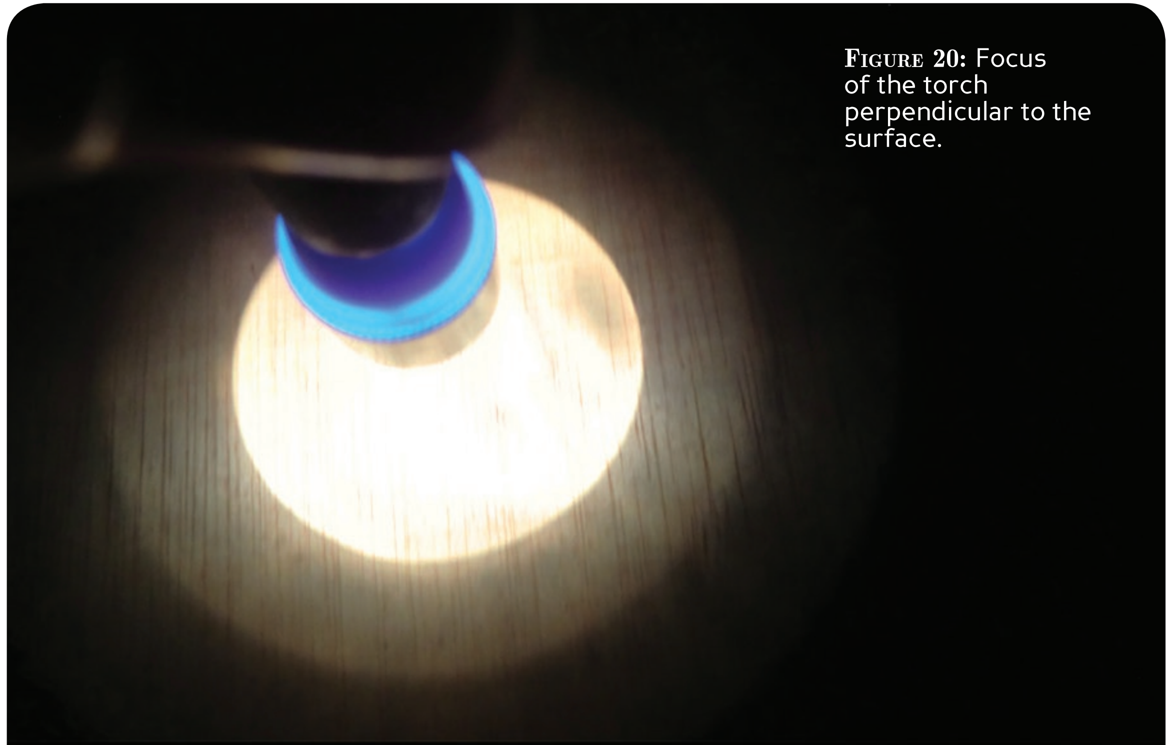


Figure 20: Focus of the torch perpendicular to the surface.

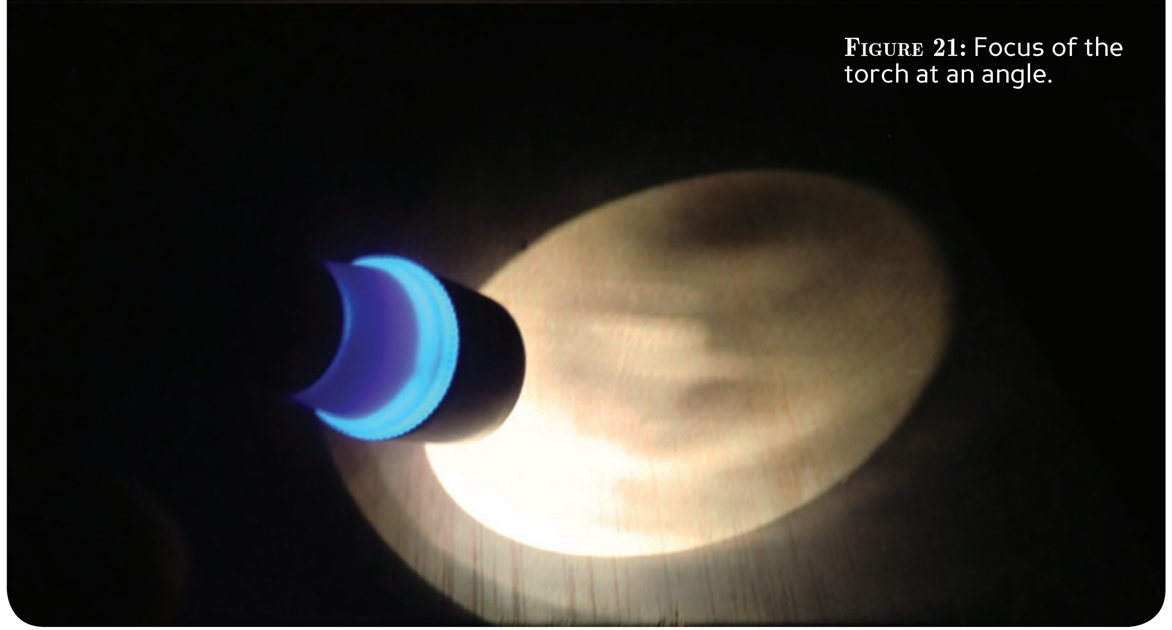


Figure 21: Focus of the torch at an angle.

If we place gnomons along the Equator, we can work out the evolution of the shadows and the time anywhere on Earth

We find that throughout the day, the shadows go from West to East through the North if you are in the Northern Hemisphere. But if you live in the Southern Hemisphere, in the morning, they go towards the West, at noon towards the South and in the afternoon towards the East. Also, if we look at the shadow at one place we can work out the approximate time at that place.

Figure 22: Gnomons along the Equator. Some of them cast their shadow to the right and some others to the left.

Conclusions

The Earth rotates in the opposite direction from the rotational motion seen from the shadow line on our 'parallel Earth'.

Seasons result from the tilt in the Earth's axis and change in angle of sunlight falling on us during the year.

When it is summer in the Northern Hemisphere, it is winter in the Southern Hemisphere and vice versa.

In summer, there are more hours of day and fewer of night and the corresponding polar ice cap may have continuous daylight.

In winter, there are fewer hours of day and more of night and the corresponding polar ice cap may have continuous night.

In spring and autumn, there are equal hours of day and night.

Figure 23: Working with the 'parallel Earth' in summer.

Other suggestions for working with the 'parallel Earth' model

'Parallel Earth' is useful to get an overall picture of the Earth, to see the perspectives of the living beings that inhabit it as a whole, and to demystify the physical, cultural and racial boundaries that are often negatively presented.

The 'parallel Earth' gives us a starting point to understand the lives of children living in different places on Earth, to see how their activities and habits are not only closely linked to the cultural wealth of their countries but also to their natural environments.

Starting from the images of 'The Earth from the Air' by Yann Arthus-Bertrand, you can talk about what they show, the Earth area they are from, what they suggest and why. The dialogues are very rich and give us the opportunity to introduce the concepts of landscape, climate, labour, economy, lifestyles and environmental protection.

Next, we try to find out where exactly the pictures are from; we reduce their size and put them in the right place on the sphere. In this way, we find frames of reference that help us understand the diversity and complexity of our planet and of its inhabitants.

Younger students can also enjoy finding pictures of different animals and place them on a terrestrial sphere, according to what they think their habitats might be. Another option, also linked to the type of weather in different areas of our planet, is to illustrate various types of housing. In this case, we should look for different pictures of typical houses and we place them after carefully assessing their characteristics. For this purpose, we need to consider the possible connection between their architecture and the specific climate of the region.

Figure 24: Pasting pictures to illustrate different parts of the globe in the corresponding places on Earth.

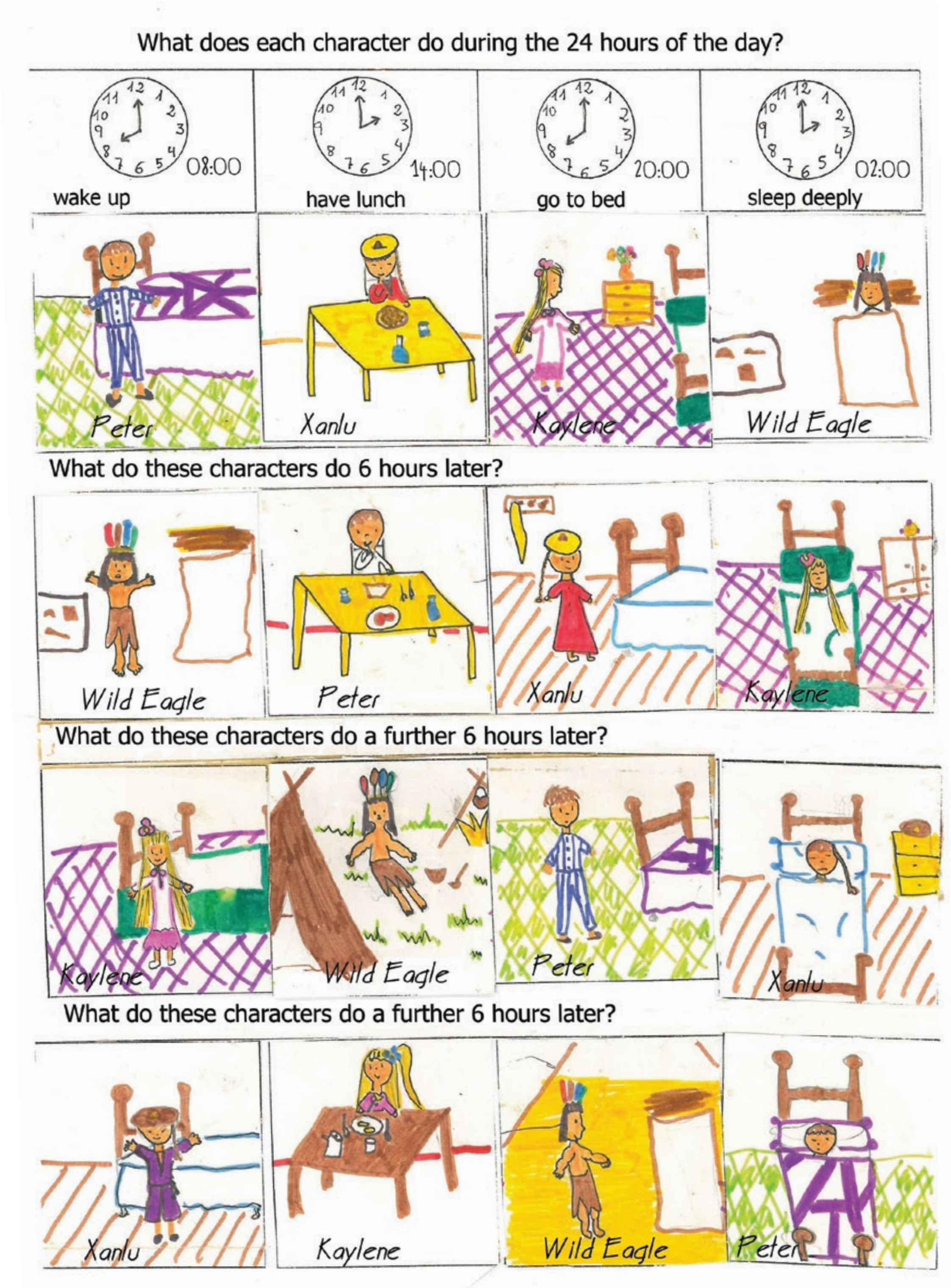
Figure 25: The 'parallel Earth' with pictures of animals corresponding to different habitats on the Earth's surface.

Tales of 'parallel Earth'

Another interesting activity to do with students is to invent four characters—four children—living in areas of the Earth that lie 90 degrees, or six hours, from each other.

A boy from Spain named Peter, a Chinese boy named Xanlu, a girl living in New Zealand named Kaylene and an American boy named Wild Eagle.

This experiment was carried out with students on several occasions. We had a chat with these characters about the place where they live, their cultural characteristics, lifestyles, climate, vegetation, food, and so on. Starting from these dialogues, students wrote stories in which these characters were the protagonists and the scripts were designed to include the cultural characteristics of each of them. The characters interacted with each other according to their different local times.



Proposals, subdivided by discipline, for various activities that can be carried out in relation to the 'parallel Earth' experiment

Mathematics

Shapes. Study of the sphere. Shadows on a sphere. Shadows of the sphere onto a plane and onto another field. Lines on a sphere. Position of a point on a surface. Orientation on the surface of a sphere: meridians and parallels...

The notions of radius, diameter, maximum circumference, angle...

The notions and measurements of angles, surfaces, volumes...

The dimensions of the radius or diameter of the Earth. Ratios between our sphere and the real Earth. The notion of scale.

Geography and Social Sciences

Interpretation of a map. Different flat representations of the terrestrial sphere. Meridians and terrestrial parallels. The prime meridian. The notions of latitude and longitude. Continents, countries, oceans, major mountain ranges, significant mountains, lakes, large rivers, climate zones, vegetation zones, deserts...

Human Geography: Earth's population. Relationship between the behaviour of living beings (including humans) and the place they inhabit...

Writing

Reporting on the projects related to 'parallel Earth'. Interpretation of the data. Reading and interpreting reports and texts related to the geographic space...

Preparation and interpretation of the codes of the working group for data transfer...

Natural Sciences, Astronomy

Effects of the rotational and orbital motion of the Earth and the inclination of its rotational axis to the orbital plane. Day and night, time zones, seasons, equinoxes and solstices, the tropics and the Equator, the length of day and night at different times of the year at different latitudes.

Environmental Sciences

Fauna and flora of various large areas of our planet.

Climate studies, weather factors.

Values

It is difficult to mention all the values related to the development of this model. It incorporates team work, and the duration of the tasks offers great opportunities to improve the cohesion of the group and to realize the need for combining individual and collaborative efforts. Values learnt include learning to progress slowly in the task, without losing patience and enthusiasm and learning to perceive the work as the result of both individual and joint efforts.

Understanding diversity as something positive.

Understanding different cultural features related to region.

Learning about the birthplaces of classmates, about their customs, landscapes, climates, seasons, fauna and flora linked to their geographical location.

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Links:

http://phobos.xtec.cat/a8028072/

http://es.unawe.org

http://unawe.org

http://sac.csic.es/unawe

The aim of UNAWE is that children from all countries may have a personal, enjoyable relationship with astronomy. EU-UNAWE is the European branch of this global project and involves Germany, Italy, the Netherlands, Spain, United Kingdom and South Africa. Through experiences and emotions related to stargazing children begin to understand that they are also part of the universe and they have a world in front of them ready to be explored.

EU UNIVERSE AWARENESS

SEVENTH FRAMEWORK PROGRAMME

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