SPACE awareness

PEER-REVIEWED EDUCATION ACTIVITIES
SCIENCE CENTRES AND MUSEUMS

LET'S INSPIRE A NEW GENERATION OF SPACE EXPLORERS!

The **Space Awareness project** uses the excitement of space to engage young people with science and technology and stimulate their **sense of European and global citizenship**. Space Awareness shows **children and adolescents** the relevance of **space science and technology** in their lives and the career opportunities offered by the space sector for their future.

The **Space Awareness activities** have been selected following the most popular topics for space in the school curricula. These topics are the result from a survey disseminated to educators in 10 European countries and South Africa in 2015. **All resources have been reviewed by an educator and a scientist** and are tested and improved by teachers and educators all around **Europe and beyond.**

This **compendium** brings together a selection of Space Awareness activities to be implemented at **informal learning** settings.

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A VIEW FROM ABOVE

Analyse real satellite data like professionals

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Curriculum topic
satellites, surface

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet

Keywords
remote sensing, Earth observation, vegetation, climate, satellites, satellite imagery, Copernicus, Sentinel, Landsat, light spectrum, spectral index

Age range
14 - 19

Education level
Secondary School, University, Informal

Time
1h30

Group size
Individual

Supervised for safety
Unsupervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Analysing and interpreting data, Using mathematics and computational thinking, Constructing explanations, Engaging in argument from evidence, Communicating information

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

Students investigate how satellite images obtained at different wavelengths help to identify Earth surface features like vegetation and open water areas by using a specially designed software package, LEO Works. Students inspect and analyse real satellite data to produce colour images and maps of spectral indices and learn how to interpret them and their uses.

GOALS

Students will get an insight into how multispectral satellite images can be diagnostic in deciphering Earth surface features like vegetation and the degree thereof as well as open water areas. They will get a hands-on understanding of how real remote sensing satellite data are being analysed. This will be done via a specially designed educational software package (LEO Works) which permits close to professional treatment of up to date satellite data. Students will understand the importance of such data for the lives of billions of people around the Earth and maybe grow interest in working in this field. Finally, the students will produce images and maps that are needed for the analysis. In the end, the students will be confident analysing satellite data on their own.

LEARNING OBJECTIVES

- Students will inspect and analyse real satellite data at a close to professional standard.
- Students will combine datasets to produce colour images and maps of spectral indices.
- Students will answer questions and identify different surface features, such as vegetation and open water, by interpreting the maps of spectral indices.
- Students will answer questions to discuss the importance of satellite data when dealing with issues like disaster management and climate change.

EVALUATION

The major part of this activity is analysing satellite images. The products created during this exercise are images generated by combining the images in a certain way. The success can be evaluated by comparing the maps and images with the ones provided with this material. In addition, students will answer questions that will show how well they understood the importance of satellite data for various aspects.

MATERIALS

- Worksheet for students (needs to contain background information and activity steps)
- Computer (the software needed is independent of the operating system)
- Software installed: LEO Works 4, download at: http://leoworks.terrasigna.com
- For the extension for advanced students: Landsat satellite data files:
  Venice_Landsat_ETM_multispectral_Jan2002.tif
  Venice_Landsat_ETM_multispectral_Jul2002.tif

BACKGROUND INFORMATION

Remote sensing

The term *remote sensing* indicates a measurement technique that probes and analyses the Earth from outer space. Besides classical in-situ methods like weather stations, field surveying or taking samples, satellite based measurements are becoming an increasingly important source of data. The advantage is the fast and complete coverage of large areas. However, satellite data are not always easy to interpret and need substantial treatment.

The most abundant remote sensing devices are weather satellites. By employing suitable sensors, they provide information about cloud coverage, temperature distributions, wind speed and directions, water levels and snow thickness. Keeping the evolving climate change in mind, those data play an increasingly important role in disaster management during draughts and floods, climate simulations, atmospheric gas content and vegetation monitoring. In addition, urban and landscape management benefit from satellite data.

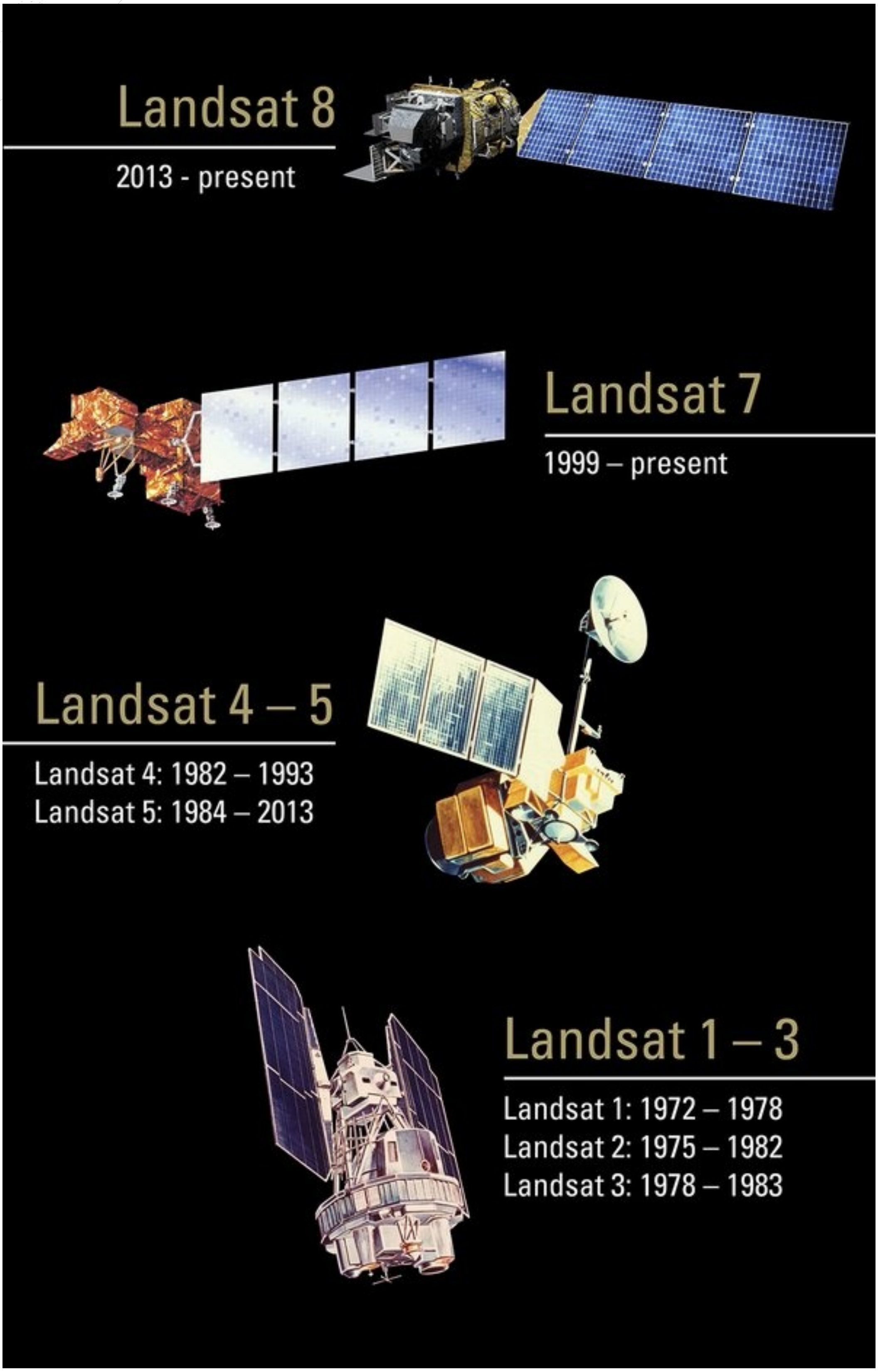


Figure 1: Overview of Landsat remote sensing satellites of NASA (NASA, https://www.usgs.gov/

media/images/landsat-program).

The first weather satellites were launched by NASA as early as 1960. In the beginning of the 1970s, NASA started their earth observation programme using Landsat satellites (Figure 5). In Europe, France was first using their SPOT satellite fleet. They were followed by the remaining European countries in the 1990s after the foundation of ESA, the European Space Agency.

The Copernicus Programme

Already since 1997, the USA and NASA have been building a large programme for exploring the Earth, labelled the Earth Observation System, which consists of a large number of different satellites. Starting in 1998, the European equivalent, the Global Monitoring for Environment and Security (GMES) is being developed. In 2012, the programme was renamed to *Copernicus*. Information products for six applications are being derived from the satellite data: ocean, land and atmosphere monitoring, emergency response, security and climate change. The data products are offered to everyone free of charge. They are supplied via two branches: space based remote sensing devices (satellite component) as well as airborne, ground and marine probing (in-situ component). The core of the satellite component is the fleet of Sentinel satellites that have been and are being built exclusively for the Copernicus projects. They are supplemented by other domestic and commercial partner missions. The first Sentinel satellite (Sentinel 1-A) was launched 2014. Sentinel-2A and 3-A followed 2015 and 2016, respectively.

Figure 2: Computer model of the Sentinel-2A satellite launched on 23 June 2015 (Credit: ESA/ATG medialab, http://www.esa.int/spaceinimages/Images/2014/07/Sentinel-2_brings_land_into_focus).

Electromagnetic Spectrum

The kind of radiation that the human eye can see and interpret is called light. However, the full range of electromagnetic radiation (the spectrum) is much bigger. The part that is invisible to us can be detected by special cameras, such as the ones put on astronomical telescopes and satellites. A good overview on the different kinds of radiation is provided in Figure 3.

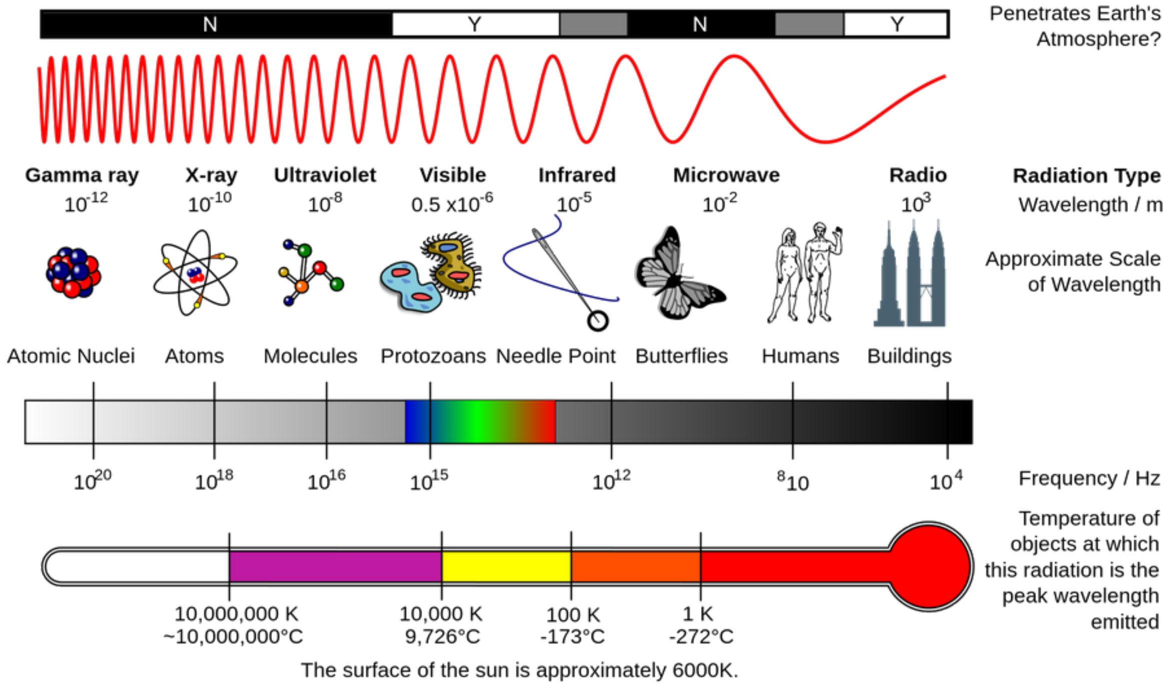


Figure 3: The spectrum of electromagnetic radiation. The visible light is only a very small part inside the full range (Inductiveload, https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_reflected.svg, "EM Spectrum Properties reflected", cropped by Markus Nielbock, https://creativecommons.org/licenses/by-sa/3.0/legalcode).

Multi-spectral Imaging

One of the core purposes of earth observation and remote sensing is taking and analysing pictures. Similar to modern astronomy, taking images with different spectral filters is very diagnostic when identifying and analysing terrestrial surface features. For this kind of data acquisition, the cameras rely on the sunlight that illuminates the Earth's surface. Hence, they receive the portion of the sunlight that is reflected by the various surface features. Compared to the incident sunlight, the reflected light is modified by brightness and spectral composition.

Table 1: Spectral bands of the MSI camera of the Sentinel-2A satellite (Source: Sentinel Online).

Band	Central wavelength (µm)	Bandwidth (µm)	Spatial resolution (m)
1	0.443	0.020	60
2	0.490	0.065	10
3	0.560	0.035	10

Band	Central wavelength (µm)	Bandwidth (µm)	Spatial resolution (m)
4	0.665	0.030	10
5	0.705	0.015	20
6	0.740	0.015	20
7	0.783	0.020	20
8	0.842	0.115	10
8a	0.865	0.020	20
9	0.945	0.020	60
10	1.380	0.030	60
11	1.610	0.090	20
12	2.190	0.180	20

The spectral bands of the camera "Multi-Spectral Instrument (MSI)" of the Sentinel-2A satellite is given as an example in Table 1. For example, band 2 covers a wavelength range of 0.065 µm centred on a wavelength of 0.490 µm. The smallest feature that could be seen in this band would be 10 m across. Those bands cannot be chosen arbitrarily because of the wavelength dependent transparency of the Earth atmosphere (grey area in Figure 4). They are referred to as spectral windows. The main culprit for the wavelength ranges, where the atmosphere blocks external radiation, is water vapour. Therefore, observations with cameras have to be designed in a way that only those wave bands are used, where the radiation is transmitted well enough to receive a good signal. Thus, these ranges are the ones the optical filters of the cameras are designed for.

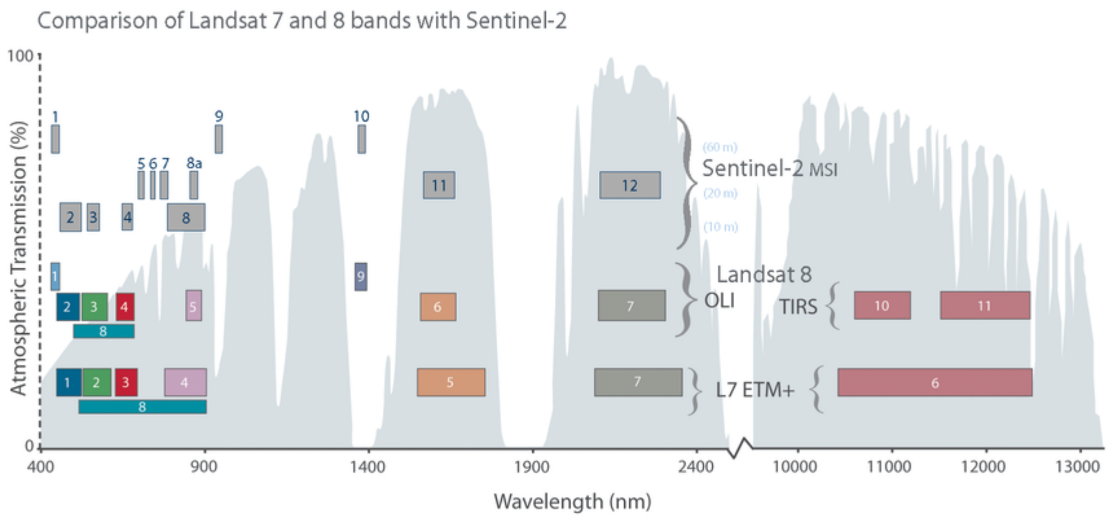


Figure 4: Graphical representation of the spectral bands of MSI/Sentinel-2A compared to the cameras of the Landsat 7 and 8 satellites. The axes depict the wavelength in nanometres (1 nm = 10^{-3} µm = 10^{-9} m) and the terrestrial atmospheric transmission (grey) in percent (Credit: NASA, https://landsat.gsfc.nasa.gov/sentinel-2a-launches-our-compliments-our-complements/).

A proper choice of optical filters not only permits distinguishing between water and landscape, but also allows deciphering the state of vegetation or surface conditions. For instance, it indicates a noticeable difference between the reflective spectra of fresh and dry grass. The main reason for this is the absorption power of chlorophyll. In particular, the transition between the red (band 4) and the infrared ranges (bands 7 to 9) sees a sudden jump in the spectrum of fresh, green grass, while the spectrum of dry grass remains rather constant. When subtracting the signals of the bands, one can distinguish between the two states.

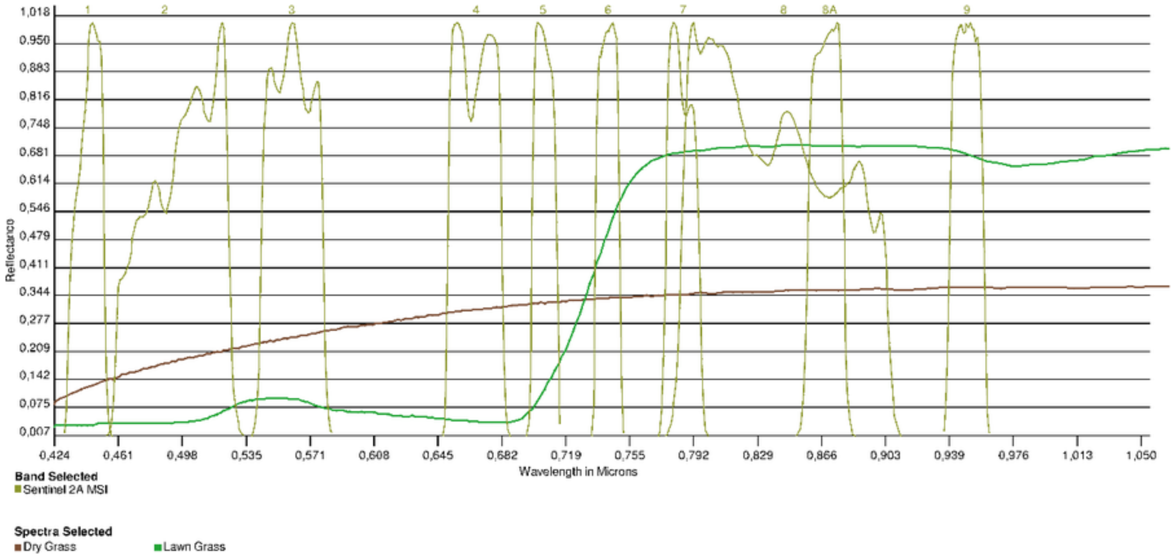


Figure 5: Reflective spectra of fresh (green curve) and dry (brown curve) grass in a wavelength range covered by the MSI/Sentinel-2 bands (yellow curves). There is a strong jump in the green grass spectrum between band 4 and band 7 (Credit: USGS Spectral Viewer, NASA).

Satellite images contain pixel values that represent the brightness or intensity of the reflected light in a given optical band. They are usually displayed in greyscale. Combining those images according to the rules of additive mixture of colour stimuli leads to the construction of coloured images. When selecting the images of the spectral bands representing the colours red, green, and blue, the resulting RGB image displays the colours in a realistic way (Figure 6, left).

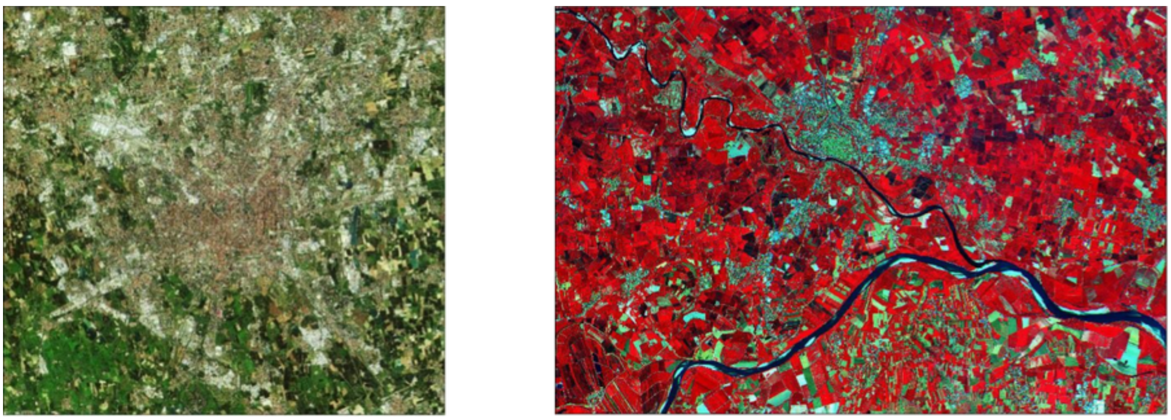


Figure 6: Images obtained with MSI/Sentinel-2A. Left: Realistic RGB coloured image of the city

of Milan; right: false colour visualisation of the area around the river Po, Italy. The colour red represents the near infrared band which is sensitive for green vegetation (Source: Copernicus data 2015/ESA).

Spectral index

By merging data from different optical bands, much can be learnt about vegetation or construction areas in a qualitative way (Figure 6, right). If quantitative information is required, a more detailed analysis is needed. An established tool is a spectral index. This is a number that is calculated from data obtained at different wavelengths and allows comparing the relative brightness of different wavelengths of light that is reflected by the Earth's surface.

Normalised Differenced Vegetation Index (NDVI)

An important spectral index used for identifying healthy vegetation is the *Normalised Differenced Vegetation Index (NDVI)*. It is calculated from the measured intensities obtained in the red (*R*) and near infrared (*NIR*) spectral regimes. As mentioned, the transition between those bands is diagnostic in distinguishing between green vegetation from other features (Figure 5). It is calculated as follows.

$$NDVI = \frac{NIR - R}{NIR + R}$$

With:
R: Intensity/brightness of reflected light in the red filter (ca. 0.6 – 0.7 μm)
NIR: Intensity/brightness of reflected light in the near infrared filter (ca. 0.8 – 0.9 μm)

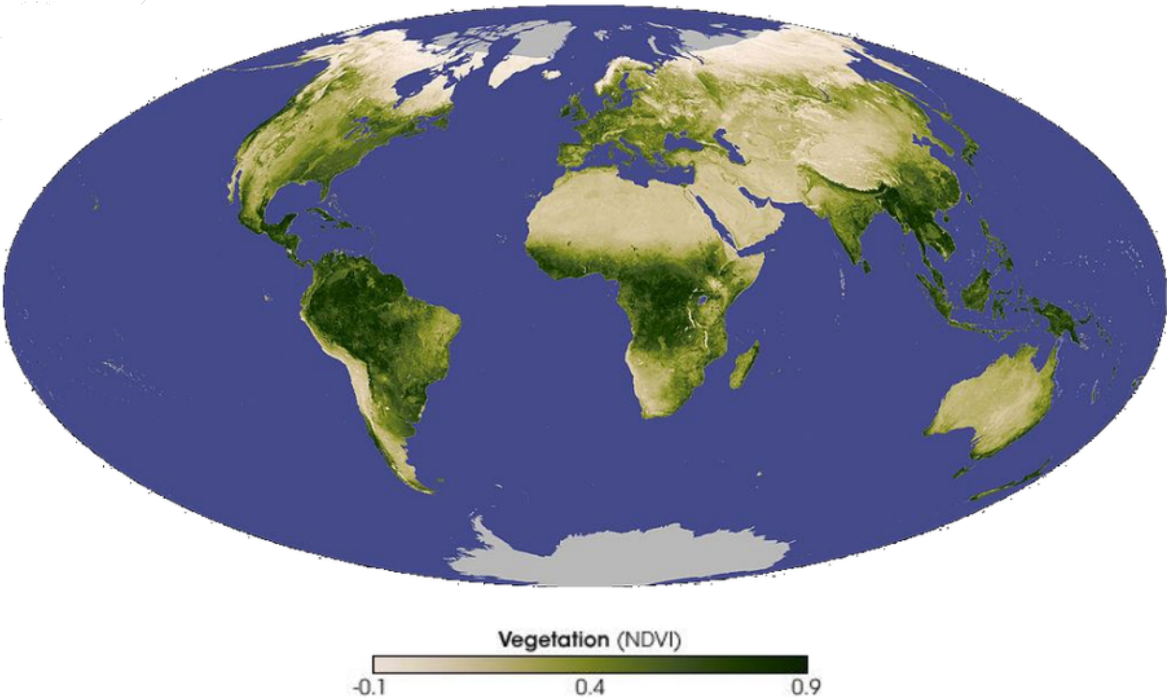


Figure 7: NDVI world map of November 2007 based on data of the "Resolution Imaging Spectroradiometer (MODIS)" of the NASA Terra satellite (Credit: NASA).

They are provided by the bands 4 and 8 of the Sentinel-2 MSI camera (Table 1). The difference between *NIR* and *R* is normalised by their sum resulting in a range of values between -1 and +1. Negative values indicate water areas. A value between 0 and 0.2 represents nearly vegetation free surfaces, while a value close to +1 hints to a high coverage of green vegetation.

Normalised Differenced Moisture Index (NDMI)

Another spectral index is the *Normalised Differenced Moisture Index (NDMI)* or *Normalised Differenced Water Index (NDWI)*. It is sensitive for humid vegetation and open wetland. It supplements the NDVI.

$$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$$

With:
NIR: Intensity/brightness of reflected light in the near infrared filter (ca. 0.8 – 0.9 µm)
SWIR: Intensity/brightness of reflected light in the shortwave infrared filter (ca. 1.5 – 1.8 µm)

The NDMI helps distinguishing between dry and wet areas.

Modified Normalised Differenced Water Index (MNDWI)

The *Modified Normalised Differenced Water Index (MNDWI)* is regarded as an improvement of the NDMI. It helps identifying open wetland and excludes artificial buildings, vegetation and agricultural areas.

$$MNDWI = \frac{G - SWIR}{G + SWIR}$$

With:
G: Intensity/brightness of reflected light in the green filter (ca. 0.5 – 0.6 µm)
SWIR: Intensity/brightness of reflected light in the shortwave infrared filter (ca. 1.5 – 1.8 µm)

Open wetland attains higher positive values than with the NDWI, while other landmarks like buildings, vegetation and crop land have negative values.

The software LEO Works 4

The European Space Agency (ESA) has developed an educational tool for teaching and learning the basic steps of analysing satellite data. The latest version 4 is being developed by Terrasigna in Romania. Since it is based on Java, it is independent of the operating system. It will be used for carrying out this activity.

Figure 8: Launch window of LEO Works 4.0, a software for treating and analysing satellite data for educational purposes. It can be downloaded at http://leoworks.terrasigna.com and runs on a wide variety of operating systems.

Literature

Gao, B.-C. (1996). A normalized difference water index for remote sensing of vegetation liquid water from space. Remote Sensing of Environment, 257-266

McFeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. International Journal of Remote Sensing, Vol. 17, Issue 7, 1425-1432

Rouse, J., Haas, R., Scheel, J., & Deering, D. (1974). Monitoring Vegetation Systems in the Great Plains with ERTS. 3rd Earth Resource Technology Satellite (ERTS) Symposium, (pp. 48-62)

FULL ACTIVITY DESCRIPTION

Preparation

Make printed or digital copies of the worksheet available to students. This contains the information in the background information which is needed to successfully analyse the data.

Install the LEO Works 4 software http://leoworks.terrasigna.com and make it available on the students' computers. It is required in order to perform this activity.

Introduction

Introduce the topic by asking students what they know about Earth observing. How can we observe the Earth and what is remote sensing? What information can we collect by remote sensing and what are their applications? The most obvious answers should include weather satellites.

Ask the students, if they knew where the images in Google Maps or Earth come from. The source of the images is mentioned at the bottom of the screen. They might find names like SPOT or Landsat. Ask students to choose one of these satellite campaigns to research. Let them compile information on satellite launch dates, their orbits and countries of origin.

Hands-on activity

The activity is set up as a step-by-step instruction to analyse real satellite data. The exercise is interspersed with questions to evaluate the students' understanding as well as to point to the relevance of the satellite data. Some tasks contain very similar and repeating The activity is set up as a step-by-step instruction to analyse real satellite data. The exercise is interspersed with questions to evaluate the students' understanding as well as to point to the relevance of the satellite data. Some tasks contain very similar and repeating procedures that are used to reinforce the steps used in the analysis.

Analysis of satellite imagery data using LEO Works 4

This activity introduces basic tasks for processing and analysing remote sensing satellite data.

The installed version already contains some example data sets that can be used for exercise purposes. They are stored in the *leoworks.data* folder. When using MS Windows, it can be found in the user directory. From the existing data sets, the one labelled Venice will be used.

Reading the data

After launching, the software presents its workspace as shown in Figure 9. Open the file *Venice_Landsat_ETM_multispectral.tif* by clicking on the first icon in the menu bar or via the menu *File -> Open -> Single File Dataset(s)*. A window appears from which the file is selected (Figure 10).

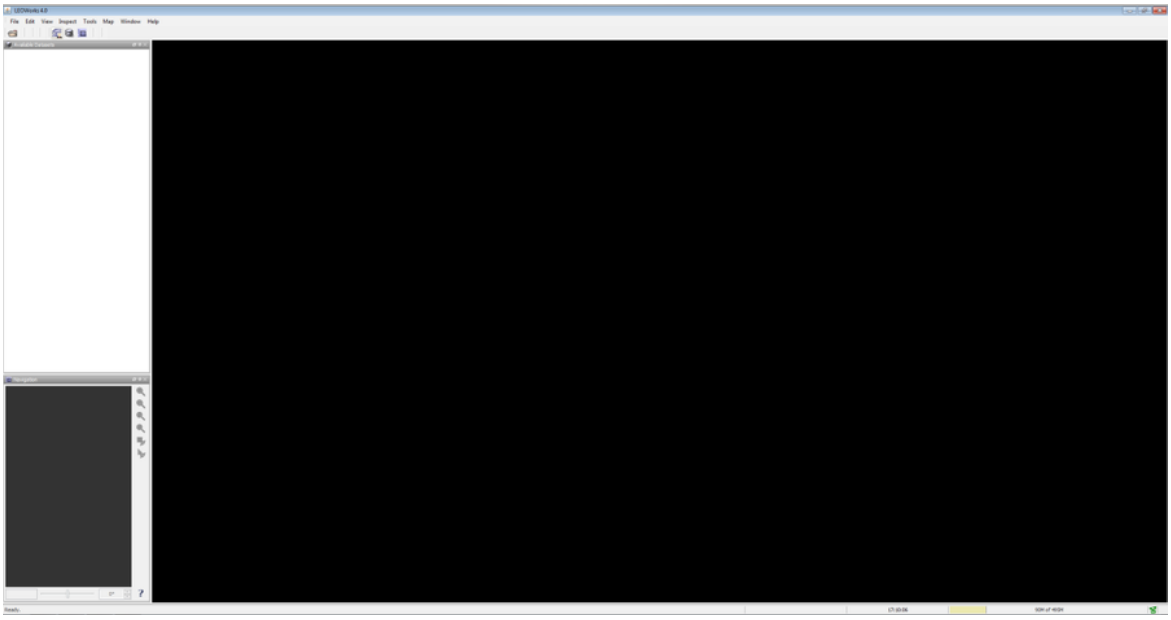


Figure 9: LEO Works 4 workspace. The menu bar contains procedures and tolls for displaying and analysing the data. There are three windows below that provide a list of the loaded data sets and image displays.

The file contains seven individual images obtained in seven bands of the camera “Enhanced Thematic Mapper Plus (ETM+)” of NASA’s Landsat 7 satellite (Table 2) covering the vicinity around the city of Venice in Italy. When the window *Specify Subset* appears, acknowledge by clicking *OK*.

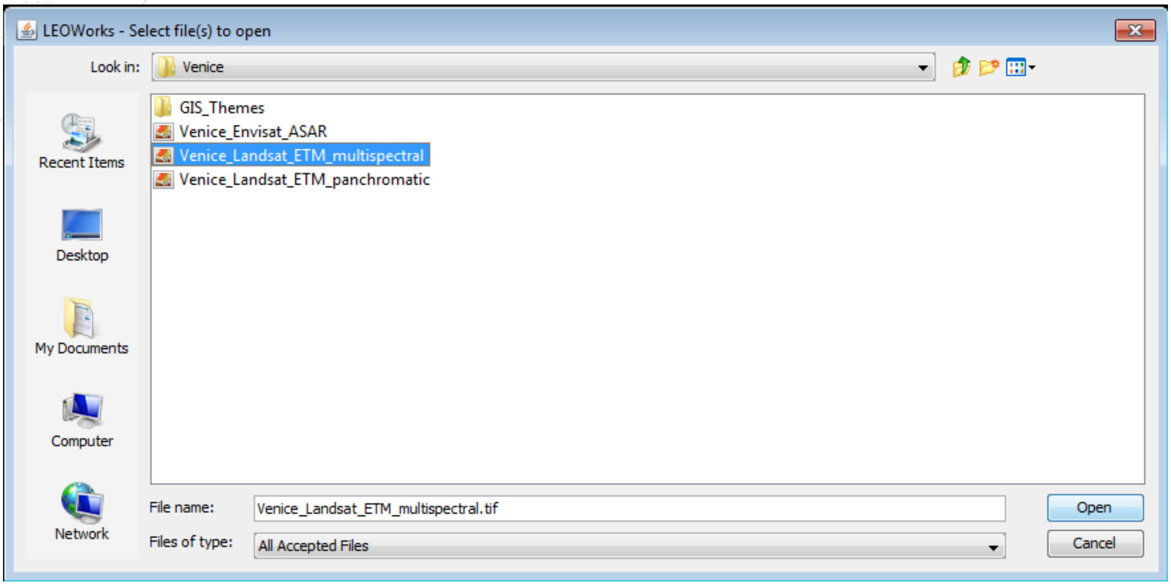


Figure 10: Window for file selection.

The data automatically appear in the window to the upper left. The element *Bands* can be expanded by clicking on it to show the list of the seven images. They are labelled *band_1* to *band_7* and correspond to the spectral bands of Table 2.

Table 2: List of the seven spectral bands of the "Enhanced Thematic Mapper Plus (ETM+)" camera of the Landsat 7 satellite (Source: NASA, column with colours is not revealed to students).

Landsat 7	Wavelength (µm)	Resolution (m)	Colour
Band 1	0.45 - 0.52	30	Blue
Band 2	0.52 - 0.60	30	Green
Band 3	0.63 - 0.69	30	Red
Band 4	0.77 - 0.90	30	NIR
Band 5	1.55 - 1.75	30	SWIR
Band 6	10.40 - 12.50	60* (30)	Thermal IR
Band 7	2.09 - 2.35	30	IR

*The data were obtained with a spatial resolution of 60 m and scaled to a 30 m resolution.

Action: Fill in the column labelled "Colour" of Table 2 for bands 1 to 5. Use the information provided with the introduction of the spectral indices.

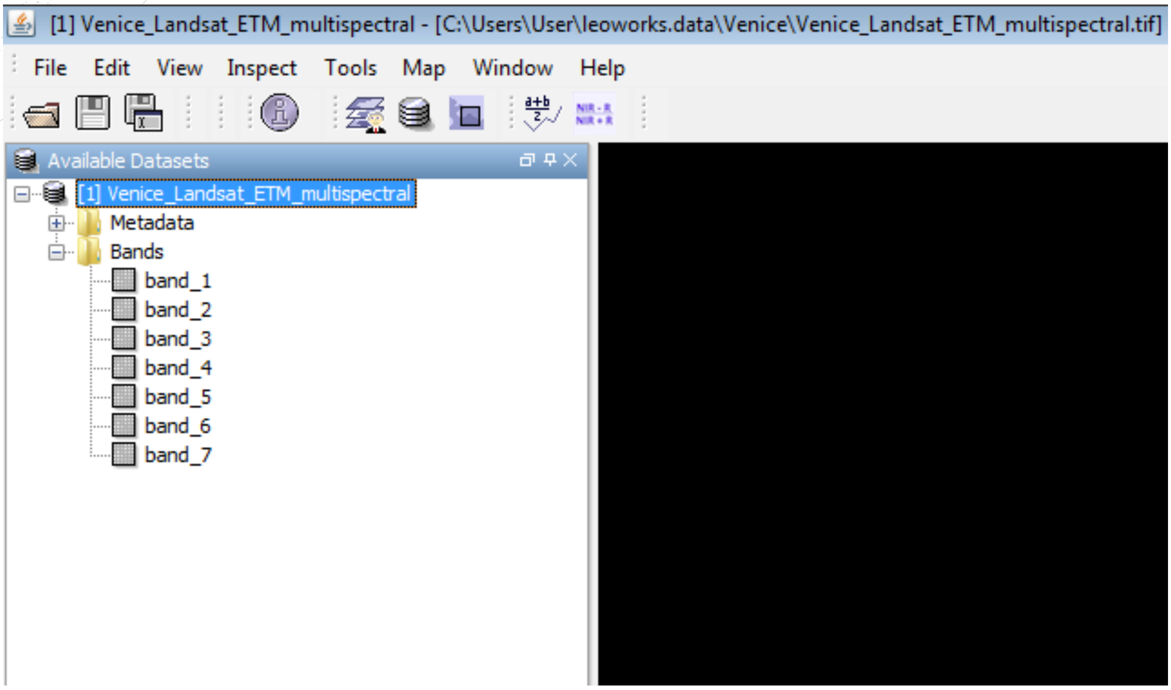


Figure 11: List of loaded data.

Image display

A double-click on the band name issues a command that displays the image.

Action: Do this for band 1 first.

You will see an image of the city of Venice and its surroundings. It consists of different shades of grey, a greyscale display, that correspond to the brightness or intensity measured at a given spot (pixel) in the image. The contrast is a quite poor and should be adjusted using the tool *Interactive Stretching*.

Action: Find the corresponding button or menu item.

You can explore the meaning of the different buttons when moving the mouse pointer above them. After clicking, a new window appears as shown in Figure 12.

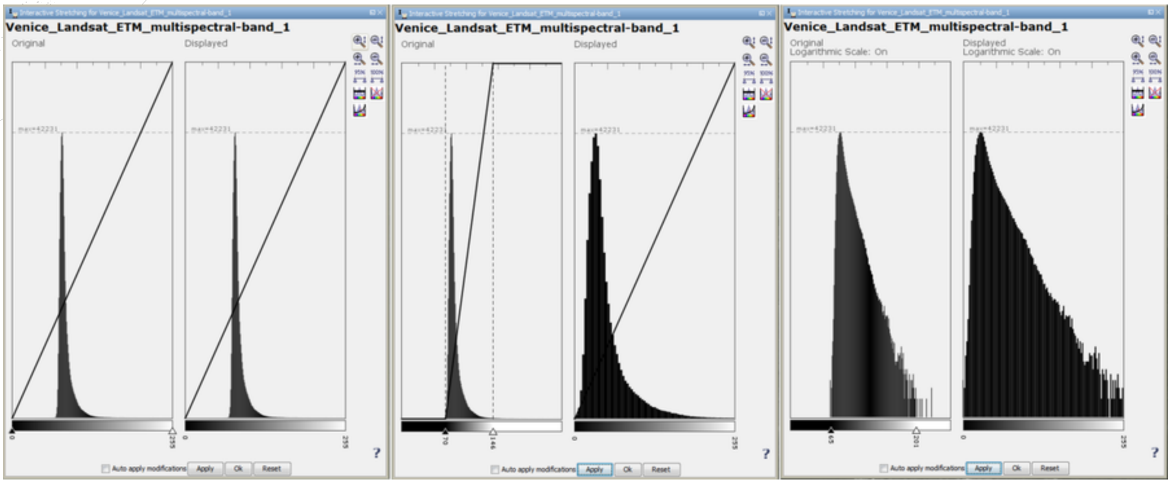


Figure 12: Windows for adjusting the contrast levels using *Interactive Stretching*. A window contains two graphs showing the distribution of pixel values in the image and the ones used for display, respectively. Adjustment is done by moving the flags. The setting is adopted by clicking *Apply*. Left: Distribution before adjustment; middle: after adopting the adjustment; right: the same shown in logarithmic scale, acquired by clicking the bottom left icon to the right.

The scaling of the contrast is accomplished by moving the flags. The window provides additional tools like displaying the data in a logarithmic scale.

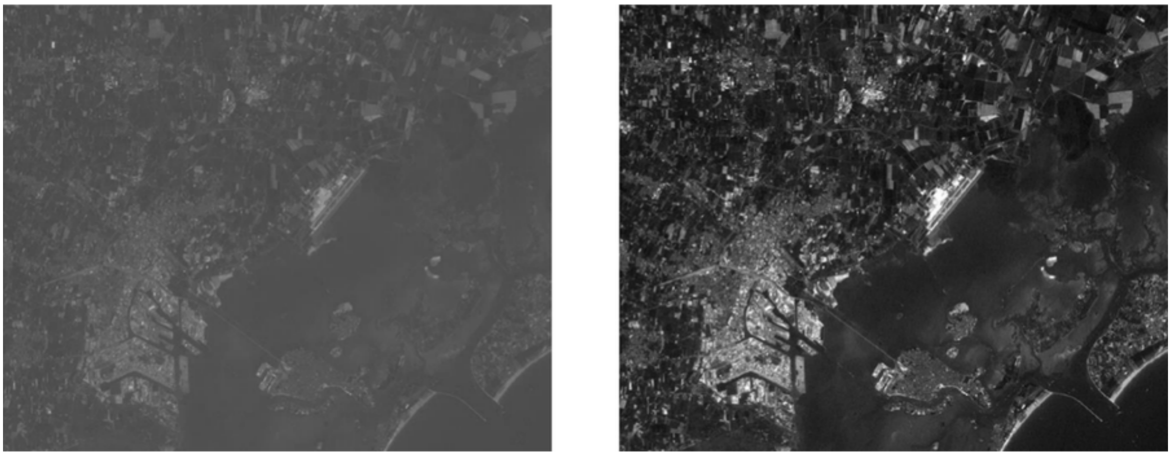


Figure 13: Image of band 1 before (left) and after (right) adjusting contrast scaling.

Action: Display the seven images and adjust their scaling.

Creating a realistically coloured image

After having adjusted the contrast settings, a colour picture can be produced by superposing three images. A bad contrast will lead to shallow colours. For a realistic impression, the three bands representing blue, green, and red have to be selected.

Action: Find the corresponding bands in Table 2. If you need help assigning colours to wavelengths, research the missing information on the internet.

Select *View -> New RGB View*. A new window appears (Figure 14). Choose the matching bands for red, green, blue and click on *OK*.

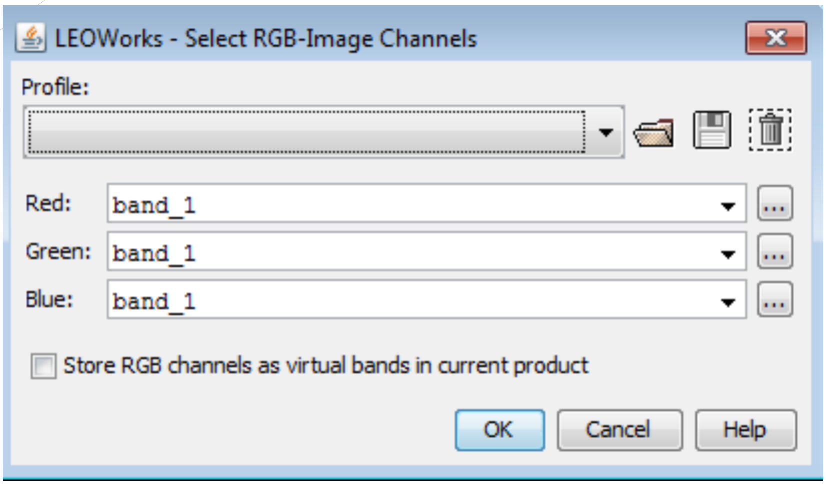


Figure 14: Window for selecting the bands to be used for constructing an RGB image.

A new colour image appears. If necessary, you can adjust the colours with Interactive Stretching.

Actions: Inspect the result and try to identify landscape elements (buildings, water, soil, vegetation).

Find the airport.

Figure 15: Three-colour image (RGB) created from satellite data of Venice.

Creating a false colour image

You have just produced an RGB image that corresponds to the natural impression of colours how humans see it. It consists of the colours red, green, and blue. Imagine other species like bees or snakes. They can see other parts of the electromagnetic spectrum like the ultraviolet (UV) or the infrared (IR). We can simulate such kind of vision skills by combining different spectral bands than red, green and blue. The resulting colours do not match the natural ones we can see with our eyes, but they can help making interesting details visible.

Use the knowledge that the chlorophyll in green plants absorbs red light but reflects infrared radiation.

Actions: Produce a three-colour image from the near infrared (ca. 0.8 μm), red (ca. 0.65 μm), and green (ca. 0.5 μm).

What are the corresponding bands?

Put the infrared band in the red channel, the red band in the green channel and the green band in the blue channel of the RGB image.

Compare this image with Figure 14. Where do you find green vegetation?

Can you distinguish between green crops and green water (algae)?

What does uncultivated land look like?

Figure 16: False colour image produced by combining the green, red and infrared bands.

Analysis via NDVI

You have already seen in the information section that the NDVI is a colour or spectral index

$$NDVI = \frac{NIR - R}{NIR + R}$$

that is particularly sensitive to green vegetation. The index provides a number that objectively reflects the degree of vegetation. Remember that there is a jump in the spectrum of green vegetation between the red (R) and the infrared (NIR) range (Figure 5). You will now construct a map that contains the NDVI for every image pixel. LEO Works provides a tool for this.

Action: Find the NDVI tool.

After activating that tool, a new window pops up. You select the dataset at the top. The next line contains the name of the image to be constructed and how it appears in the list of data. A name is already suggested. Select the suitable bands in the following rows below.

Action: What are the bands to be selected here? The answer can be found in the section about the NDVI and Table 2.

The formula is shown below. In the beginning, the variables show "null" as long as no band is selected. It is automatically updated as soon as you select the band corresponding to the NIR and the R bands. The NDVI map is created by clicking *OK*. A suitable false colour representation is chosen automatically, which helps identify green vegetation. However, the scaling of the colour table must be adjusted.

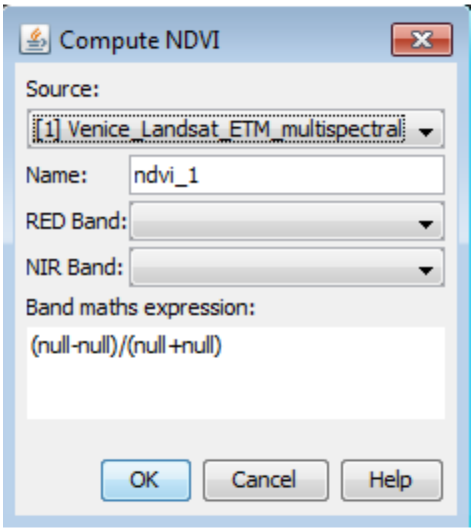


Figure 17: Window of the NDVI computing tool.

The tool *Color manipulation* is used for this. Move the flag of the maximum value to the upper end of the distribution. Then move the flag of the minimum value until the first green coloured flag reaches a value of 0.2 (Figure 17). The new setting is adopted after clicking *Apply*.

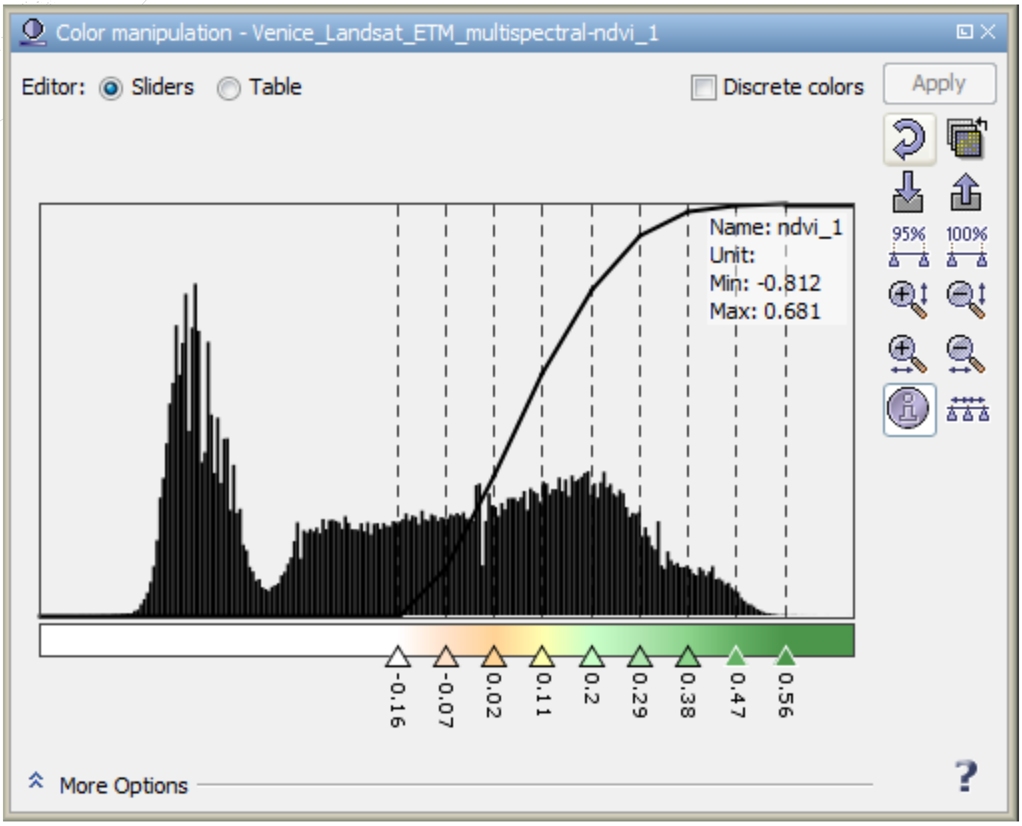


Figure 18: Window that allows adjusting the colour table.

The result should look similar to Figure 19. You see large white zones with alternating yellow and green areas in between.

Action: Compare the NDVI map with the previously produced images. What can you say about the degree of vegetation in the green and yellow areas?

Would you be able to detect a seasonal change, if the images were taken at a monthly rate?

What would be the situation during a draught?

Figure 19: Map of the NDVI in the vicinity of Venice, based on Landsat 7 satellite data.

Analysis via MNDWI

You will now use the satellite data to identify open wetland with the MNDWI.

$$MNDWI = \frac{G - SWIR}{G + SWIR}$$

Especially small ponds and narrow rivers are not easily found on naturally coloured images. The MNDWI can theoretically be constructed using the NDVI tool. However, the correct assignment of the corresponding bands can be confusing. LEO Works provides a generic tool to do all kinds of mathematical operations. The procedure is called *Band arithmetic*.

Action: Find the tool in the tool bar or in the menu and open it.

Similar to the tool for calculating the NDVI, you first select the dataset and the name of the image to construct (Figure 20, left). Then click *Edit expression …* for opening a new window (Figure 20, right). This is where you enter the formula for calculating the spectral index.

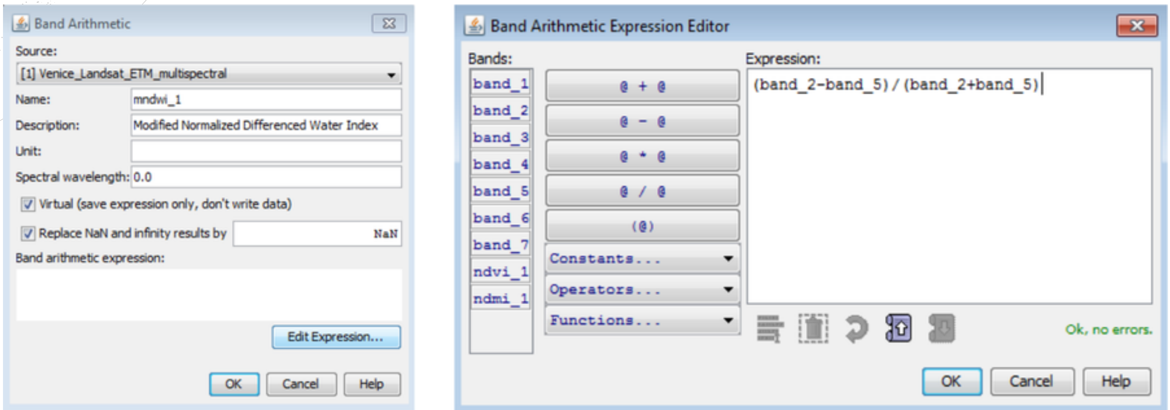


Figure 20: Window for doing mathematical operations on the spectral band images.

Action: Find out what bands are needed to calculate the MNDWI.

From the formula of this index you see that you divide the difference of the intensities of the reflected light measured in two spectral bands by their sum. Be careful with placing operators and brackets according to the formula.

After confirming the formula, it also appears in the first window. The procedure is executed by clicking *OK*.

The resulting image presents the values of the index in greyscale. To improve the readability of the map, you can assign colours to certain values via the *Color manipulation tool*. A colour table is assigned by clicking on the symbol as shown in Figure 20.

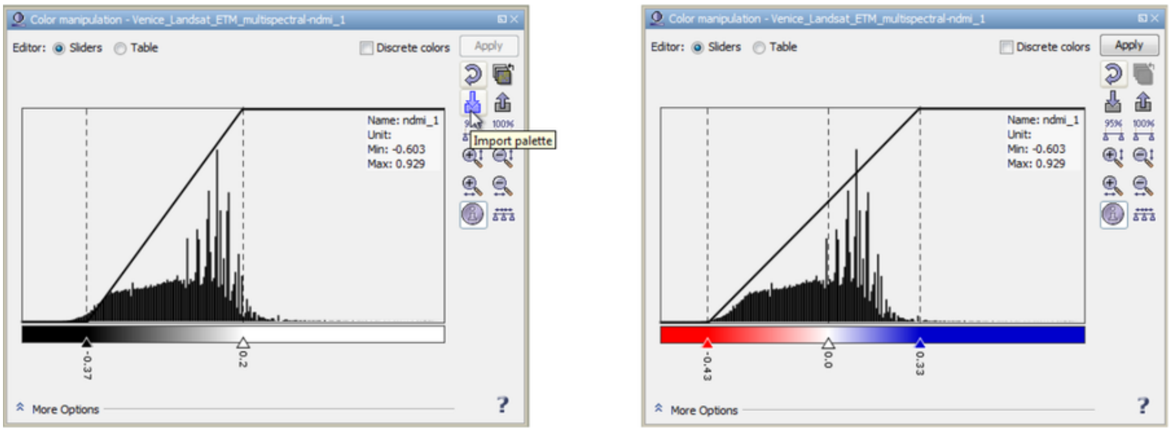


Figure 21: Colours can be assigned to image values to improve the readability of the map.

Action: Select the file gradient_red_white_blue.cpd.

Adjust the flags such that the values are well covered and the central flag represents the value 0.

What is the colour coding of water?

Compare the MNDWI map with the previously produced images. Would you be able to find wetland also on the naturally coloured image?

Can you imagine situations for which the identification of water levels can be important or even life-saving?

What would the image look like, if the water level rises?

If you have time, produce a map of the NDMI. Compare it with the other results.

Figure 21: Map of the MNDWI in the vicinity of Venice based on Landsat 7 satellite data.

For advanced students

Two additional datasets are provided that show the same area in January and July 2002. The already analysed dataset is from August 2001.

**Action: Load the two additional datasets like the previous one.

Produce naturally coloured RGB images.

Produce images of the NDVI distributions.

Compare the results from the three datasets obtained at different dates during the year. Indicate, how the vegetation changes.

In light of the results, describe and explain the advantage of satellite remote sensing.**

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, satellites, surface

Country	Level	Subject	Exam Board	Section
UK	KS 3	Geography	-	Geographical skills and fieldwork use Geographical Information Systems (GIS) to view, analyse and interpret places and data

Country	Level	Subject	Exam Board	Section
UK	GCSE (2016)	Geography	AQA	Skills 3.4.5: Use of qualitative and quantitative data from both primary and secondary sources to obtain, illustrate, communicate, interpret, analyse and evaluate geographical information. Including: - geo-spatial data presented in a geographical information system (GIS) framework - satellite imagery Maps in association with photographs: - be able to compare maps - photographs: use and interpret ground, aerial and satellite photographs - describe human and physical landscapes (landforms, natural vegetation, land-use and settlement) and geographical phenomena from photographs.
UK	GCSE (2016)	Geography	Edexcel	Cartographic skills describe and interpret geo-spatial data presented in a GIS framework framework (e.g. analysis of flood hazard using the interactive maps on the Environment Agency website)
UK	GCSE (2016)	Geography	OCR A and B	Geographical skills 1.6. Describe, interpret and analyse geo-spatial data presented in a GIS framework. 4.1. Deconstruct, interpret, analyse and evaluate visual images including photographs, cartoons, pictures and diagrams.
UK	GCSE	Geography	WJEC A and B (2016)	Cartographic skills 3.4 Describe and interpret geo-spatial data presented in a GIS framework
UK	AS/ A level	Geography	AQA (2016)	3.5.2.5 ICT skills - Use of remotely sensed data (as described in Core skills) 3.5.1 Quantitative data: understanding of what makes data geographical and the geospatial technologies (e.g. GIS) that are used to collect, analyse and present geographical data

Country	Level	Subject	Exam Board	Section
UK	A level	Geography	Edexcel	Geographical Skills: 2. Quantitative data a) understand what makes data geographical and the geospatial technologies (e.g. GIS) that are used to collect, analyse and present geographical data b) demonstrate an ability to collect and to use digital, geo-located data, and to understand a range of approaches to the use and analysis of such data c) use, interpret and analyse geographical information including ..., linear and logarithmic scales, ..., satellite images, GIS.
UK	A level	Geography	OCR	Geographical skills: the use of technology, e.g. GIS, remote sensing, etc. as research tools.
UK	A level	Geography	WJEC	Geographical skills non-numerical: 5. Cartographical information for landscape system identification 7. Digital and geo-located data: geospatial technologies including aerial photographs, digital images, satellite images, geographic information systems (GIS), global positioning systems (GPS), databases.

ADDITIONAL INFORMATION

Suitable image material from other areas can be downloaded via the ESA Eduspace image server at: http://www.esa.int/SPECIALS/Eduspace_EN/SEMLK0F1EHH_0.html

Another source of suitable satellite data: https://earthexplorer.usgs.gov

CONCLUSION

The students used the LEO Works software to inspect and analyse real satellite data at a close to professional standard. They combined datasets to produce colour images and maps of spectral indices and learnt how to interpret them. Students should understand the importance of satellite data when dealing with issues like disaster management and climate change.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

SPACE awareness

THE INTERTROPICAL CONVERGENCE ZONE

Discover how the sun drives the winds on Earth

Markus Nielbock, Haus der Astronomie

Curriculum topic
Atmosphere, surface

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet

Keywords
Equator. Atmosphere, Updraft, Winds, Convection

Age range
8 - 16

Education level
Middle School, Secondary School, Informal

Time
1h

Group size
Group

Supervised for safety
Supervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Planning and carrying out investigations, Constructing explanations, Engaging in argument from evidence, Communicating information

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

The students learn that warm air rises over cold air. They will understand that this basic phenomenon is the cause for the large scale air circulation systems on Earth and the warm and humid climate near the equator.

GOALS

The students will learn how the Sun drives the main engine of atmospheric circulation. They will experience hands-on, how irradiation and heat can drive convection. A minor aspect is the seasonal change of the global circulation system.

LEARNING OBJECTIVES

The students will learn how the Sun drives the main engine of atmospheric circulation. They will experience hands-on, how irradiation and heat can drive convection.

Desired Student Outcomes for Activity 1
After this activity, the students will understand that warm air rises above the surrounding cooler air. The uplift can be strong enough to launch objects up into the air.

Desired Student Outcomes for Activity 2
After this activity, the students will understand that a continuous convection stream can be produce, provided the energy source injects heat constantly. They will also understand that fresh needs to be replenished to keep the engine going.

Desired Student Outcomes for Activity 3
This worksheet helps the students to transfer the knowledge to the situation on Earth, where the Sun is the main heat source. They will understand that the Intertropical Convergence Zone is only a part of a larger air circulation system that is the cause for the climate zones between the Tropics and the Subtropics.

EVALUATION

The teacher starts off with some introductory remarks. The students are stipulated by a series of questions and possible answers that lead through the various aspects to be learned. The answers given by the students – partially stimulated by discussion – are the gauge by which the teacher can evaluate the learning outcome.

Q: Where are the poles? Where does the equator lie relative to the poles?
A: The equator is the line or circumference on the globe half way between the poles.

Q: Can you name countries that touch the equator? Do you know any cities close to it?
A: e.g. Ecuador (Quito, Galapagos), Brazil, Gabun (Libreville), Kongo, Uganda (Kampala), Kenia, Malaysia, Indonesia

Q: What is the typical vegetation there? A closer look at the satellite images helps to answer the question.
A: Rainforest

Q: What is the typical weather there (humid or dry, cold or warm)?
A: humid and warm, lots of rain

Q: Can you think of a reason, why it is so warm there all year? Show them a model of the Sun-Earth-System.
A: The Sun is the main heating source. Near the equator, it is always almost directly above.

Q: The air is heated up by the hot surface of the Earth. What happens with hot air? Imagine a hot-air balloon.
A: Warm/hot air rises above cold air.

The final activity, a worksheet, summarises the learning achievements and puts into the perspective of a global system on Earth. From this, it should be straightforward to judge, to what degree the individual elements have been understood.

Activity 1: Flying flames

Q: What happened to the air around the burning paper?
A: It was heated.

Q: What happens with heated air?
A: It rises.

Q: Can you explain why in the end the burning paper lifted off?
A: It was dragged along with rising air.

Activity 2: Updraft tower

Q: Why does the fan rotate?
A: The air inside the tower is heated up and streams upward.

Q: How is the air heated? Remember that the lamp does not shine inside the tower.
A: The lamp heats the black tower, which in turn heats the air inside.

Q: What are holes at the bottom for?
A: They permit replenishing the tower with fresh air.

Q: If you compare this with the situation on Earth, what does the Sun do in the belt around the equator? What happens with the surface and the air above?
A: The Sun heats the ground which, in turn, heats the air. Just like the model of the updraft tower, the heated air rises and produces a continuous up-current of air.

Q: Can you imagine what happens with the air, when it climbs to high altitudes?
A: The air cools down and moisture condenses to rain.

Q: Coming back to the updraft tower: it had flaps at the bottom to allow replenishing the air. The same happens on Earth. What do we call horizontal air flows?
A: wind

Activity 3: Worksheet

The answers expected from the last activity with the worksheet are as follows:

Q: Look at Fig. 1. Where on Earth does the Sun heat most efficiently?
A: around the equator

Q: Heating the air directly is quite inefficient. When you think about the updraft tower experiment, the lamp did not heat the air. Describe the process, how eventually the solar energy heats the air.
A: The irradiation from the Sun heats the ground, which in turn heats the air. This is more efficient next to the surface as compared to higher altitudes.

Q: Which part of the atmospheric layers is heated strongest?
A: The one next to the surface.

Indicate the correct attributions:
The air close to the surface of the Earth is warm
The air at high altitudes above ground is cold.

Q: What happens with the air close to the surface? Consider the temperature differences between low and high altitudes.
A: It rises above the cooler air.

Q: Warm air can store more water than cold air. What happens, when the air rises into higher layers of the atmosphere? Think of boiling water at home, when the hot air meets the cold air or cold surfaces.
A: The water vapour condenses. First to clouds, eventually to larger drops and rain.

Q: Can you explain why the equator regions of the Earth experience so much rain during the year?
A: Warm humid air is driven up to cooler atmospheric layers, where the water condenses to rain. This is a process that works almost all year.

Q: This region around the equator is also called the Intertropical Convergence Zone, abbreviated ITCZ. At some point, the air cannot rise any higher. It is diverted north and south. At those high altitudes, the air constantly cools down. What happens with cold air?
A: Cold air drops.

Q: We just mentioned that cold air can store less water than warm air. Can you explain why the desert areas north and south of the equator are so dry? What happens with the air, when it drops back to the surface?
A: When the warm air rises up to cooler layers, it cannot store water as efficiently and rain falls down. The air is dried by that process. When this air drops, it is heated up and potentially can store more water. Without replenishment with humid air, the air dries even more.

Q: Back at the surface, the air streams towards the equator region, where they converge (ITCZ). Those are winds we call the Trade Winds. Can you imagine, why?
A: The Trade Winds are a fairly constant phenomenon that helped cargo ships to sail long distances. Its direction is fairly stable as well, so ships didn't get lost so often.

For a solution for the drawing, see Fig. 3 in the background information.

MATERIALS

The activities are carried out best in groups by two. The items listed below are indicated per group.

Common items:

- paper handkerchief, napkin or dual chamber tea bag
- matches or lighter
- plate (or any other non-flammable flat surface)
- strong lamp (common bulb or tungsten halogen bulb, min. 100 W)
- scissors
- flat nose pliers, if available
- glue (for cardboard)
- pencil or similar pointed object
- aluminium wrap of a tea light
- drawing pin

For either of the following alternatives:

Alternative 1

- cardboard tube (inner part of a kitchen roll)
- black paint and brush or black coloured paper
- one piece of cardboard (approx. 1 cm wide, 8 cm long)

Alternative 2

- construction template provided with this sheet
- black cardboard (22 cm x 20 cm)
- one piece of card board (approx. 1cm wide, 12 cm long, see template)

BACKGROUND INFORMATION

The Sun is the main engine and energy source to all weather phenomena we see on Earth. When it irradiates the surface of the Earth, the light is absorbed and heats the ground. Infrared radiation is re-emitted that heats the layer of air directly above. Since warm air has a lower density than cool air, it produces an updraft which by convection drags the air up into the highest layers of the troposphere about 10 - 15 km above ground.

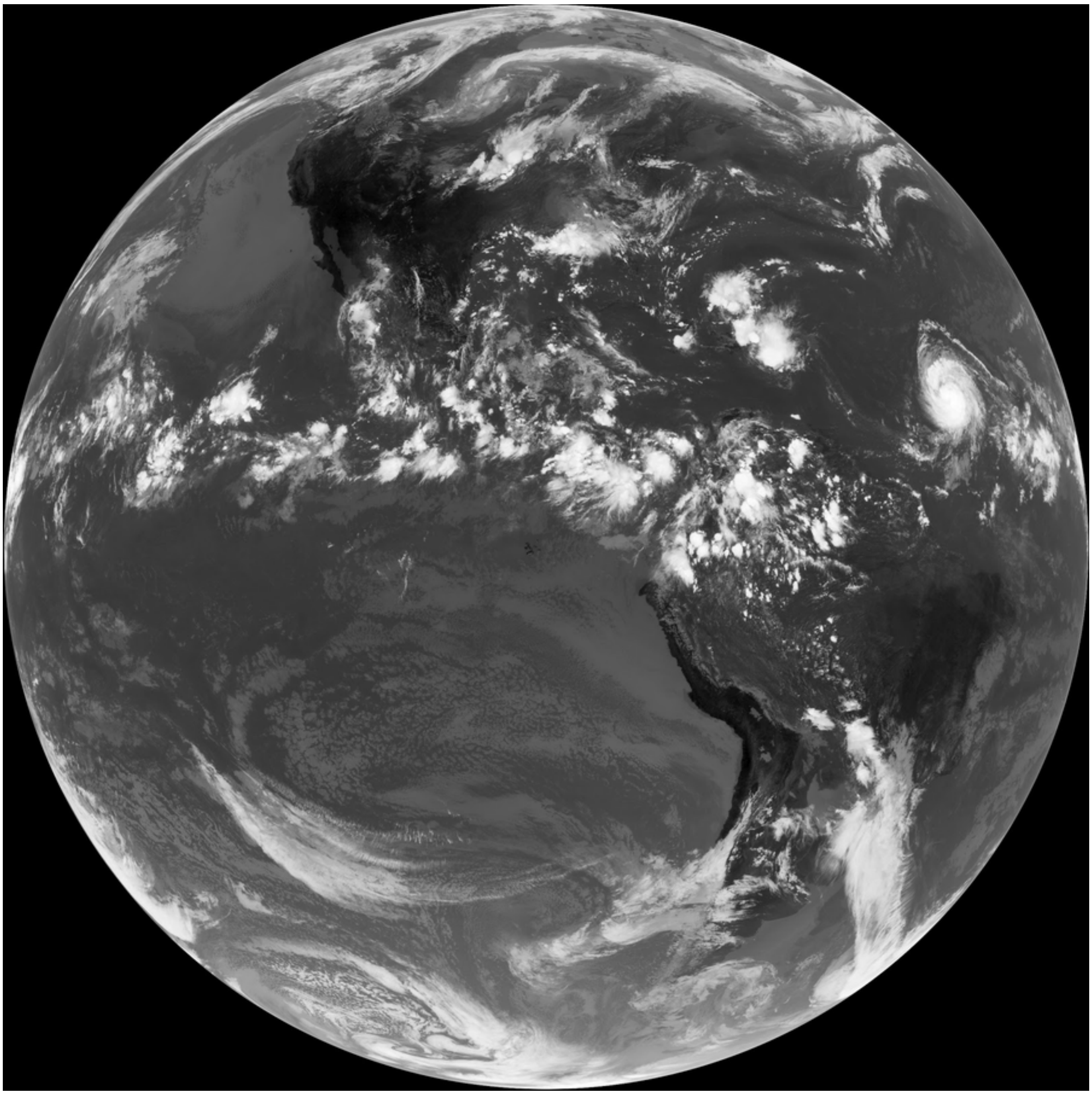


Figure 1: Image obtained with the GOES 14 satellite. The belt of cloud formation around the ITCZ is well visible (Credit: NASA, http://eoimages.gsfc.nasa.gov/images/imagerecords/39000/39848/hemisphere_goe_2009229_lrg.jpg).

This process is most effective at latitudes where the Sun is at Zenith, i.e. in a belt around the equator. This area is called the Intertropical Convergence Zone (ITCZ). It follows the Sun northward and southward during the seasons. Since the air cools down with increasing altitude, its ability to store water is continuously reduced. This leads to the formation of clouds and, consequently, thunderstorms. In extreme cases, the convection can lead to severe weather phenomena like cyclones and hurricanes. Eventually, the humidity is released via precipitation leaving the air dry. This is the reason, why the low latitudes around the equator are strongly affected by a humid, tropical climate with low pressure areas and lots of rain. On satellite images, the ITCZ is very prominent due to a global cloud belt along the equator (see Fig. 1). This demonstrates that satellite imagery can be an important tool to monitor the climate of the Earth.

The convection zone at the ITCZ is only a part of a much larger and global air circulation system (see Fig. 2). Locally, it belongs to a circulation unit called the Hadley cell. The air can only rise up to an altitude of 10 to 15 km above ground, where it is diverted poleward while it cools down again. At latitudes around 30° north and south, the already dried air drops, heats up, and is dried even more. This gives rise to the arid, subtropical climate we find there.

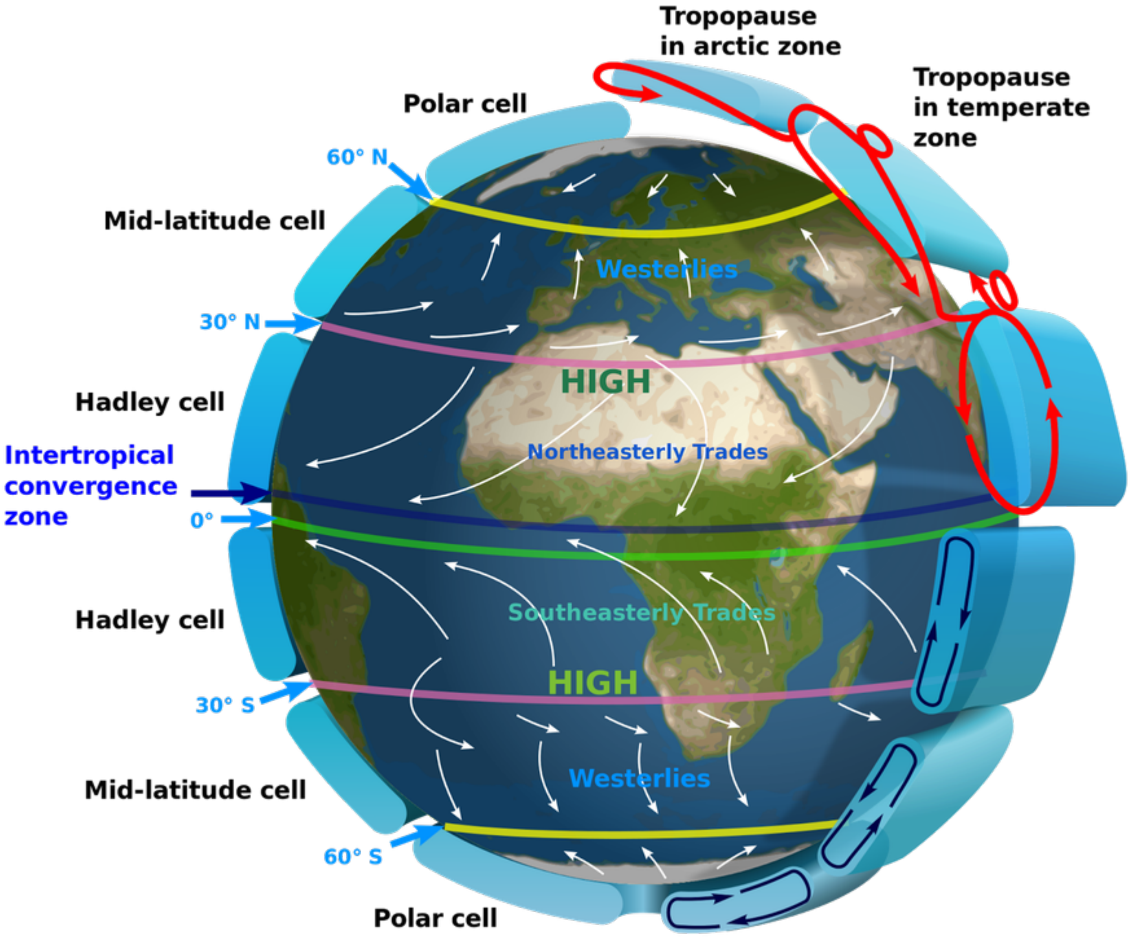


Figure 2: Global circulation of Earth's atmosphere (Credit: Kaidor, improved by the Wikigraphists of the Graphic Lab (ru), https://commons.wikimedia.org/wiki/File:Earth_Global_Circulation_-_en.svg, https://creativecommons.org/licenses/by-sa/3.0/legalcode).

The cycle of the circulation of the Hadley cell closes with the air currents flowing back to the equatorial region and the ITCZ where they feed the convection again. Because of the Coriolis force, which is caused the rotation of the Earth, those winds cannot blow directly north or south, but they are diverted westward. Since wind directions indicate their origin, this produces the wind phenomena known as the Northeasterly and Southeasterly Trade Winds.

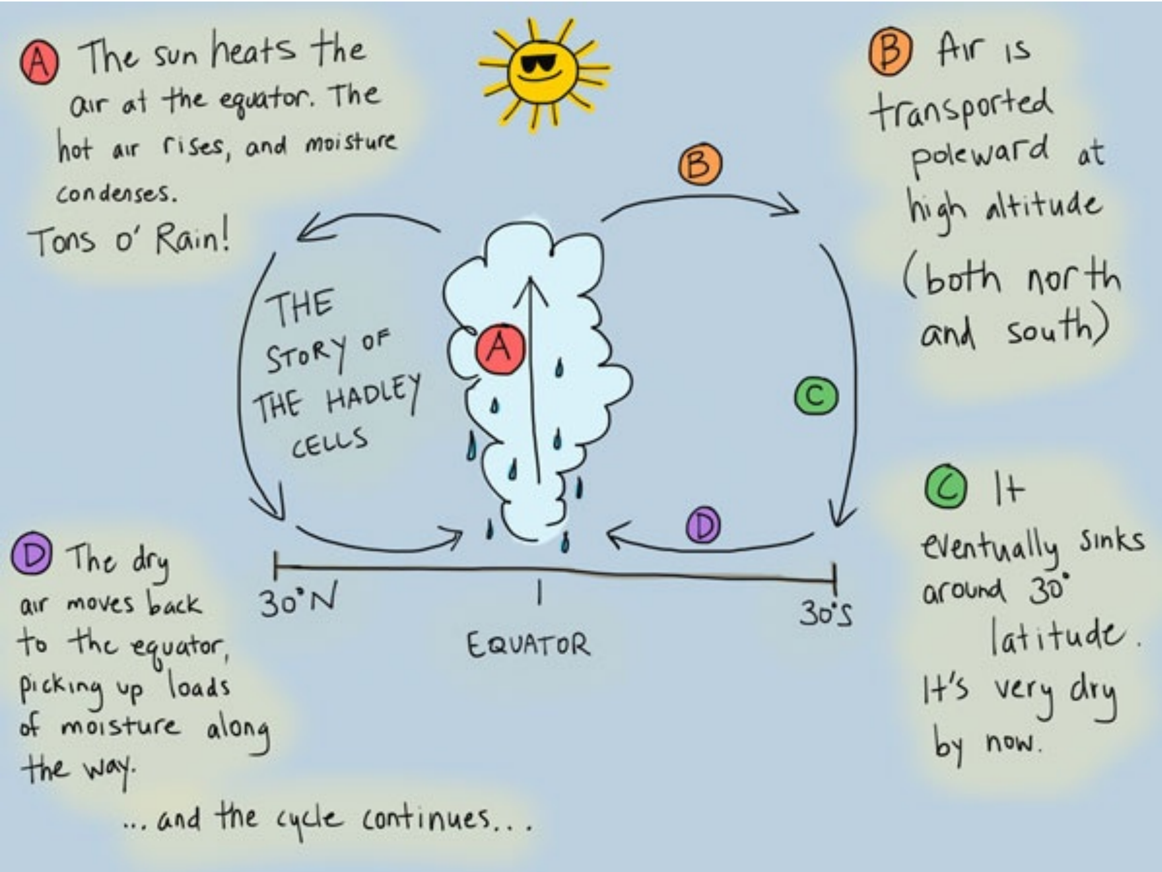


Figure 3: Schematic of the Hadley cell (Source: "The Waveform Diary" blog, The mystery of the shifting tropical rain belt, http://www.michw.com/blogwp/wp-content/uploads/2013/05/Hadley-Cells_600px.jpg, credit: M. Weirathmueller, permission for reproduction granted).

FULL ACTIVITY DESCRIPTION

Introduction: Questions and Answers

Show the students an Earth globe or a global map and ask them, if they can identify the equator.

Q: Where are the poles? Where does the equator lie relative to the poles?

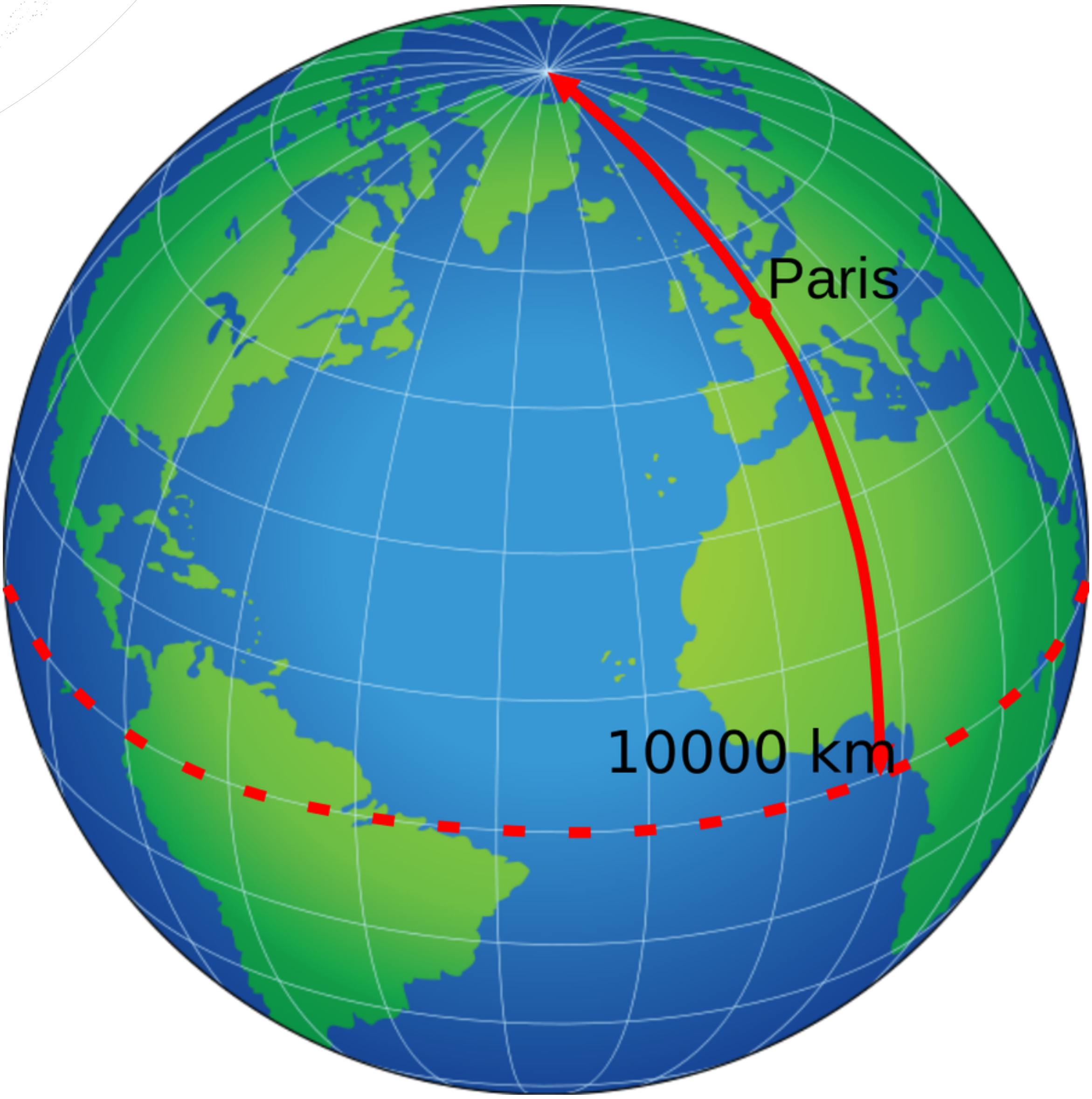


Figure 4: Illustration of the Earth globe and the position of the equator relative to the North Pole (Source: Wikimedia commons, licence: public domain).

If possible, let the students use an online map tool to investigate the geography and satellite images of the equator region.

Q: Can you name countries that touch the equator? Do you know any cities close to it?

Q: What is the typical vegetation there? A closer look at the satellite images helps to answer the question.

Q: What is the typical weather there (humid or dry, cold or warm)?

Q: Can you think of a reason, why it is so warm there all year? Show them a model of the Sun-Earth-System?

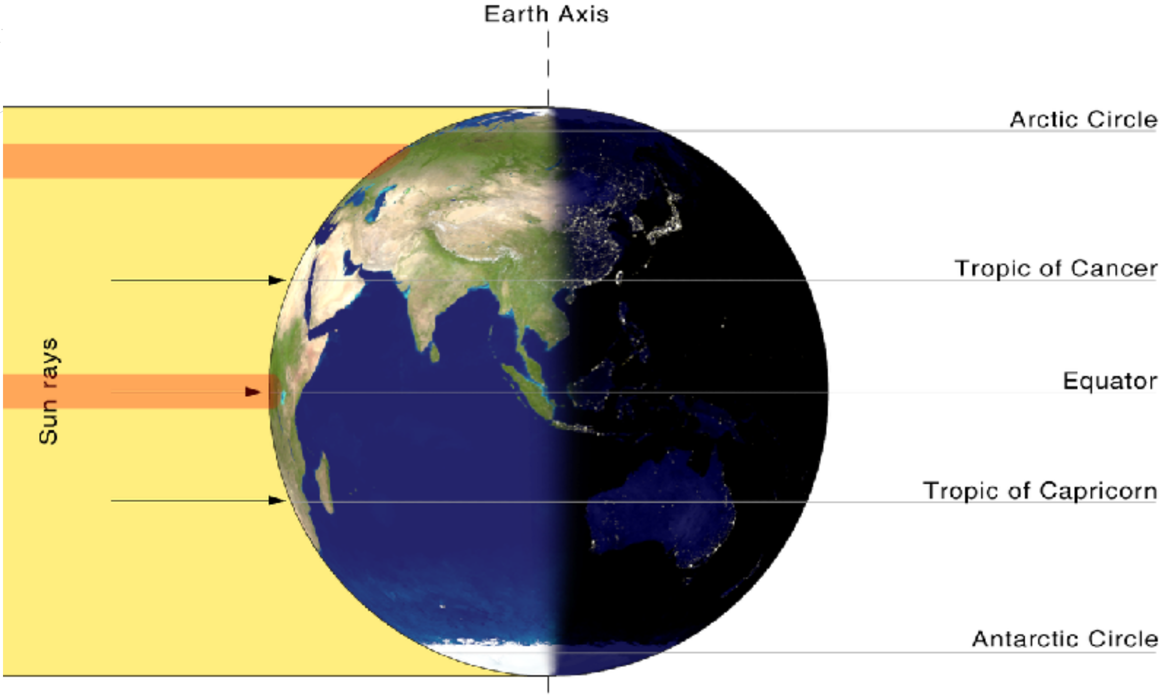


Figure 5: Illustration of the Earth by the Sun. Looking from the equator, the Sun is almost always directly above (Source: adapted from Wikimedia commons, credit: M. Nielbock, P. Idzkiewicz, https://creativecommons.org/licenses/by-sa/2.0/legalcode).

Q: The air is heated up by the hot surface of the Earth. What happens with hot air? Imagine a hot-air balloon.

Activity 1: Flying flames

WARNING! This activity is only suitable for students that are confident enough to handle a flame. If in doubt, the experiment should be demonstrated by the teacher.

Smoke detectors may have to disabled for this.

In this activity, the students will experience, how warm air rises above cooler air. The hot air produced by a burning piece of very light paper produces its own uplift and rises up in the air. This experiment should give rather a qualitative result meaning that the exact uplift force is not so important.

Gather the following items, one set per group (or one for the teacher only, if carried out as a demonstration):

- paper handkerchief, napkin or dual chamber tea bag
- matches or lighter
- plate

- scissors

Distribute the students in groups of two (suggested).

1. Prepare the wick:
   - Paper handkerchiefs and napkins consist of several layers. Take only one and cut off one quarter.
   - If a tea bag is used, cut off the top and empty the bag. Unfold it.
2. Form a tube (napkin, handkerchief, tea bag) of a few centimetres and put it on the plate, standing upright. It should stand stably. Avoid abrupt and fast movements to prevent moving air from blowing the wick away.
3. Light it.

Discuss with the students what happened. Let the students describe in detail what they saw. While the wick burns down, it lifts off at some point.

Q: What happened to the air around the burning paper?

Q: What happens with heated air?

Q: Can you explain why in the end the burning paper lifted off?

Activity 2: Updraft tower

This activity demonstrates how heated air rises. As long as the heating source is present, a continuous updraft of the heated air is generated. The students will experience this phenomenon by building a model of an updraft tower. Afterwards, the concept of air circulation can be used to explain the process of terrestrial atmospheric circulation systems and the Intertropical Convergence Zone.

Gather the following items, one set per group:

- scissors
- flat nose pliers, if available
- glue (for cardboard)
- pencil or similar pointed object
- aluminium wrap of a tea light
- drawing pin

For either of the following alternatives:

Alternative 1

- cardboard tube (inner part of a kitchen roll)
- black paint and brush or black coloured paper
- one piece of cardboard (approx. 1 cm wide, 8 cm long)

Alternative 2

- construction template provided with this sheet
- black cardboard (22 cm x 20 cm)
- one piece of card board (approx. 1cm wide, 12 cm long, see template)

Figure 6: Items needed for building an updraft tower model (Source: M. Nielbock).

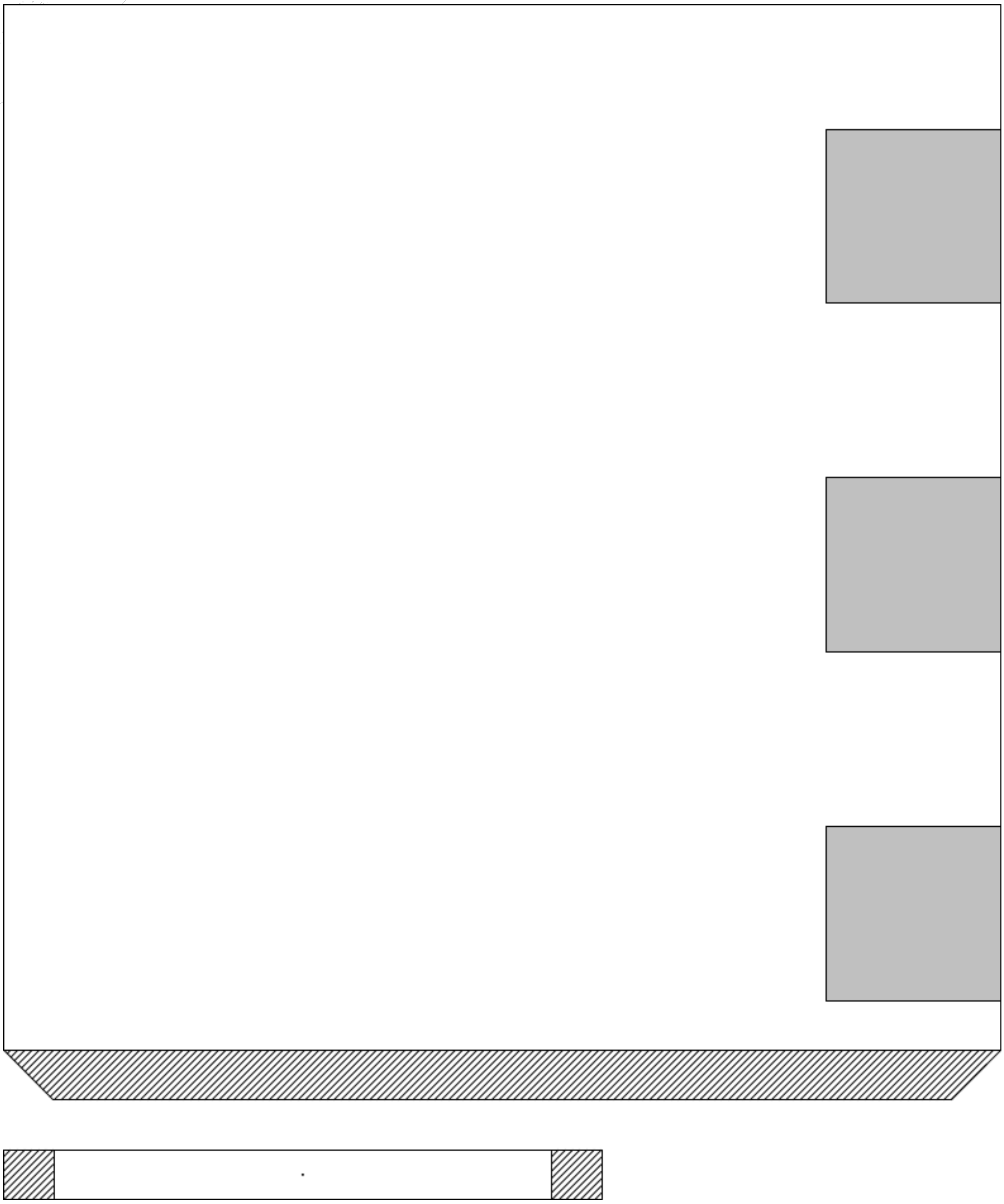


Figure 7: Construction Template (scaled down version, original version to be attached).

Building Instructions

Alternative 1:
The first version may be somewhat simpler to produce, but might be not that effective, because the cardboard tube used in this example may a bit too narrow.

1. Paint the outside of the cardboard tube black or glue it with black paper.

Alternative 2:
The second version is especially designed to match the diameters of the tower and the fan.

1. Prepare the black cardboard according to the construction template provided.
2. Roll the cardboard perpendicularly to the hashed area.
3. Glue the tube at the hashed area.
4. Cut out the grey areas or cut them from bottom to top and fold them up to form flaps.

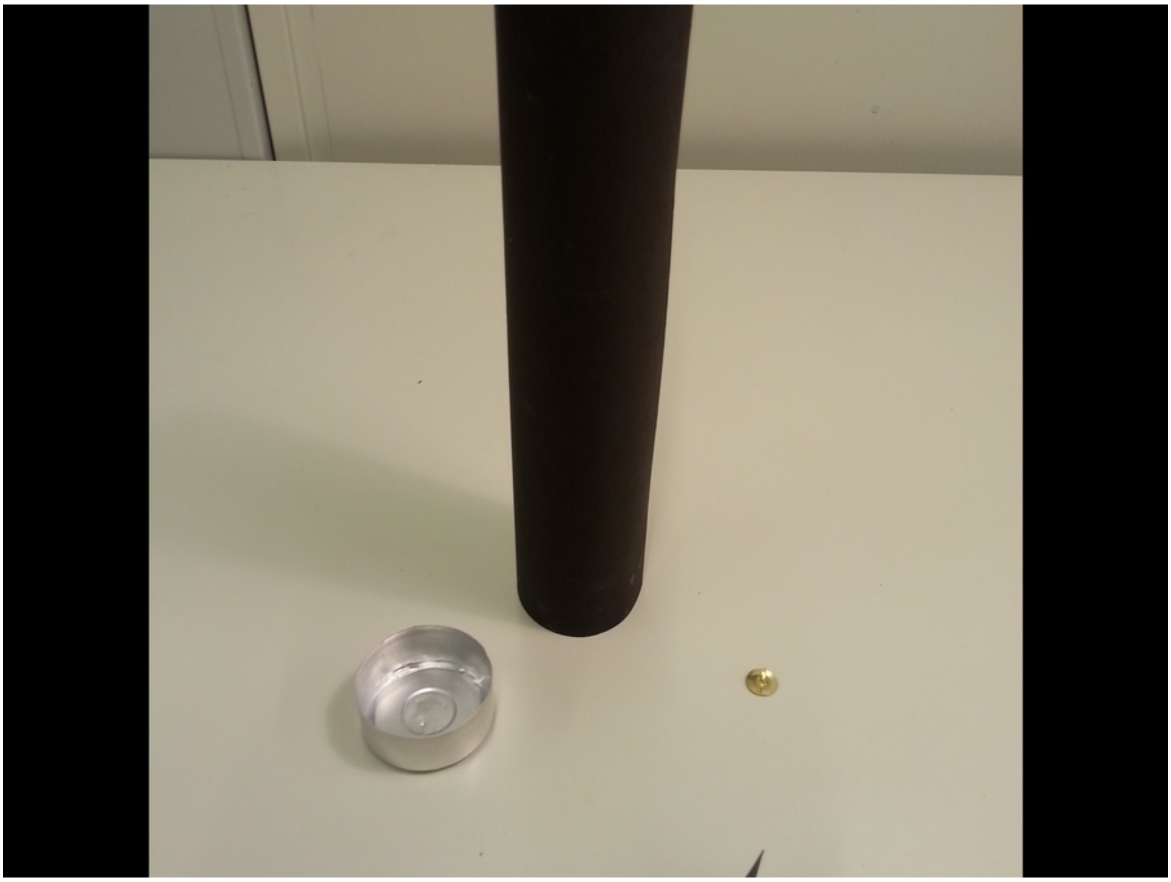


Figure 8: Set of items with the tower already built (Source: M. Nielbock).

Common steps:

1. Now we produce the fan using the tea light wrap. This part is quite delicate and has to be done very carefully.
2. Cut the walls of the tea light wrap into 16 equal sections.
3. Flatten the sections outside to the bottom of the wrap.
4. Extend the cuts to the inner circle of the bottom of the wrap.

5. Press the pencil exactly at the centre of the fan to form a small dent. Be careful not to punch a hole.
6. Bend all 16 wings of the fan around an axis from the centre to the edge. Use the pliers if available.
7. Punch the drawing pin through the centre and from the back of the small piece of cardboard.
8. Glue the small piece of cardboard to the inside at the top of the tube. It should form an arc.

Figure 9: Set of items with the tower and the fan (Source: M. Nielbock).

1. Put the fan on top of the drawing pin.
2. Balance the fan by bending the winds up and down.

Figure 10: The finished updraft tower model (Source: M. Nielbock).

1. Illuminate the tower with a strong lamp.
2. Watch the fan rotate.

Discuss the results with the students.

Q: Why does the fan rotate?

Q: How is the air heated? Remember that the lamp does not shine inside the tower.

Q: What are holes at the bottom for?

Q: If you compare this with the situation on Earth, what does the Sun do in the belt around the equator? What happens with the surface and the air above?

Q: Can you imagine what happens with the air, when it climbs to high altitudes?

Q: Coming back to the updraft tower: it had flaps at the bottom to allow replenishing the air. The same happens on Earth. What do we call horizontal air flows?

Activity 3: Worksheet: The Wind Engine of the Earth

We have seen in the experiments that a heat source can heat up the air and cause an upward flow. The very same process happens on Earth.

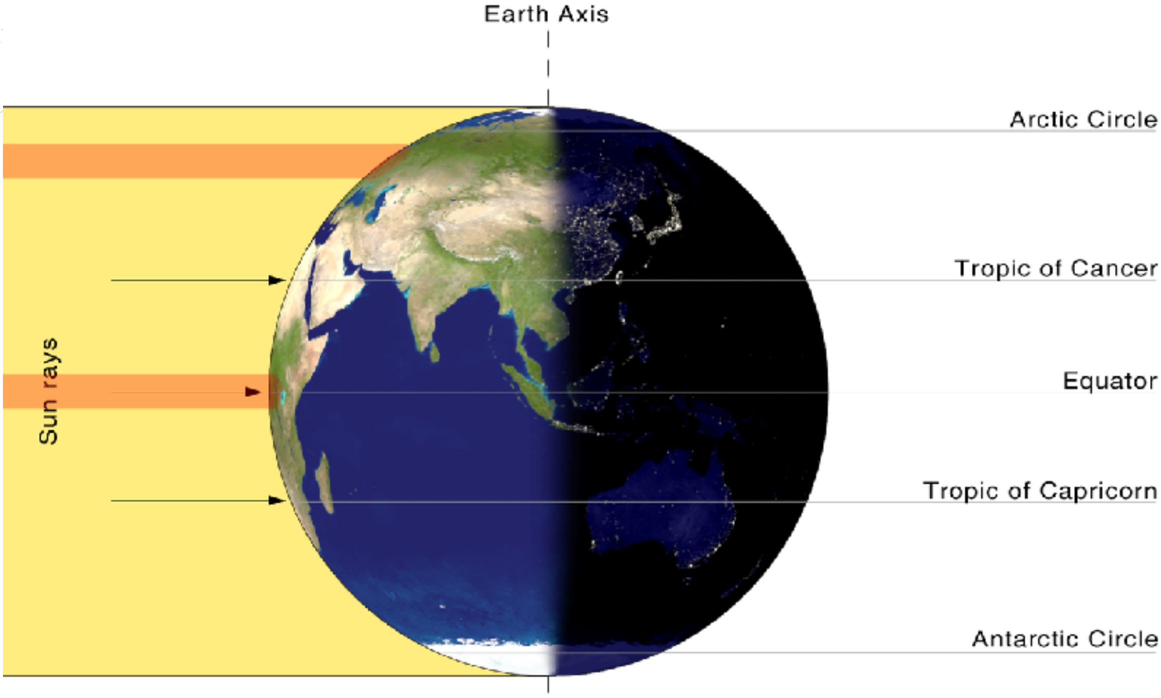


Figure 11: Illustration of the Earth by the Sun. Looking from the equator, the Sun is almost always directly above (Source: adapted from Wikimedia commons, credit: M. Nielbock, P. Idzkiewicz, https://creativecommons.org/licenses/by-sa/2.0/legalcode).

Q: Look at Fig. 1. Where on Earth does the Sun heat most efficiently?

Q: Heating the air directly is quite inefficient. When you think about the updraft tower experiment, the lamp did not heat the air. Describe the process, how eventually the solar energy heats the air.

Q: Which part of the atmospheric layers is heated strongest?

Indicate the correct attributions:
The air close to the surface of the Earth is warm/cold.
The air at high altitudes above ground is warm/cold.

Q: What happens with the air close to the surface? Consider the temperature differences between low and high altitudes.

Q: Warm air can store more water than cold air. What happens, when the air rises into higher layers of the atmosphere? Think of boiling water at home, when the hot air meets the cold air or cold surfaces.

Q: Can you explain why the equator regions of the Earth experience so much rain during the year?

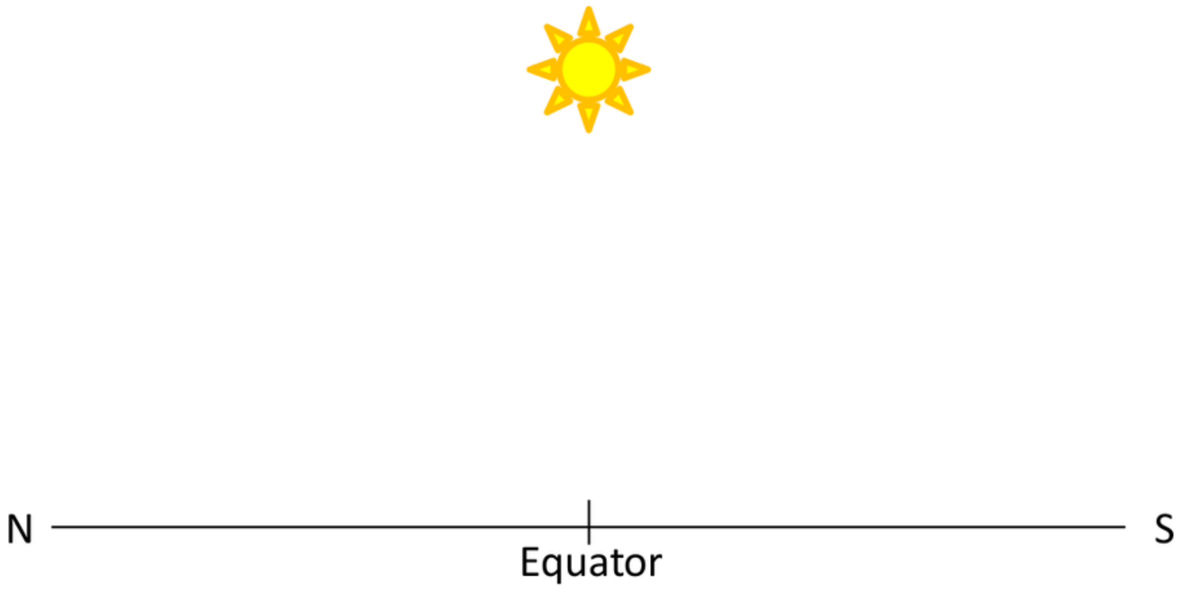
This region around the equator is also called the Intertropical Convergence Zone, abbreviated ITCZ. At some point, the air cannot rise any higher. It is diverted north and south. At those high altitudes, the air constantly cools down.

Q: What happens with cold air?

Q: We just mentioned that cold air can store less water than warm air. Can you explain why the desert areas north and south of the equator are so dry? What happens with the air, when it drops back to the surface?

Q: Back at the surface, the air streams towards the equator region, where they converge (ITCZ). Those are winds we call the Trade Winds. Can you imagine, why?

Q: We have constructed an entire circulation system that begins and ends at the equator region. This system is called the Hadley cell. Can you draw a schematic with the most relevant elements and processes? Use the prepared sketch below as a starting point.



CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, Atmosphere, surface

CONCLUSION

This learning package consists of three activities that, in a stepwise approach, illustrates the power of the Sun driving a global air circulation system that is also responsible for tropical and subtropical climate zones. In addition to an introduction, the activities comprise:

- An experiment that demonstrates how heated air rises above cool air.
- An experiment that shows how a continuous heat source produces air convection streams that can even drive a propeller.
- A worksheet that presents the big picture of the global air circulation system of the equator region by transferring the knowledge from the previous activities into a larger scale.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

SUN, EARTH AND MOON MODEL

Build an Earth-Moon-Sun model to learn about how they orbit.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
Sun-Earth-Moon system, stars

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet.

Keywords
Sun, Earth, Moon, Planet, Orbits, Satellite

Age range
8 - 10

Education level
Primary School, Informal

Time
1h

Group size
None

Supervised for safety
Supervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

Students build a model of the Sun-Earth-Moon system, exploring how the Moon revolves around the Earth, and the Earth around the Sun. Students play a memory game and learn some characteristics about the three objects.

GOALS

Students will practice fine motor skills to build a Sun-Earth-Moon mobile and use it to describe the relative movement of the three objects. Students identify some of the differing characteristics of the Sun, Earth and Moon.

LEARNING OBJECTIVES

By implementing this activity, students will be able to:

- explain that the Earth revolves around the Sun,
- explain that the Moon revolves around the Earth,
- explain that the Sun is a star,
- describe the relative temperatures and sizes of the Sun, Earth and Moon.

EVALUATION

The different parts of the activity can be evaluated as follows:

What do you already know?

- Discuss what the students have drawn/written.

The solar system memory game

- Encourage students to explain what they have learnt about the Solar System.

The Sun mobile

- Check if the mobiles are built correctly.
- Encourage the students to explain what they have learnt about the Solar System. Do they know now that in the Solar System, the Earth (a planet) revolves around the Sun (a star) and the Moon (a satellite) revolves around the Earth?

MATERIALS

Per student/mobile:

- worksheet in PDF
- A4 paper
- 1 wooden skewer
- 1 cocktail stick
- colouring pencils,
- felt-tip pens or wax crayons
- scissors
- string to attach cutouts to mobile
- sticky tape
- embroidery needles or paper punches to share with the class

Per pair of students:

- stiff card to print memory game onto

Per class:

- one sheet of A2 paper

BACKGROUND INFORMATION

Sun

The Sun is a star, a powerhouse of energy, undergoing constant nuclear fusion. It is luminous and extremely hot. Even though the Earth is about 150 million kilometres away from the Sun, we still feel the energy from the explosions that happen within it. Humans and many other creatures on Earth depends on the heat and light coming from the Sun.

Some stars in the universe are bigger and brighter than the Sun, but all other stars are very far away so appear as small points of light. For the part of the Earth that it is day time, the stars are hidden by the brightness of the Sun in the sky, as they are much fainter. When it is night time, with the Sun shining on the other side of the Earth, the stars can be seen in the dark sky.

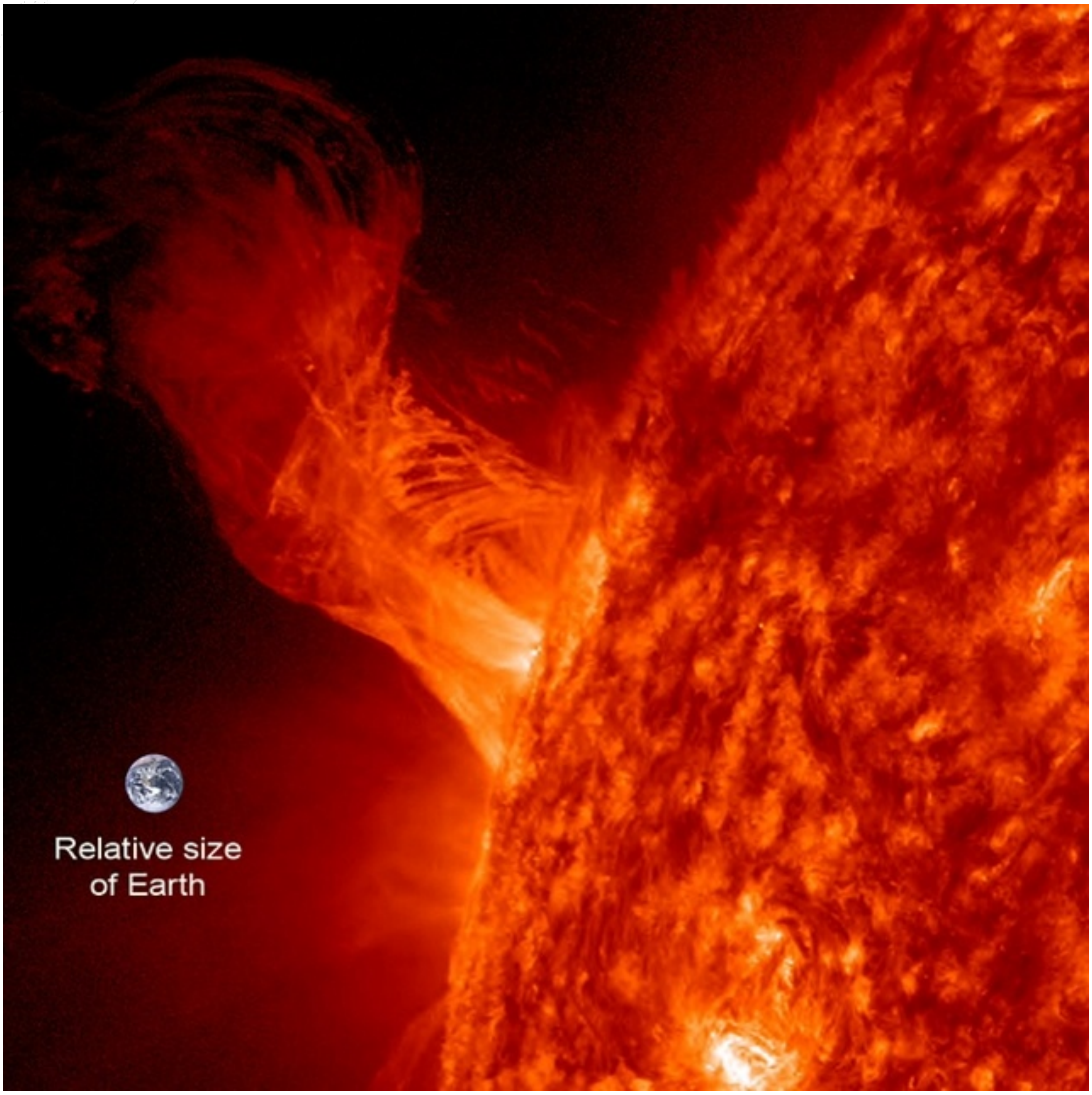


Image Credit: NASA/SDO/Steele Hill

Earth

A planet is an object orbiting a star which is spherical and bigger than an asteroid but smaller than a star. They can be rocky, like Earth, or gassy, like Jupiter. Earth is our home and the third planet from the Sun, with a mean distance of about 150 million kilometres. This distance and the atmosphere of Earth keep its average surface temperature above the freezing point of water (0°C) but below the boiling point of water (100°C), enabling liquid water to exist freely, giving us seas and oceans. This is not the case on Venus, which orbits closer to the sun, and thus has a surface temperature hotter than the boiling point pof water. Neither is it the case on Mars, which orbits further from the sun and has a surface temperature colder than the freezing point of water. Liquid water has been crucial for the development of life on our planet, the only known place where life exists in the universe.

The shape of the Earth is very close to a sphere. It spins, or rotates, once every 24 hours giving us the length of a day. Earth only has one natural satellite, the Moon, which is thought to have played a major role in stabilising the axis of rotation of the Earth. This may have also been a favourable condition for the emergence of life.

Moon

Satellites, including moons, orbit planets. The Moon is a natural satellite of Earth. It takes close to one month (27 days 8 hours) to revolve around our home planet. The Moon and Earth are about the same distance from the Sun. Despite this, the temperatures on the Moon are extreme, reaching higher and lower temperatures than on Earth, because the Moon lacks a rich atmosphere.

Solar System

A solar system refers to a star and all the objects that orbit it. Our Solar System consists of the Sun — our home star —, eight planets and their natural satellites (such as our moon), dwarf planets, asteroids and comets. It is located in an outward spiral arm of the Milky Way galaxy.

Adapted from source: NASA

- https://solarsystem.nasa.gov/planets/moon/basic
- https://solarsystem.nasa.gov/planets/earth/basic
- https://solarsystem.nasa.gov/planets/sun/basic

FULL ACTIVITY DESCRIPTION

Preparation

The activity is structured into four parts:

- (1) What do you already know?
- (2) The memory game
- (3) Revolving Earth
- (4) Sun-Earth-Moon mobile.

Print the mobile activity worksheet for each student. Prepare the listed materials. For the memory game, print one copy of the game sheet per two students onto stiff card paper.

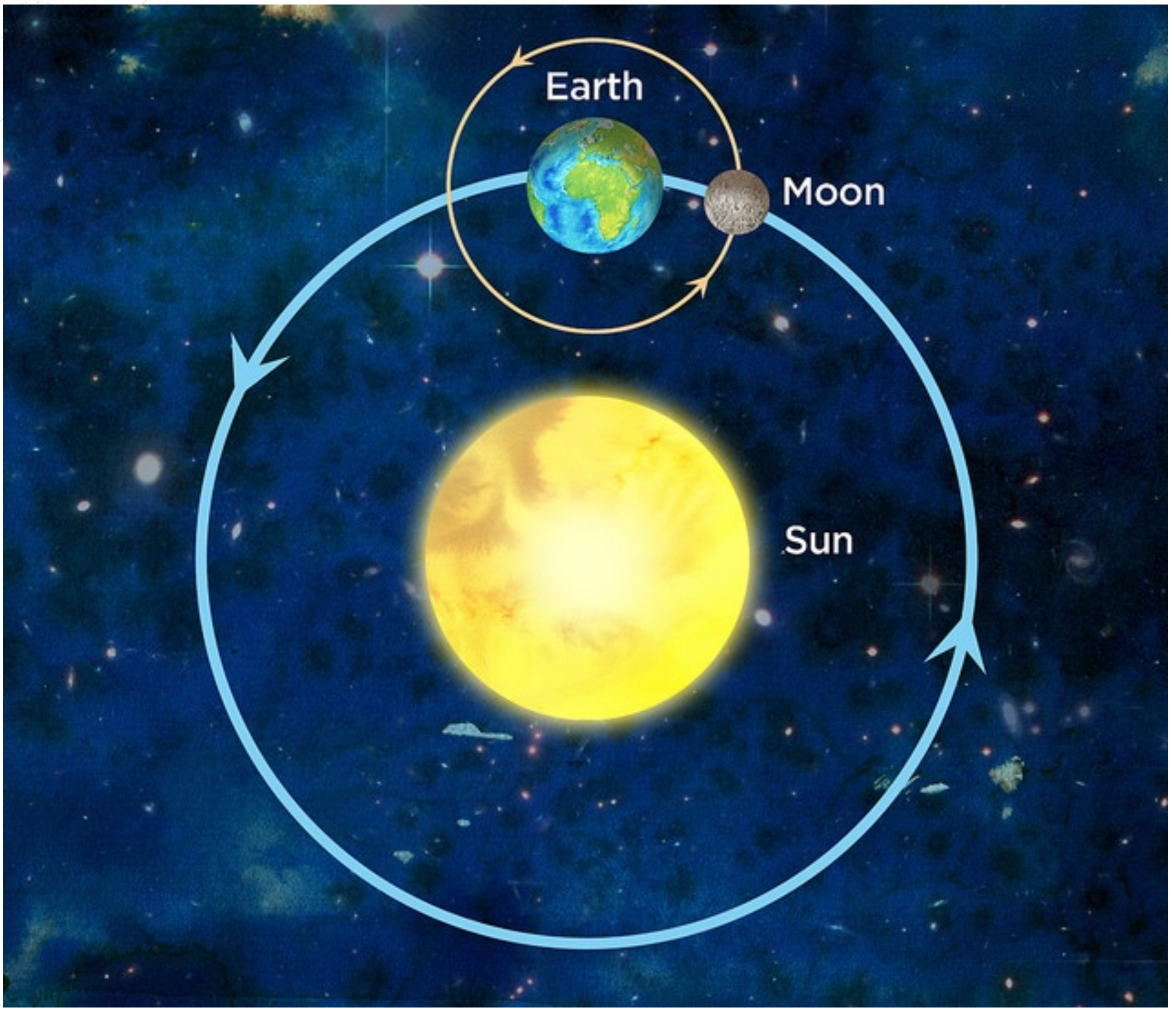


Image: Siyavula Education (not to scale)

Activity 1: What do you already know?

Step 1:

Provide each child with an A4 sheet of paper and some colouring pencils.

Step 2:

Encourage students to draw the Sun, Earth and Moon and to write any words they associate with them. Discuss what the students have drawn/written.

Step 3:

Write their ideas on an A2 sheet of paper and display it in the classroom. Explain to the students that they can add to this whenever they like, either in words or drawings.

Activity 2: Solar System memory game

Step 1:

The students play a memory game to learn some differences between the Sun, Earth and Moon. Before starting the game, encourage the students to look at all the cards from the memory game sheet.

Step 2:

Ask students to cut out the cards. Explain how the memory game works: in pairs, students put all the cards face down randomly in a grid. They take turns to select two cards. If they match, that student keeps the pair, if not they return the cards to the grid in the same place. The game finishes when all the card pairs have been found.

Step 3:

Afterwards, discuss what the students learned about the properties of the Sun, Earth and Moon, covering the following points:

- It is much hotter on the Sun than on Earth, because the Sun is a star.
- Stars are much hotter and brighter than planets.
- The temperature on Earth is hotter than the temperature water freezes, but colder than the temperature water boils, giving us liquid water, and therefore oceans, on Earth.
- The temperature on the Moon can range from very cold to very hot.
- The Sun is more than a hundred times wider than the Earth.
- The Earth is about four times wider than the Moon.

Activity 3: The revolving Earth

Step 1:

Draw a picture of the Earth in the middle of the board. Explain that the Moon revolves around the Earth, and then add it to the drawing. Now explain that both the Earth and the Moon revolve around the Sun. Draw this on the board as well.

Step 2:

Invite three students to come to the front of the class. Explain that student 1 is the Moon, student 2 is the Earth and student 3 is the Sun. Encourage the students to enact the movement of the Moon around the Earth and the spinning of the Earth on its axis while it revolves around the Sun. Explain that the Moon, a natural satellite, revolves around the Earth, a planet, and both revolve around the Sun, a star.

Step 3:

Explain that they are going to make a mobile showing this.

Activity 4: The Sun-Earth-Moon mobile

Step 1:

Now distribute the Sun-Earth-Moon mobile worksheet and explain the ten steps to making the Sun mobile. Talk through the instructions together.

Step 2:

The wooden skewers are used for the top bar. Help the students tie the string to the wooden skewers. Using the drawing, demonstrate how to put the rest of the mobile together.

Step 3:

Hang the mobiles in the classroom. Check that the mobiles they have made work properly. Does the Earth revolve around the Sun and the Moon around the Earth?

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Sun-Earth-Moon system, stars

National Curricula UK

KS2: Year 5, Science, Earth and Space: -Describe the movement of the Earth, and other planets, relative to the Sun in the solar system. -Describe the movement of the Moon relative to the Earth. -Describe the Sun, Earth and Moon as approximately spherical bodies.

CONCLUSION

In this activity, students make a model of the Sun, Earth and Moon and play a memory game. They learn that the Earth revolves around the Sun and the Moon around the Earth. Students learn that the Sun is a star and some additional characteristics about the Sun, Earth, and Moon.

ASTROEDU

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

MAKE A STAR LANTERN

Learn about constellations by building a star lantern.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
stars, constellations

Big idea of science
Earth is a very small part of the universe.

Keywords
Stars, constellations

Age range
6 - 10

Education level
Primary School, Informal

Time
1h30

Group size
None

Supervised for safety
Supervised

Cost
Expensive (> 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Communicating information

Type of learning activity
Fun learning

BRIEF DESCRIPTION

During the activity, students build a star lantern, allowing them to learn that constellations were created by people and are composed of stars. Students learn how to recognise some constellations.

GOALS

Students learn that constellations are made up from different stars. Students recognise and name different constellations. Students develop creativity skills and imagination by constructing a lantern and drawing. They develop curiosity for the night sky and presentation skills.

LEARNING OBJECTIVES

After implementation, students will be able to:

- name some constellations and describe their shapes,
- explain that a constellation is a pattern that links several stars,
- explain that constellations are imaginary patterns created by people a long time ago.

EVALUATION

- Ask the students if they know what stars are.
- Encourage the students to show their constellations and say what they represent.
- Encourage the students to describe what figures they can see in the stars.

- Show a picture of the night sky at the end of the activity, and ask students to recognise or find a constellation.

MATERIALS

- Worksheet (PDF) (If you do not have a printer, you can use a model that you can prepare before. Students will use the model to make the constellation on the lantern.)
- Coloured A3 card sheet, one per student
- Lantern lights, one per student
- Embroidery needles and newspaper
- Sticks to hold the lantern, one per student
- Crepe paper and tissue paper in different colours
- Brushes
- A4 paper or printed sky maps
- Luminous paint (or normal paint)
- Glue
- Stapler
- String
- Camera (optional)

BACKGROUND INFORMATION

What is a star?

A star can be described as a big ball full of burning gases, essentially helium and hydrogen, kept together by its own gravity. Stars emit light and heat and appear in the night sky as a multitude of luminous points. The closest star to the Earth is the Sun. If the distance between the Earth and the Sun was 1 meter, the next nearest star (Proxima Centauri) would be at 260,000 km away from us!

Why do we see stars better during the night?

Stars are always in the sky, both during night and day. But when it is day, the Sun, our own star lights up the sky and makes it so bright that we cannot see other stars, which are further away. On the other hand, when it is night, the sky gets dark and the light of stars further away becomes visible. To demonstrate this to students, you can use an activity about day and night.

Origin of the Constellations

Ever since people first wandered the Earth, great significance has been given to celestial objects seen in the sky. Throughout human history and across many different cultures, names and mythical stories have been attributed to the star patterns in the night sky to remember and recognise them more easily, thus giving birth to what we know as constellations.

When were the first constellations recorded?

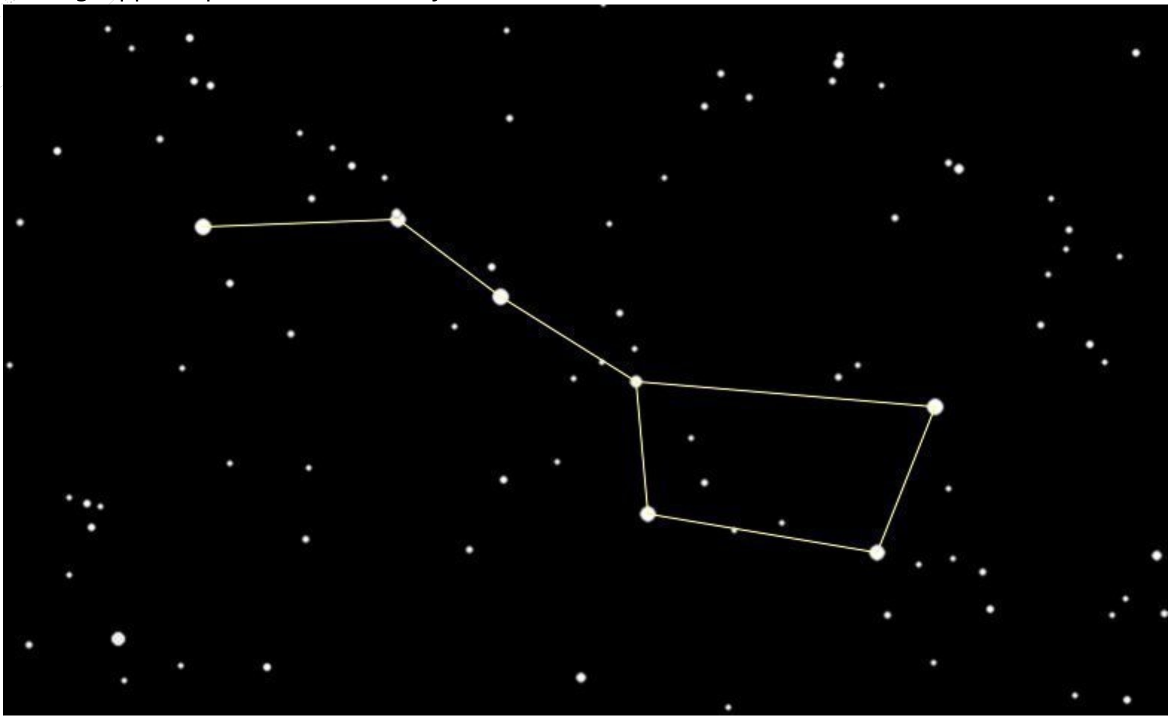
Archaeological studies have identified possible paintings representing constellations, for example, on the walls in a cave system at Lascaux in southern France made almost 17,300 years ago. The ancient Greeks were the first to describe over half of the 88 constellations recognised by the International Astronomical Union today. Between the 16th and 17th century AD, European astronomers and celestial cartographers added new constellations to the 48 previously described by Ptolemy; these new constellations were mainly ‘new discoveries’ made by the Europeans who first explored the Southern Hemisphere.

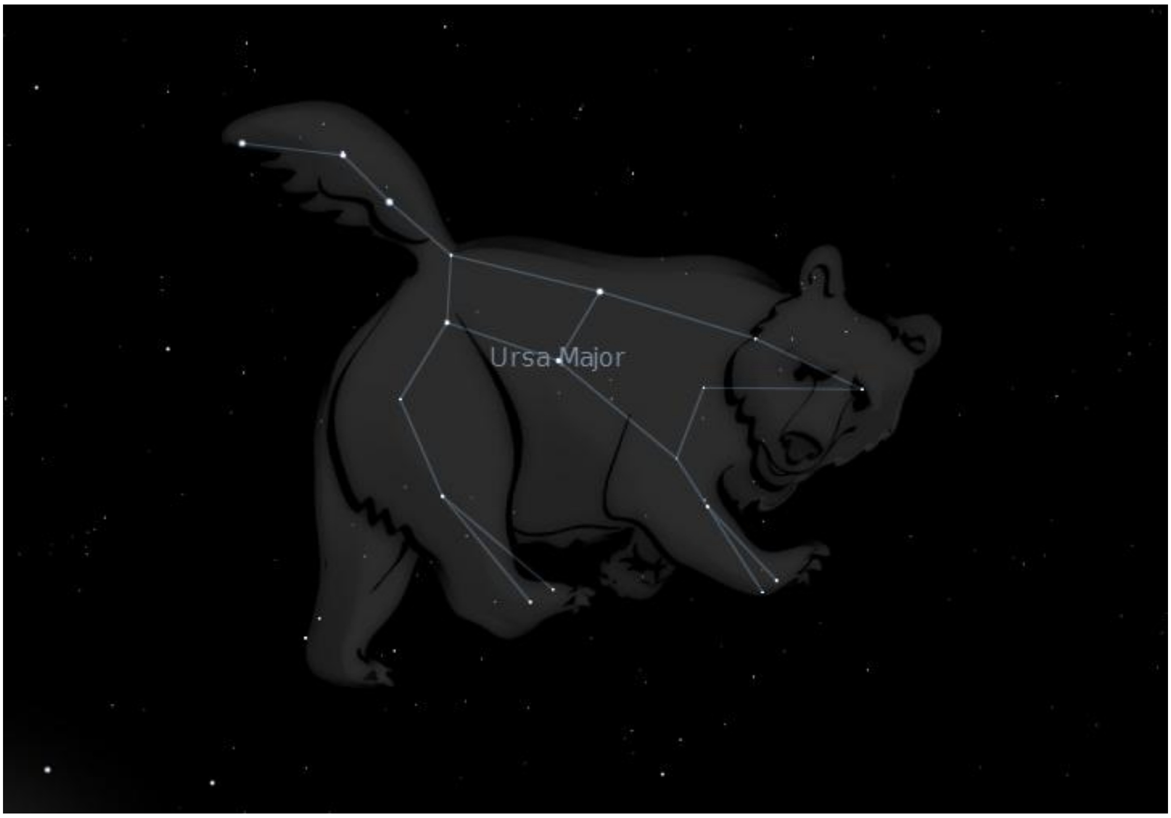
People used constellations for many different reasons. This fastened the discovery of new constellations. The first uses were probably religious but constellations had mainly practical uses. For example, in agriculture, constellations could help determine when the seasons were coming before using calendars. Constellations also helped navigators and explorers to find their way across the planet. Nowadays, astronomers still use the names of constellations to identify where a celestial object can be seen in the sky.

Constellation Figures

In star maps, it is common to mark ‘line patterns’ of the shape that makes a constellation. Famous ones include Orion and Ursa Major (illustrated below). However, the IAU defines a constellation by its boundary (indicated by sky coordinates) and not by its pattern and the same constellation may have several variants in its representation. The constellations should be differentiated from asterisms. Asterisms are patterns or shapes of stars that are not related to the known constellations, but nonetheless are widely recognised by laypeople or in the amateur astronomy community. Examples of asterisms include the seven bright stars in Ursa Major known as ‘the Plough’ in Europe or ‘the Big Dipper’ in the United States of America.

The big dipper is part of the Ursa Major constellation.





Text adapted from the constellations page - International Astronomical Union, http://www.iau.org/public/themes/constellations/

FULL ACTIVITY DESCRIPTION

Preparation

For the activity 'Make a Star Lantern', copy the constellations from the worksheet onto various colours of A3 card. Provide lights for the lanterns or ask the students to bring their own.

Image: This ground-based photo shows a wide angle view of the constellation Corvus and part of contellation Hydra. Credit: NASA, ESA, Z. Levay (STScI) and A. Fujii

Activity 1: What constellations do you recognise?

Step 1:

Sit in a circle with the students. Ask the students if they know what stars are.

Step 2:

Explain that you can see the stars best at night. Stars give light but during the day, the Sun, our star, gives so much light that we cannot see the others.

Step 3:

Place the drawings of the constellations on the worksheet in the middle of the circle. From top to bottom the constellations shown are: Leo (lion), Pisces (a pair of fish), and Scorpio (scorpion).

Step 4:

Encourage the students to describe what figures they can see in the stars. Explain that we call these figures constellations.

Step 5:

Look at each constellation and describe what it is supposed to look like and what it is called. Explain that long ago, people thought this was what the constellations looked like if you joined up the stars.

Activity 2: Make a star lantern

Step 1:

Give each child a sheet of A3 card with a copied constellation, an embroidery needle and a thick layer of newspaper.

Step 2:

Ask the students to prick holes in the points of the star sign, using the layers of newspaper as a pad under the card. Encourage them to prick big holes, or the light won't shine through them clearly.

Step 3:

Roll the card to form a cylinder and staple the edges together.

Step 4:

Make two holes at the top and tie a piece of string across.

Step 5:

Hang the lantern on the stick and use a piece of string to hang the lamp inside the lantern. The lanterns are ready.

Tip: Encourage the children to make small balls of crepe paper. They can paste these onto their lantern, but make sure they don’t cover the holes. When the children have finished decorating the card, put the lanterns aside to dry. You can paste coloured tissue paper on the inside of the lantern for a nice effect.

Activity 3: Let the stars shine

Step 1:

Turn off the lights and/or close the blinds in the classroom.

Step 2:

Ask the students to switch on their lantern lights.

Step 3:

Ask them what they can see on their lantern.

Step 4:

Explain that the spots of light on their lantern form a constellation. The lights are the stars. Optional: Take and print a photograph of each child with their lantern. Can you recognise the constellations on the photographs? Compare the constellation with a real picture of the sky. You can show pictures of other famous and bright constellations.

Step 5:

Explain that we cannot always see the same constellations; some are not visible during the whole year. This is because the Earth is spinning and moving around the Sun. This gives us the impression that the stars are moving.

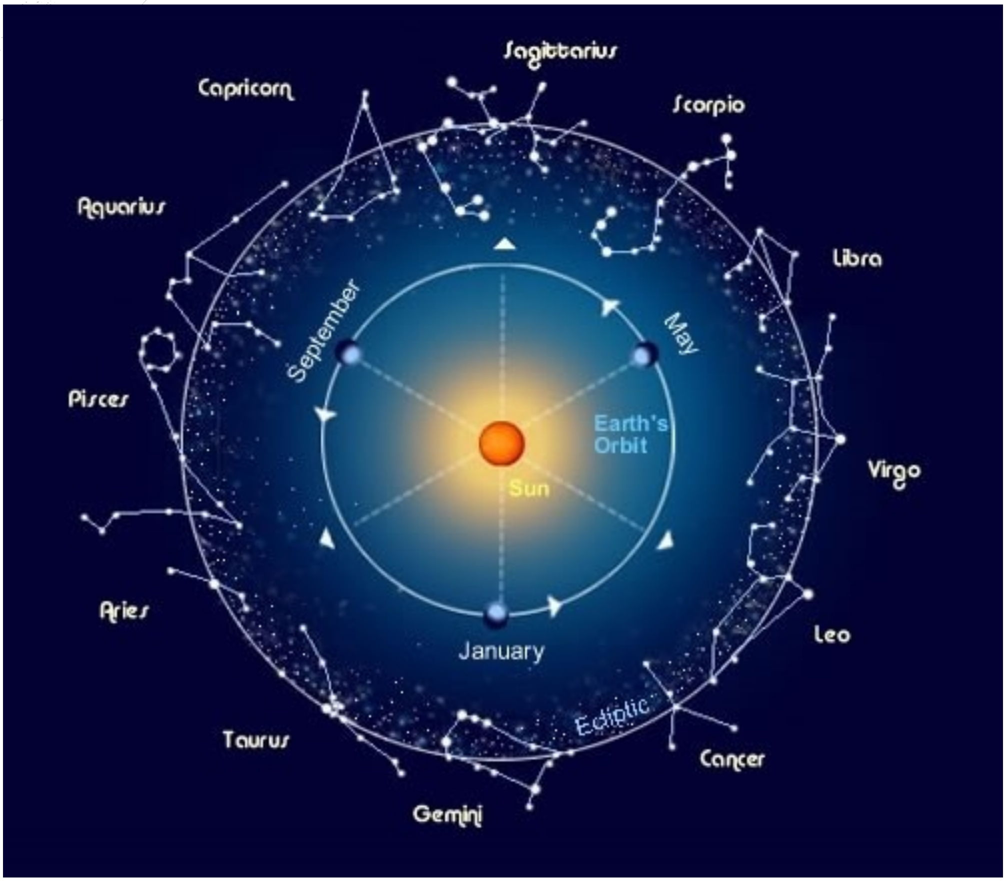


Image: Illustration of the 'zodiac band' with a few of the constellations depicting the objects they represent. Credit: LPI USRA

Design your own constellation

Step 1:

The students use luminous paint to paint their own constellation on paper or on a sky map. They can make it any shape they like. They can use existing stars on the sky map or draw their own on white paper.

Step 2:

Explain that they can paint spots (to represent the individual stars), or they can choose to make a drawing of the constellation using the luminous paint. Let the paintings dry on the windowsill or near the radiators.

Step 3:

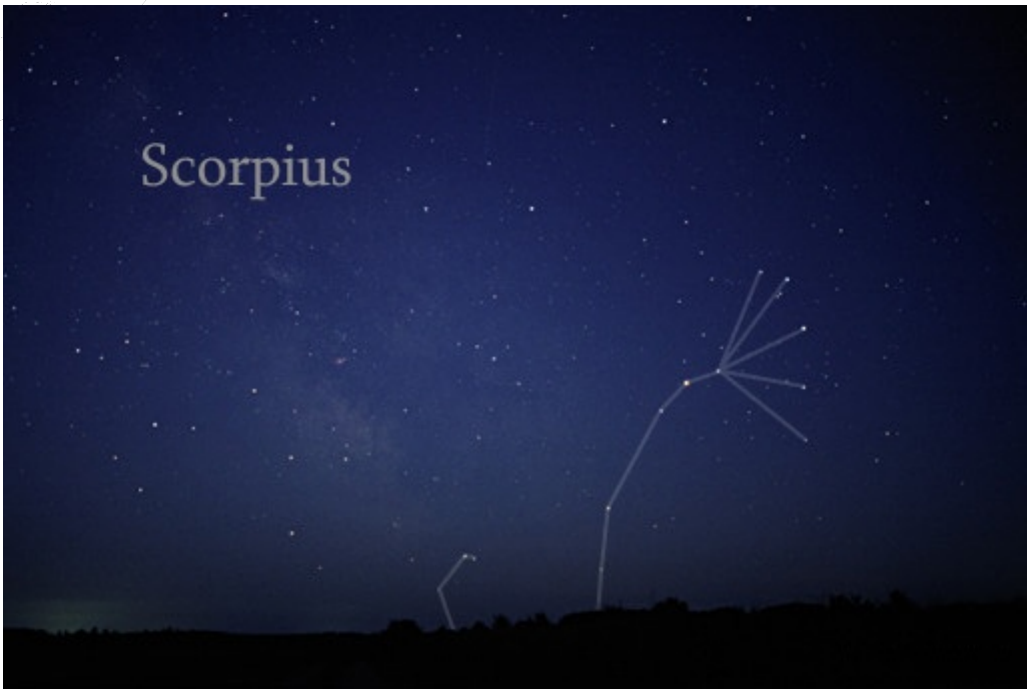
Once the paintings are dry, make it dark in the classroom. Encourage the students to show their constellations, give them a name, and say what they represent.

Step 4:

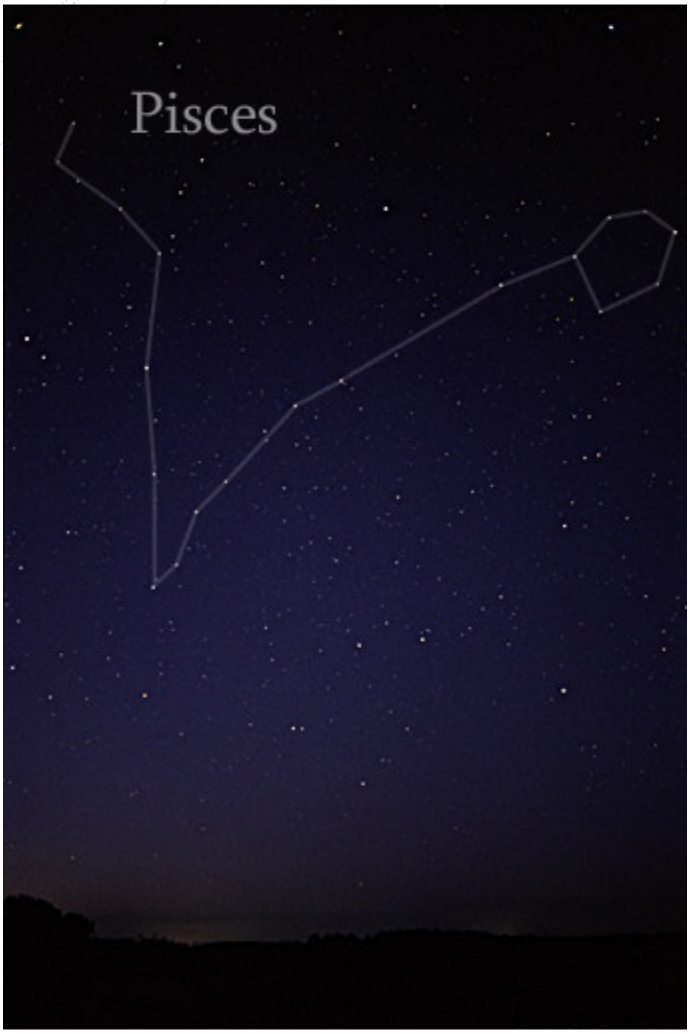
Show a picture of the night sky at the end of the activity, ask students if they recognise or can find a constellation.

Step 5:

Encourage the students to look at the real night sky at night and find constellations.
Safety note: this activity uses embroidery needles for building the lanterns and requires supervision.


Scorpius


Leo



CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, stars, constellations

Space Awareness curricula topics (EU and South Africa)

Our Wonderful Universe, stars, constellations

National Curricula UK

KS1 - Art and Design: use drawing, painting, and sculpture to develop and share their ideas, experiences, and imagination.

ADDITIONAL INFORMATION

To check if the constellations discussed during the activity are visible in the sky at the time of the activity, you can download free software like Stellarium, http://stellarium.org/. The more famous and bright constellations could be used, e.g., Cassiopeia, Ursa Major, Orion, or Cygnus.

CONCLUSION

Students build a star lantern. By implementing this activity, students learn that people have created constellations. They learn that a constellation is composed of different stars and can recognise some of them.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement nº 638653

HISTORY OF THE UNIVERSE

Build a timeline to discover the relative ages of the Universe, the solar system and the appearance of humans, on the scale of a year.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
the origins of the Universe

Big idea of science
Earth is a very small part of the universe.

Keywords
Universe, Earth, Mathematics, Timeline

Age range
8 - 10

Education level
Primary School, Informal

Time
1h30

Group size
None

Supervised for safety
Supervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Using mathematics and computational thinking, Communicating information

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

Students investigate how old the universe is and when important events took place in the universe and on Earth. They draw the universe timeline from the beginning until today on the scale of a year.

GOALS

During the activity, students create a timeline showing various events from the beginning of the universe to the present day. They learn about the relative ages of the universe, the Earth, and the existence of humans on the planet.

LEARNING OBJECTIVES

Implementing the activity, students will be able to:

- explain that the universe is very old,
- explain that the Earth was created relatively recently compared to the age of the universe,
- discuss that humans have been on the planet for a relatively short time, compared to the age of the Earth,
- practise maths skills by converting between time units, using scales and division to create their timeline.

EVALUATION

Ask students to explain the order of important events in the universe and on Earth, and how long ago they occurred. They should be able to explain that the universe is very old, that the Earth came into existence relatively recently and that people have only lived on the planet for a relatively short time. Has the students' concept of 'old' changed?

Optional: Ask students to calculate the difference between two times: e.g. how many years older is the birth of the solar system than the appearance of humans on Earth.

MATERIALS

For each group of three students:

- craft paper
- calculator or squared paper
- scissors
- glue
- colouring pencils (or other medium of colouring e.g.: water colours, pens, paint)

For each student:

- Worksheet PDF
- Pencil or pen

For the class timeline:

- 12 sheets of A4 paper, plain or coloured
- 1 sheet of coloured A4 paper for clock

BACKGROUND INFORMATION

Earth

Earth is our home and the third planet from the Sun. With a mean distance between the Sun and Earth of 150 million kilometres, the average surface temperature is above the freezing point of water (0 degrees C). Unlike on Venus or Mars, whose surface temperatures are either much warmer or colder, this means that liquid water can exist freely on Earth. This has played a fundamental role in the development of life on our planet. Earth only has one natural satellite, the Moon, which is thought to have played a major role in stabilising the axis of rotation of the Earth. Once again, this may have been a favourable element in the emergence of life.

One billion years after the Sun and Earth formed, around 3.8 billion years ago, the first known life on Earth emerged: single-celled organisms such as bacteria. One billion years later, multicellular life appeared, though not in forms we would recognise today. Insects and then fish began to evolve around 500 million years ago, and dinosaurs and then mammals around 200 million years ago. 65 million years ago, the extinction of the dinosaurs occurred, and the number of mammals increased. By comparison humans (Homo sapiens) are very recent, emerging only 200,000 years ago.

Universe

The universe is the vast expanse of space which contains all of the matter and energy in existence.

The universe contains all the galaxies, stars, and planets. The exact size of the universe is unknown. Scientists postulate that the universe is still expanding outward: the result of a violent, powerful explosion that occurred about 13.7 billion years ago. This explosion is known as the Big Bang. By looking at the change in colour of light (its electromagnetic spectrum) from an object, scientists can determine if an object is moving away from or towards Earth. If the colour of light from an object is shifted towards red, it is moving away from us. The more redshifted the light, the faster it is moving away from us. All of the distant galaxies have tremendous redshifts. Based on these data, scientists postulate that the universe is still expanding outward.

Image: NASA ESA STScI (S. Beckwith) HUDF Team

FULL ACTIVITY DESCRIPTION

Preparation

For the activity you will need a timeline made from 12 sheets of A4 paper. Each sheet of paper represents one month. Divide the month of December into 31 squares. These are the days. Number the days 1 to 31. On a sheet of coloured A4 paper, draw a section of a circle and divide it into 10 equal parts. This represents the last 10 minutes of December. Display the timeline, together with the section of the circle, on the wall in the classroom, preferably within reach of the students.

Activity 1: What is a year?

Step 1:

The students complete Task 1 on the worksheet.

Step 2:

Explain briefly what a year is. Ask if every year is the same length of time.

Step 3:

Discuss the following questions: How old is old? Is a father old? And a grandfather? Father Christmas? An antique chair?

Step 4:

Discuss with the students how far back in time we know about. Explain that most of what we know about long ago comes from written sources. Everything that we know about the time before people learned to write has been deduced by scientists on the basis of research, such as archaeological digs.

Step 5:

The students will investigate how old the universe is and when important events took place in the universe and on Earth.

Activity 2: Timeline of the universe

Step 1:

Draw the students' attention to the timeline. Ask students if they know what the universe is. Explain that this timeline shows time from the beginning of the universe to the present day. Now look at the section of the circle and explain that this shows the last ten minutes in the year.

Step 2:

Organise the students into groups of three. Give each group a calculator or a sheet of squared paper.

Step 3:

The students complete Tasks 2a to c. Help them to complete the table. Explain how to calculate how long a month on the timeline is in reality (15 billion years divided by 12 months = each month on the timeline is 1.25 billion years in reality). You can find the answers in the list below. The students will need this information for the next task.

Time on timeline	Time in reality
1 year	15 billion years
1 month	1.25 billion (1250 million) years
1 week	300 million years
1 day	43 billion years
1 hour	1.8 million (1,800,000) years
1 minute	30,000 years
1 second	500 years

Good to know

According to the Big Bang theory, the universe was "born" around 13.7 billion years ago (however, in the remainder of this exercise we will say that it was born 15 billion years ago, for ease of calculation). After this, the universe developed, the galaxies (including our own, the Milky Way) were formed, the Sun was born, and the Earth took shape. The various geological eras passed, and life as we know it today evolved from the first living organisms. On the timeline the students will be making, the Big Bang took place at 00.00 on 1 January. Earth was born in September, and the first humans appeared on 31 December at 23.57.

Time on timeline	Time in reality	Event
1 January	15 billion years ago	beginning of the universe
early January – mid-march	12 – 14.7 billion years ago	birth of solar systems
early September	5 billion years ago	birth of Sun and planets
end of September	3.8 billion years ago	emergence of first life forms
25 December	225 million years ago	mammals appear on Earth
29 December	65 million years ago	extinction of dinosaurs, more mammals appear
30 December	5 million years ago	first ancestors of man appear
31 December 23.53.00	195,000 years ago	Homo Sapiens appears
31 December 23.59.52	4300 years ago	building of Stonehenge
31 December 23.59.59	around 400 years ago	invention of the telescope

Step 4:

Give each group a specific event to investigate. The third column of the above table shows eleven events that can be shared among the groups.

Step 5:

The groups complete Tasks 2d to j. The students calculate the point on the timeline at which their event took place. Before they begin, discuss the example on the worksheet.

Step 6:

For Task 2k hand out craft paper, colouring pencils, glue and scissors. Encourage the students to make something associated with the event they have just investigated and paste it in the correct place on the timeline.

Activity 3: How old is old?

Step 1:

The students complete Task 3 on the worksheet.

Step 2:

Discuss the answers and the timeline. Explain that the entire timeline covers a span of 15 billion years. So one second on the timeline actually represents 500 years! Come to the conclusion that the universe is very old, that the Earth came into existence relatively recently and that people have only lived on the planet for a really short time.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, the origins of the Universe

National Curricula UK

KS1, History, Art and Design KS2: Year 5, Maths KS2: Year 6, Maths KS2: Year 6, Science

CONCLUSION

During the activity, students build a timeline showing various events from the beginning of the universe to the present day. Students learn that the universe is very old and that the Earth and humans appeared relatively recently.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement nº 638653

LIVING IN THE MILKY WAY

Build a model of the Milky Way to discover the size of our galaxy and what it contains.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
Galaxies

Big idea of science
Earth is a very small part of the universe.

Keywords
Galaxy, Milky Way, Solar system, stars

Age range
6 - 10

Education level
Primary School, Informal

Time
1h30

Group size
None

Supervised for safety
Supervised

Cost
Expensive (> 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Communicating information

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

During the activity, students build a model of the Milky Way and develop an understanding of the objects contained in the Milky Way and of the distances between these objects.

GOALS

The activity introduces our galaxy, the Milky Way, to students. They learn what the Milky Way looks like and what objects it contains through building a model of the Milky Way. Students watch a video to gain an idea of the distances in the Milky Way and answer questions on the worksheet.

It is important for students to know about the Milky Way because our Solar System is located in this galaxy. Moreover, galaxies as a whole are very important in the study of how the Universe formed and how it evolves.

LEARNING OBJECTIVES

After implementing the activity, students will be able to:

- describe what the Milky Way looks like,
- identify the position of our Solar System in the Milky Way,
- explain that the Milky Way contains dust, gas, and lots of stars,
- explain that the Earth and the Milky Way are very tiny compared to the universe,
- describe where the name Milky Way comes from.

EVALUATION

After students have made their models, offer descriptions of different objects in the Milky Way and ask students to point them out on their models. Can they locate where the Solar System is? Ask students how big the Milky Way is and how this compares to the size of the Solar System. Ask students to explain where the name Milky Way came from.

Another way to evaluate students' knowledge is to ask them to compare the Milky Way with images of other galaxies (classification).

Students can also be invited to think how the Milky Way moves and to imagine how we know its size. Some methods used to infer the size of the Milky Way are included on this website: http://imagine.gsfc.nasa.gov/features/cosmic/milkyway_info.html

More traditional methods, i.e. matching terms with their explanation or filling in the blanks of a text with the appropriate words can also be useful.

MATERIALS

Per student or model:

- worksheet in PDF
- 1 sheet black A4 card
- drawing compass
- scissors
- white paint
- red paint
- paintbrush
- cotton wool
- glue
- red clay
- 5 cocktail sticks
- fishing line

As a class:

- computer with internet
- powers of Ten video on YouTube (https://www.youtube.com/watch?v=0fKBhvDjuy0)

BACKGROUND INFORMATION

The Milky Way:

Our home Galaxy consists of about 200 billion stars, with the Sun being a fairly typical specimen. The Milky Way is a fairly large spiral galaxy and it has three main components: a disk, in which the Solar System resides, a central bulge at the core, and an all-encompassing halo.

The disk of the Milky Way has four spiral arms and it is approximately 300 parsecs thick (1 parsec is approximately 3.26 light-years) and 30,000 parsecs in diameter. Compare this to the four hours it takes light to travel from the Sun to Neptune! Our Galaxy is made up predominantly of Population I stars, which tend to be blue and are reasonably young, spanning a million and ten billion years in age.

The bulge at the centre of the Galaxy is a flattened ellipse of 1000 parsecs by 6000 parsecs. This is a high-density region where Population II stars predominate- stars that tend toward red and are very old: about 10 billion years. There is growing evidence for a very massive black hole at its centre.

The halo, a diffused spherical region, surrounds the disk. It has a low density of old stars mainly in globular clusters (consisting of between 10,000 and 1,000,000 stars). The halo is believed to be composed mostly of dark matter, which may extend well beyond the edge of the disk.

Light-year:

A light-year is how astronomers measure astronomical distances and it is equivalent to the distance that light travels in one year, nearly 9.46 trillion kilometres.

Black holes

Black holes are the monsters of space! Anything that gets too close to a Black Hole is pulled to it with such a strong force that it has no chance of escape. The monster will gobble it up! Even light – the fastest thing in the Universe – is doomed if it goes near one of these monsters. This is why black holes are black. However, they are not really holes and they are not empty. Black Holes are actually filled with a lot of material that is crammed into an extremely small region.

Dark Matter

According to scientists roughly 80 per cent of the mass of the universe is made up of material that they cannot observe directly. This material, known as dark matter, does not emit light or energy.

Classification of Galaxies:

There are two main categories of galaxies, the spiral and elliptical, and two others lenticular and irregular.

Our Galaxy belongs to the spiral category. Spiral galaxies fall into several classes depending on their shape and the relative size of the bulge: ordinary spirals are labelled either Sa, b, c, d, or m while those that have developed a bar in the interior region of the spiral arms are labelled SBa, b, c, d, or m. Spiral galaxies are characterised by the presence of gas in the disk, which implies that star formation is active at the present time, hence the younger population of stars. Spirals are usually found in a low-density galactic field where their delicate shape can avoid disruption by tidal forces from neighbouring galaxies.

Elliptical galaxies are placed in categories E0-7 depending on their degree of ellipticity, with E0 being least elliptical. They have a uniform luminosity and are similar to the bulge in a spiral galaxy, but with no disk. The stars are old and there is no gas present. Ellipticals are usually found in a high-density field, at the centre of clusters.

Lenticulars are labelled S0 and, although they possess both a bulge and a disk, they have no spiral arms. There is little or no gas and so all the stars are old. They appear to be an intermediate.

Irregulars are small galaxies, labelled Irr, with no bulge and an ill-defined shape.

Tidal forces

These forces are a secondary effect of the gravitational forces between two objects orbiting each other, such as the Earth and the Moon. Tidal forces are responsible for the fluctuation of the tides as well as for the synchronous rotation of certain moons as they orbit their planets.

FULL ACTIVITY DESCRIPTION

Tip: You can see the Milky Way with the naked eye. You can see it best in January when the Moon is new. Encourage the students to look for this if possible.

Preparation

For the activity Further and further away use the link provided in the materials to access Powers of Ten on youtube. Watch this video and pay attention so that you know precisely when each question is discussed. Prepare to show the film to the class. During the first six minutes, scales from 1m to beyond the scale of clusters of galaxies are shown.

Activity 1: Further and further away

Step 1:

Read the e-mail in Task 1 of the worksheet with the students. The students need to find answers to the following questions from the researchers:

- What does the Milky Way look like?
- Whereabouts in the Milky Way is our Solar System?
- Why can't we see the whole Milky Way from Earth?
- Is Earth large or small compared with the universe?
- Is the Milky Way large or small compared with the universe?
- What is the Milky Way made of?

Step 2:

Watch the film Powers of Ten with the students in order to find the answers to the researchers' questions. This film shows a journey from a picnic in a grassy meadow in America to a location far beyond the Milky Way. Halfway through the film the journey returns to the grassy meadow and into the hand of one of the picnickers. You are recommended to play the film until the journey returns to the picnic field so that the students get a good impression of the immense size of the universe, and just how tiny the Earth is in comparison.

Step 3:

Start by watching the whole film with the students. Explain what they are seeing. Then watch the film again, but this time pause it where relevant to give the students the opportunity to answer the research questions. After they have seen the film, the students will be able to answer questions a to e. Once they have completed the "Make a Milky Way" craft project, the students can answer the final question.

Step 4:

The students investigate what the Milky Way looks like and its position in the universe in relation to our Solar System.

Activity 2: Make a Milky Way

Now the students have some idea of what the Milky Way looks like, they are going to make a model of it. The students complete Task 2 on the worksheet.

Activity 3: What do you know about the Milky Way?

The students read the instructions in Task 3 and write all the answers to the research questions in the e-mail in Task 1. If necessary, watch the film Powers of Ten one more time. Discuss the answers in the e-mail.

- If we could view the Milky Way from the side, it would look like a saucer with a bulge in the middle.

- The Earth's solar system is situated on a spiral arm about two-thirds of the way from the centre of the Milky Way.
- We don't have any telescopes that can reach far enough out from the Milky Way to take a good photograph of it as a whole. The existing pictures of the Milky Way look like real photographs, but are in fact an artist's impression of what we think it looks like. Explain that it is possible to see part of the Milky Way disc at night when the sky is dark. It is easy to photograph the Milky Way disc from Earth, because this is the part we can see.
- The most important aspect of this question is that the students see that our Solar System is only a tiny part of the Milky Way.
- Here again, the Milky Way is only a tiny part of a much larger universe.
- The Milky Way is a galaxy made up of dust, gas, and at least 200 billion stars, most of which can be found in the disc. The system contains old stars, younger stars, dust, and gas clouds. It is composed of a central bulge and a disc with four large and several smaller spiral arms.

Good to know:

It takes 8 minutes for light from the Sun to reach Earth. It takes much longer for light from the other stars to reach Earth. So when we look at the universe we are really looking into the past. The mass of the universe is estimated to be 100 billion times greater than the mass of the Sun.

Activity 4: The name Milky Way

Ask the students if they know where the name Milky Way comes from.

Egyptian mythology describes the Milky Way as being formed by the milk from a celestial cow. The four feet of the cow were supported by the four corners of the Earth. Greek mythology tells the story that Hera, the wife of Zeus had been given the baby Heracles to breastfeed. When she realised he was not her own child, she pushed him away. The milk that was spilled became the Milky Way.

It is important that the students realise that long ago people had no idea what the Milky Way really was.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Galaxies

National Curricula UK

KS2: Year 5, Maths: Number – number and place value: count forwards or backwards in steps of powers of 10 for any given number up to 1 000 000.

KS1, Art and Design: To use drawing, painting and sculpture to develop and share their ideas, experiences and imagination.

KS1: Year 1, English: Reading- comprehension: develop pleasure in reading, motivation to read, vocabulary and understanding by: listening to and discussing a wide range of poems, stories and non-fiction at a level beyond that at which they can read independently.

ADDITIONAL INFORMATION

What Part Of The Milky Way Can We See? https://www.youtube.com/watch?v=pdFWbEwsOmA

Explore the different shapes of galaxies by contributing to the citizen science project "Galaxy Zoo": http://www.space-awareness.org/en/games/galaxy-zoo/

CONCLUSION

This activity helps students to learn what the Milky Way looks like and the objects it contain. They also gain an idea about the distances involved, and the place of the Solar System in our Galaxy. During the activity, students build a model of the Milky Way.

ASTROEDU

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

MAKING A SUNDIAL

Build a sundial and discover how time can be measured.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
Instruments for Navigation

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet.

Keywords
Time, Sun, navigation, Babylonians, cultures

Age range
6 - 10

Education level
Primary School, Informal

Time
1h

Group size
None

Supervised for safety
Unsupervised

Cost
Average (5 - 25 EUR)

Location
Outdoors

Core skills
Asking questions, Developing and using models, Analysing and interpreting data, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

In this activity, students discuss the notion of time and how time can be measured. They learn that a long time ago, people used different tools to measure time. Students build and use a sundial and discover that a long time ago, it was much more difficult to accurately tell the time than it is today.

GOALS

Students build a sundial to measure time. They explain how a sundial works with sunlight. They tell the time using a sundial and compare the accuracy and precision of this method with modern ways of telling time.

LEARNING OBJECTIVES

After implementing the activity, students will be able to:

- name different instruments used to tell the time;
- explain how a sundial works with sunlight;
- demonstrate how to tell the time using a sundial.

EVALUATION

- At the beginning of the activity, ask students if they know how to tell the time and what instruments they know that can measure time.
- Ask students to describe what happens to the position and size of the shadow on the sundial over the course of a day.
- Ask students to explain why the position of the Sun changes during the day. Encourage students to illustrate their explanation by drawing or demonstrating the Earth’s rotation on its axis and position of the Sun at different times of a day.

- Ask students to read the time with the sundial at different times of the day and to compare their reading with a modern way to tell time (e.g., a watch or clock).

MATERIALS

- 12 large stones
- scissors
- glue
- 150-centimetre long stick (approx.)
- a large protractor
- a marker pen
- a compass to tell where North is
- 1 worksheet per student

Optional:

- extra small stones
- equatorial sundial (PDF)

BACKGROUND INFORMATION

Sun

The Sun is a star, a ball of burning gas that emits light and heat. It is a rather ordinary star, not particularly big or small, not particularly young or old. It is the source of heat that sustains life on Earth, and controls our climate and weather. It is the closest star to Earth, and the most closely studied. From it we have learned a great deal about the physical processes that determine the structure and evolution of stars in general.

Observing the Sun

Looking directly at the Sun, even for a brief moment, is a bad idea — our eyes are very sensitive to its light. Even in the dark, at least when there is only the tiniest amount of light, your eyes still manage to detect things. So imagine what happens when you focus all that bright light from the Sun on a tiny area like the eye. The light detectors at the back of the eye get burned. Unfortunately, unlike a sunburn on your skin, your eye probably won't recover and you could lose your sight.

If you would like a very visual demonstration of how damaging the Sun can be, have a look at Stuart Lowe's astronomy blog http://www.strudel.org.uk/blog/astro/000347.shtml. He has made a video of what happens when a grape is put up to the eyepiece of a telescope that is pointed directly at the Sun, with no filters. Very quickly the grape begins to blacken and burn.

The eye is much more delicate than a grape so the demonstration is quite a powerful reminder to be careful when looking at the Sun. So, please, no matter what, do not look directly at the Sun.

Sundial

During the daytime we notice that time passes by because of the Sun in the sky. Because the Earth completes a rotation on its axis in one day, the Sun appears to rise in the east at the beginning of the day, climb high at noon and then disappear into the horizon in the evening in the west. Babylonians observed this movement of the Sun and constructed the sundial, which was the first version of a wall clock or a hand watch. Using sunlight and the sundial, the Babylonians divided the day into hours.

The time on a sundial is shown by a shadow produced by a gnomon, and falling onto a surface called the dial face or dial plate. Due to our relative locations to the Sun, a sundial used in the northern hemisphere must be reversed to be used in the southern hemisphere.

Different types of sundial exists. The shadow can be cast on the ground, creating a horizontal sundial, or it can be cast on a wall, creating a vertical sundial. The lines showing the hours will be different depending on the latitude of the location. If you use a sundial at the north pole in summer, hourly marks would have a separation of 15 degrees. One day equals 24 hours, and one rotation divides into 360 degrees. Therefore, 1 hour on a sundial is represented by 15 degrees of rotation.

An equatorial sundial has a dial plate parallel to the Earth's equator. The gnomon should be perpendicular to the dial plate so it is inclined at an angle equal to the latitude of the observer and points towards true north. The hour lines are spaced at 15 degrees.

Image: Equatorial Sundial example

FULL ACTIVITY DESCRIPTION

Preparation

For the activity 'The large sundial', you will need a playing field that is in sunlight most of the day.

What time is it?

Ask if any of the students are wearing a watch. Why is it handy to have a watch? Explain that 600 years ago nobody had a watch. Ask how the people back then knew what time it was. Before the mechanical clock was invented, it was much more difficult to know the time of the day. People found out that they could use the Sun to tell the time. They did this using a sundial.

Long ago people also used other devices to tell the time, such as an hourglass.

Ask if any students have ever seen a sundial? Do they know how it works? Explain that a sundial has a stick or pointer that makes a shadow. This is called the gnomon. It is important that in the Northern Hemisphere, the gnomon always points north, or you will not be able to read the sundial. Explain that the Earth turns on its axis. This means that the position of the Sun with regard to the Earth is always changing. If necessary demonstrate this using a torch and an orange or globe. Explain that the shadow of an object also changes as the Earth rotates. The sundial uses this fact. By looking at the position of the shadow of the gnomon on the sundial, you can tell what time it is.

The students make two sundials.

Good to know: when the Sun is due south and the shadow is pointing to the north, it is noon. That means it is exactly 12 o'clock in solar time. Solar time is not always exactly the same as the time shown on your watch. That is because the time we use today is not based on the Sun's actual position in the sky.

Make a sundial

Hand out scissors, glue, and the activity sheet.

The students complete Task 1 on the worksheet.

Important: To calculate the angle for the gnomon, you need to know the latitude of your town. You can look this up in an atlas or on the internet. For example the latitude of London is 51 degrees N, so the angle needed for a sundial in London is 51 degrees. The instructions are on the worksheet. When the sundial is ready, the students should put it somewhere with the arrow facing south.

The students read the time shown by the sundial. Can they see what time it is? The students complete Task 1 on the worksheet. Discuss the tasks. Come to the conclusion that today we always know exactly what time it is because there are so many clocks around us. Long ago, when there weren't any watches and clocks, it was much more difficult to tell the time. And of course they could not use a sundial at night!

Good to know: this sundial is based on GMT+1. This may need adjusting depending on your local time. For example, in the UK, this would match British Summer Time, but for wintertime every hour number would need to be one hour earlier. So 12 would be 11, 1 would be 12, etc. If you are making it in Central European Summer Time (GMT+2), you will need to change the numbers. Every hour number will need to be one hour later. So will be 1, 1 will be 2, etc.

The large sundial

Make a large sundial with the students. Take the students outside to a location where the Sun shines most of the day. Mark the direction of north, using a compass if necessary.

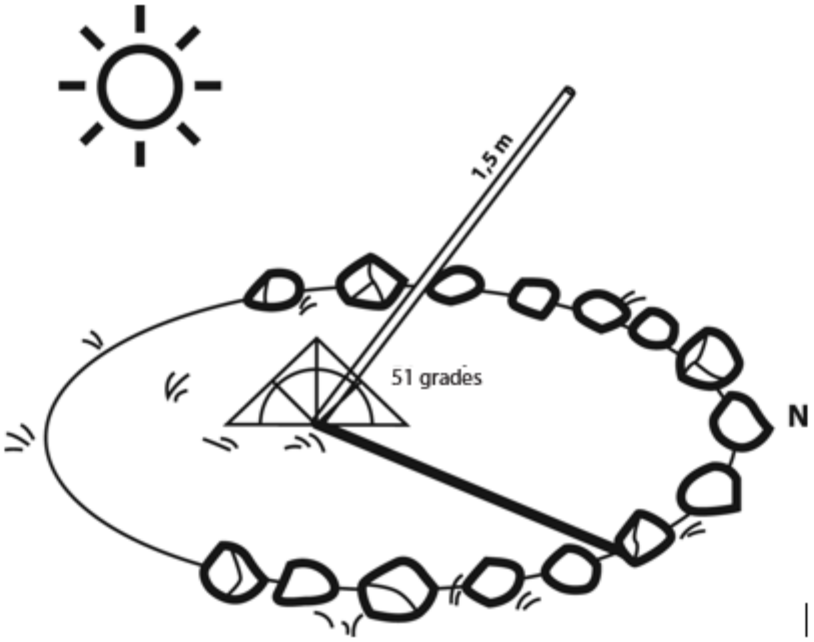
Stand the large protractor upright on its long side in the grass. Use it to measure the correct angle to the ground, as described above. Stick the stick firmly in the ground at the chosen angle, facing north. See the picture for how this should be done.

Every hour the students place a large stone on the ground where the shadow of the stick falls. One of the students uses the marker pen to write the number of the hour on the stone. You can use the smaller stones to mark the quarter and half hours.

Image: Horizontal Sundial

If you don't want to take the students outside every hour, you can just place two stone markers, one in the morning (for example at 9.00) and one in the afternoon (for example at 14.00). Of course your sundial will be less accurate.

To finish the sundial, the rest of the day after school-time needs to be divided using the stones. In the example shown below, five hours have passed and so the time in between needs to be divided into five. Encourage the students to write the numbers of the hours on the stones and place them in the correct position. The next day, take the students outside to see if they can read what time it is. They compare the time they read on the sundial with the time shown by a watch.



How accurate is their sundial? Discuss that long ago, it was more difficult and less precise to tell the time than nowadays.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Navigation through the ages, Instruments for Navigation

Space Awareness curricula topics (EU and South Africa)

Navigation through the ages, instruments

National Curricula

KS1: Year 1 - Maths, measurement: measure and begin to record time. KS2: Year 5 - Science, Earth and Space: use the idea of the Earth's rotation to explain day and night and the apparent movement of the Sun across the sky.

CONCLUSION

In this activity, students discuss the notion of time and how time can be measured. They build and use a sundial. The activity allows students to learn that you can tell the time using the Sun with a sundial and discover that a long time ago, it was much more difficult to tell the time than it is today.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

WHAT IS TIME?

Build an hourglass to understand what time is and how to measure it.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
basic concepts of time, instruments

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet.

Keywords
Time, hourglass

Age range
6 - 10

Education level
Primary School, Informal

Time
1h

Group size
Group

Supervised for safety
Unsupervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Planning and carrying out investigations

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

In this activity, students discuss the notion of time and how time can be measured. They build an hourglass to measure time and test it. This activity will allow students to have a better understanding of time and the instruments that can be used to measure it.

GOALS

The goal of the activity is for students to understand what time is and how to measure it.

LEARNING OBJECTIVES

After implementing the activity, students will be able to:

- name instruments you can use to measure time;
- list different units of time;
- design and make an instrument to measure time and discuss its limitations.

EVALUATION

- Have students fill in the worksheet provided with the activity. Look at students' hourglass designs.
- After the activity, ask students if and why they think it is important to be able to measure time accurately.
- Ask the students to list the units of time they know and the instruments that allow us to measure time.
- After performing experiments to measure time, ask students to suggest the advantages and disadvantages of using hourglasses to measure time.

MATERIALS

To make an hourglass per pair of students:

- Two small light bottles of the same size
- Stopwatch
- A piece of cardboard slightly larger than the mouth of the bottle
- Scissors
- Sticky tape
- Sand (enough to nearly fill a bottle)

Per student:

- Worksheet printout
- Pencil

BACKGROUND INFORMATION

Time allows us to order events from the past to the present to the future. Time is also the measure of duration between two given events. Many instruments have been invented to measure time. One of the first instruments to give the time was the sundial, which used the sun's motion.

Another instrument is used in the activity. The hourglass measures the passage of time. An hourglass is made of two different compartments, often glass bulbs, connected by a narrow tube, allowing sand or other material to go from the upper to lower compartment at a constant speed—thus in a given time. An hourglass works by gravity pulling on the sand so that it falls downwards. Nowadays, we can use a stopwatch to measure the time between when it is activated and when it is deactivated.

FULL ACTIVITY DESCRIPTION

Preparation

To make an hourglass you will need to make sure the sand is dry. The bottles also need to be dry and not too heavy. Make sure the mouths of each pair of bottles are the same size. Place the materials for the hourglass (bottles, pencils, pieces of card, scissors, sticky tape, and sand) ready at the front of the classroom.

Activity 1: How long does a minute last?

Step 1

Ask the question: What is time? Can you tell what time it is without agreeing on some things beforehand?

Step 2

Organise the students into pairs. Explain that they are going to see how long 1 minute takes. Give student 1 a stopwatch. Student 1 gives a signal when he/she starts the stopwatch. When student 2 thinks that 1 minute has passed, he/she gives a signal and student 1 stops the stopwatch. How much time does the stopwatch show?

Step 3

Explain that they are going to repeat the experiment. Now they have to think of a way to help them make a more accurate estimate of when 1 minute has passed. They could count, or draw lines. Encourage the students to try out their suggestions; then discuss how successful the experiment was. Were they able to make a better estimate the second time? What did they use to help them?

Step 4

The students complete Task 1 on the worksheet.

Step 5

Ask why they think it is important to know how much time has passed. And why is it important to make agreements about time? Come to the conclusion that it is important that everyone uses the same definition when they refer to time. This makes sure we arrive on time for an appointment, for example.

Step 6

Ask the question: 'What ways of measuring time do you know?' If necessary, add the following to their ideas: stopwatch, looking at the position of the sun, or using an hourglass (egg-timer).

Activity 2: Make an hourglass

Step 1

Explain that an hourglass works by gravity pulling on the sand so that it falls downwards. Gravity pulls objects towards the centre of the Earth. This happens at a constant speed when we consider a small distance like in an hourglass, so an hourglass is a reliable way to measure time.

Good to know: long ago sailors used an hourglass to ring the ship's bell every hour and half hour. Doctors used a 15-second hourglass to measure their patients' pulse.

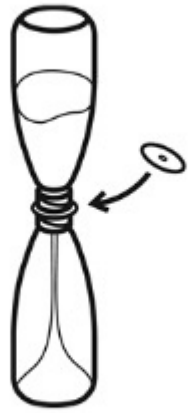
Step 2

Organise the students into pairs. The students examine the materials you have prepared at the front of the classroom and decide how they will use these to make their hourglass. Give each pair of students a pencil. Assist them by asking what an hourglass looks like. What is inside it? And how can this 'flow'? The students complete Task 2 on the worksheet, up to step 5.

Step 3

An example of how you could make an hourglass: cut out a cardboard circle that fits between the mouths of the two bottles.

Make a small hole in the centre of the card. Pour some sand in one of the bottles. Place the card on the mouth of the bottle, and place the second bottle upside down on the first. Stick them together at the middle using sticky tape. Make sure that the bottles used for the hourglass are light to make a stable assembly.



Step 4

Look at the drawings showing the students' ideas. Do they look like they will work? Ask the students how much sand they will use, how large will they make the hole in the card, and how will they fix the bottles together. Note: the larger the hole, the less time it takes for all the sand to run through it. The more sand there is in the bottle, the more time it takes to all pass through the hole. This experiment will only work if the bottles and the sand are perfectly dry.

Step 5

Once the students have created a good picture of their design, they can make their hourglass.

Step 6

The students test their hourglasses to see if they work properly. The worksheet contains some tips on how they can improve their design. Now they complete step 5 of Task 2 on the worksheet. Each hourglass will take a different length of time to empty. Explain that this has to do with the size of their hole and the amount of sand they used.

Activity 3: Use your hourglass

Step 1

Take the students to the playground and encourage them to use their own hourglass to measure how long it takes them to run a certain distance. Mark a start and finish line. One student from each pair gets ready to run. The other student waits for the starting signal, and then turns over their hourglass.

Step 2

How long did it take for the student to cross the finish line? Could they measure it with their hourglass? Was there enough sand to measure the time? Ask the students to swap places and repeat the task.

Step 3

The students return to the classroom to complete Task 3 on the worksheet.

Step 4

Discuss these tasks. Come to the conclusion that it is difficult to measure the exact time with an hourglass. If the hourglass is only partially empty, you can only guess how much time has passed.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Navigation through the ages, basic concepts of time, instruments

National Curricula UK

KS1, science, working scientifically: using their observations and ideas to suggest answers to questions KS1: Year 2, science, use of everyday materials: identify and compare the suitability of a variety of everyday materials. KS2: Years 3 and 4, science, working scientifically: using results to draw simple conclusions, make predictions for new values, suggesting improvements and raising further questions. KS1: Year 1, maths, measurement: compare, describe and solve practical problems for time; measure and begin to record time. KS1: Year 2, maths, measurement: compare and sequence intervals of time. KS2: Year 3, maths, measurement: record and compare time in terms of hours, minutes, seconds; compare duration of tasks.

CONCLUSION

After implementing this activity, students acquire an understanding of what causes day and night and comprehend time difference. Students will learn about different units of time and about which instruments can be used to measure time. Students will understand that it is difficult to tell the time without an instrument and will build and test an hourglass to measure time.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

DAY AND NIGHT IN THE WORLD

Compare diurnal and nocturnal animals and experiment with day and night.

NEMO Science Museum, ESERO NL / ESA

Curriculum topic
orbit and rotation, Sun-Earth-Moon

Big idea of science
Earth is a system of systems which influences and is influenced by life on the planet.

Keywords
Diurnal and nocturnal animals, days and nights, Earth

Age range
6 - 10

Education level
Primary School, Informal

Time
1h

Group size
None

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Planning and carrying out investigations, Constructing explanations

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

This activity allows pupils to learn the difference between diurnal and nocturnal animals, understand that when it is day here, it is night on the other side of the world, and that it is light when the Sun comes up and it is dark when the Sun goes down. At the end, pupils build a model of the Earth and can experiment with day and night.

GOALS

In this activity, students investigate the differences between day and night by comparing nocturnal and diurnal animals. They use a model of the Earth to demonstrate how day and night occur on Earth and explain that people and animals living on different parts of the planet experience different times of day.

LEARNING OBJECTIVES

After implementing this activity, students will be able to:

- explain the difference between diurnal and nocturnal animals;
- demonstrate and explain that different regions of the Earth do not have daylight at the same time;
- explain that it is light (daytime) when the Sun comes up and that it is dark (night time) when the Sun goes down.

EVALUATION

At the end of the activity, students should be able to answer the questions asked in the learning objectives. The teacher can use the model of the Earth to show different lighting situations to add complementary questions such as in this situation, is it light or day in Europe? Show the orange or globe with the light on one side. Ask students to stick the pictures of diurnal and nocturnal animals on the orange or globe at the time they would be active.

Ask students where they would place themselves on the orange at the time you are doing the activity. Ask what would children living on the dark side of the orange be doing at the same time.

The teacher can use pictures of additional nocturnal and diurnal animals to expand the activity. The teacher can ask students to classify them into nocturnal or diurnal.

Students can also imagine and draw an animal living during the night. Ask them to explain how it is suited to being nocturnal.

MATERIALS

- photographs of diurnal animals (PDF)
- photographs of nocturnal animals (PDF)
- worksheet
- 24 split pins
- 2 cocktail sticks
- torch
- orange
- scissors
- A4 paper
- colouring pencils
- embroidery needles

Note: instead of an orange and pins, an Earth ball with stickers or other big balls can be used to better represent the Earth and show latitudes differences.

BACKGROUND INFORMATION

Day and night

The Earth rotates on its own axis from west to east in 24 hours and around the Sun in a year. That is why the Sun appears to rise from the East and set in the West. Only half of the globe is facing the Sun at any one time, but because the Earth rotates in 24 hours all of the Earth has faced the Sun during this time. In the part lit by the Sun, it is day. The other side of the globe is in the shadow and does not receive the light of the Sun. In this part of the Earth, it is night. As the axis of the Earth is tilted, days and nights are not equal: day and night do not last 12 hours each but their length changes over the year as the Earth rotates around the Sun and its position changes.

Nocturnal animals

By definition a nocturnal animal is an animal that is active during the night and sleeps during the day contrary to diurnal animals. Many of these animals are nocturnal to avoid the heat of the day, like desert animals. These animals have natural adaptations to help them live in the dark. They can for example have very good hearing (rabbits), smell, or eyes (owls, cats). These are natural adaptations allowing them to live or hunt during the night.

Global citizenship

Speaking about the Earth as a globe is an opportunity to give students a sense of global citizenship. We all live on the same tiny blue planet floating around in the vast emptiness of space. Everyone on this planet sees the same Moon and the same Sun in the same sky, and experiences days and nights. Dealing with astronomy is identical for any human being. The realisation that we all share this little sphere as our home and have the same experiences bonds us as a species and makes us think about how we can work together to cherish the only safe haven in space that we have.

FULL ACTIVITY DESCRIPTION

Preparation

This resource Day and Night is divided into four activities. For the activity 'Animals in the night' you will need the photographs of diurnal and nocturnal animals from the Appendix. For the activity ‘Children in the world’, cut 24 squares of paper, the same size as the square on the cut-out sheet.

Animals in the night

Sit in a circle with the students. Place the photographs of the diurnal and nocturnal animals in the middle of the circle. Ask if animals sleep at night, just like people. Which animals don't sleep at night? When are they awake?

Remove the photographs of the diurnal animals. Look at the photographs of the nocturnal animals and talk about how you can recognise a nocturnal animal. Come to the conclusion that nocturnal animals often have bigger eyes than diurnal animals so that they can see better at night. Sometimes they have adapted in other ways as well.

Nocturnal animals can be recognised by specific features, because they live in the dark. The nocturnal animals in the photographs are the bat, the owl, the hedgehog, and the panther.

Good to know Bats have such poor eyesight that they do not find their prey by looking with their eyes but by emitting ultrasonic sounds. This sound is reflected from the prey back to their ears. This tells them the distance to their prey. Owls have strikingly large eyes. This means they can see their prey clearly at night. A panther has eyes with a reflective layer. This enables them to make optimal use of the little light during the night.

Children in the world

Give each student a paper square, a pair of scissors, and colouring pencils. Students complete Task 1 on the worksheet. Read the instructions together and look at the example. Explain that they need to fold the paper into a triangle. They fold this triangle in half, and in half again. At the top of the folded paper they draw a child as shown in the example on the worksheet. Then they cut this out. Make sure the students only cut the outside of the paper (that they do not cut the centre point).

The circle in the middle of the paper should remain intact. When the paper is unfolded, the students will see a planet with a group of children holding hands all around it. Explain that this represents all the children on Earth. Get everyone to colour in two opposite children in two different colours. Explain that one child lives in Europe and the other in Australia. Australia is all the way around the other side of the world.

Day and night in the world I

Give each child an embroidery needle and a split pin. Students complete Task 2 on the worksheet. Ask them not to cut out the small black circle in the middle. The students place the square over the world with the children from Task 1. They use the embroidery needle to prick a hole in the black circle and a hole in the centre of the world from task 1. They place the square over the children of the world and fasten the two together with a split pin.

Demonstrate how it works. The students see that half of the world is covered by the semicircle. The students turn the uppermost circle around and see that when it is day for the child in Europe it is night in Australia and vice-versa. Ask where it is light when it is dark in Europe. Turn the uppermost circle a little at a time. Can the children see that it is night at a different place on the planet at each time? If it is day for the child in Europe, what is it for the child in Australia? Use this to make it clear to the students that when it is day for us, it is night on the other side of the world.

Good to know. Light always travels in a straight line. It is unable to travel around an object. The Earth turns on its own axis once in every 24 hours, and during this time the Sun only shines on the half of the Earth that is facing the Sun. On the other side of the planet it is then night. So we have day and night because the Earth turns on its own axis.

Day and night in the world II

Take an orange or a globe. Explain to the students that you are going to stick a sticker or a cocktail stick in it to show Europe and one to show Australia. Who knows where the stickers/ sticks should go? Stick a piece of tape on the stick for Europe so you can tell them apart. Take a torch and say this represents the Sun. Make it dark in the classroom so the light of the torch shows up clearly. Ask the children from which direction the torch needs to shine if it is night in Australia. And if it is night in Europe? Come to the conclusion that it is night there because the Sun is not shining on that side of the Earth.

Repeat the same steps comparing the northern latitudes in Europe, and the Arctic Circle, to Southern Europe. Show that sometimes (in Summer), northern latitudes have shorter nights than in the south. Ask students if they ever experienced that when travelling.

Emphasise what the students have learnt during this lesson by showing an entire day and night. Start with the Sun coming up. Show that the Sun makes it light in Europe. Show that this also means that it is dark on the other side of the world. It is night there. Turn the orange or globe. Show the students that at a certain moment the Sun is no longer shining on Europe. It is now night. The Sun is shining on the other side of the world. Compare this with what the students saw in Task 2.

Show the orange or globe with the light on one side. Ask students to stick the pictures of diurnal and nocturnal animals on the orange or globe at the time they would be active. Ask students where they would place themselves on the orange at the time you are doing the activity. Ask what would children living on the dark side of the orange be doing at the same time.

Explain that all humans share the same planet and that everyone on this planet sees the same Moon and the same Sun in the same sky, and experience days and nights at different moments.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, orbit and rotation, Sun-Earth-Moon

National Curricula

KS2: Year 5, Science, Earth and space: use the idea of the Earth's rotation to explain day and night and the apparent movement of the sun across the sky. KS2: Year 3, Science, Light: recognise that they need light in order to see things and that dark is the absence of light. KS2: Year 4, Science, Living things and their habitats: recognise that living things can be grouped in a variety of ways.

ADDITIONAL INFORMATION

In addition to the astronomical topic, the activity focuses on animals' lives, the location of some countries/continents on the Earth, as well as global citizenship (that is, priority 3 of the UN Secretary General's Global Education First initiative).

CONCLUSION

In this activity, students follow different steps to understand and produce cut-out worlds showing day and night. At the end of the activity, students have learnt the difference between diurnal and nocturnal animals; the fact that when it is day here, it is night on the other side of the world; and that it is light when the Sun comes up, and that it is dark when the Sun goes down.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

SPACE awareness

SEASONS AROUND THE WORLD

Demonstrate the seasons on Earth using a model.

Stephanie O'Neill, Science Foundation Ireland

SPACE awareness

Curriculum topic
seasons

Big idea of science
Earth is a very small part of the universe.

Keywords
Earth, seasons, sun-earth-moon system

Age range
6 - 10

Education level
Primary School, Informal

Time
45min

Group size
Group

Supervised for safety
Supervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Planning and carrying out investigations, Analysing and interpreting data, Constructing explanations

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

Build a model of the Earth, with its spin-axis, and a lamp as the Sun to demonstrate the concept of seasons.

GOALS

- Understanding why we have seasons and the cause of seasonal variation in temperature.
- Learning about how the Earth rotates on a tilted axis compared to its orbit around the Sun.

LEARNING OBJECTIVES

- Students learn about seasons by building a model of the Earth and the Sun, and investigating how sunlight hits the Northern and Southern Hemispheres during different seasons.
- Students explain that the same amount of light hitting the ground heats up a small area more than a large area
- Students show that the angle at which the sunlight hits the Earth influences how much the sunlight heats up the Earth.
- Students demonstrate that the angle at which the sunlight hits the Earth is related to the tilt of the Earth's rotational axis compared to the Earth's orbit around the Sun.

EVALUATION

Students should be able to answer questions related to the learning objectives.

- Why do we have seasons?
- How is the Earth's tilt related to the sunlight received somewhere on the Earth?
- Show the positions of the Earth and the Sun, and show the tilt of the Earth, when it is spring, summer, autumn and winter in the Southern Hemisphere.

- What is the difference between where the Sun is in the sky when it's summer and winter? (Sun is higher at midday in summer than in winter).

MATERIALS

Per pair of students:

- 3 cocktail sticks – other types of location indicators, e.g. stickers can be used for a ball
- 1 pen to draw on an orange
- 1 torch
- 1 orange – a ball can be used instead

Worksheet PDF (one per student)

BACKGROUND INFORMATION

When sunlight hits the Earth, it does not produce same effect everywhere on the planet. Because the Earth is round, a given amount of sunlight will cover a larger or smaller surface depending on the location we consider. The closer the Sun is to being vertical over our heads, the more it warms up Earth's surface. The Earth's rotation is not upright. The Earth's rotation axis is slightly tilted or leaning on its side by 23.5 degrees compared to the Earth's orbit around the Sun. This tilt means that during summer in the Northern Hemisphere, the northern end of the Earth's spin axis points towards the Sun. During winter in the Northern Hemisphere, the southern end of the Earth spin axis points towards the Sun.

Now consider a location on the Earth. The rotation of the planet around the Sun, and around Earth's axis means that more or less sunlight is received, because less light is received when the Sun is closer to the horizon. The amount of received sunlight directly influences the amount of heat delivered by the Sun. This leads to different seasons.

FULL ACTIVITY DESCRIPTION

Preparation:

For the activity, you will need to make a model of the Earth, using an orange. Make sure you can make the classroom dark. It would help if students are already aware that seasons exist and they are associated with different weather patterns and temperatures.

Activity 1: Vertical or shallow angle

Step 1:

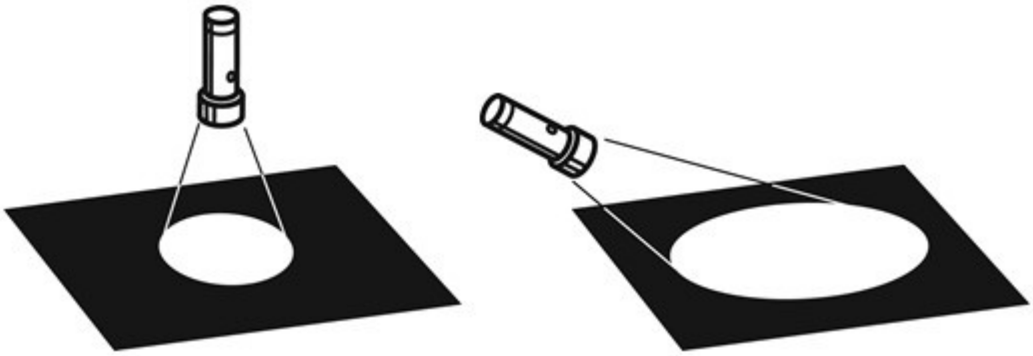
Turn off the lights and close the blinds in the classroom.

Step 2:

Organise the student into pairs. Give each pair a torch and tell them to shine it onto their table at different angles. Can they see a difference in the size of the area covered by the light?

Step 3:

Explain that light shone at a shallow angle covers a larger surface area than light shone from a right-angle. The students complete Task 1 on the worksheet.



Activity 2: Hot or cold?

Step 1:

Give each pair of students an orange. Explain that the orange represents the Earth. The top of the orange is the North Pole. The bottom of the orange is the South Pole.

Step 2:

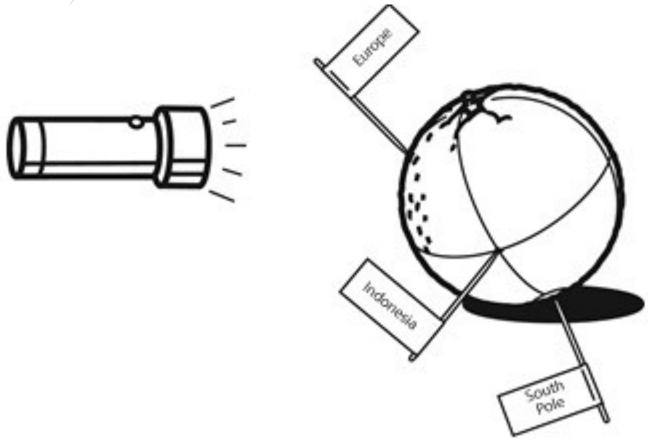
The students complete Task 2 on the worksheet, up to step 11.

Step 3:

Discuss the tasks. Explain that the Sun, like the torch, produces a fixed amount of light. The larger the surface area on which the sun shines, the larger the area over which the heat is spread. So each part of that area gets less heat than when the light from the Sun is concentrated on a smaller area. At the Equator the Sun shines vertically on the Earth's surface, so it falls on a smaller area. This means it is warmer at the Equator.

Step 4:

Together, look at the drawings on the worksheet. Use your orange to show that the Earth is tilted slightly diagonally. Rotate the orange around the torch. Start with the North Pole turned away from the Sun. Now the students can see that sometimes the North Pole is turned towards the Sun, and sometimes away from it.



Step 5:

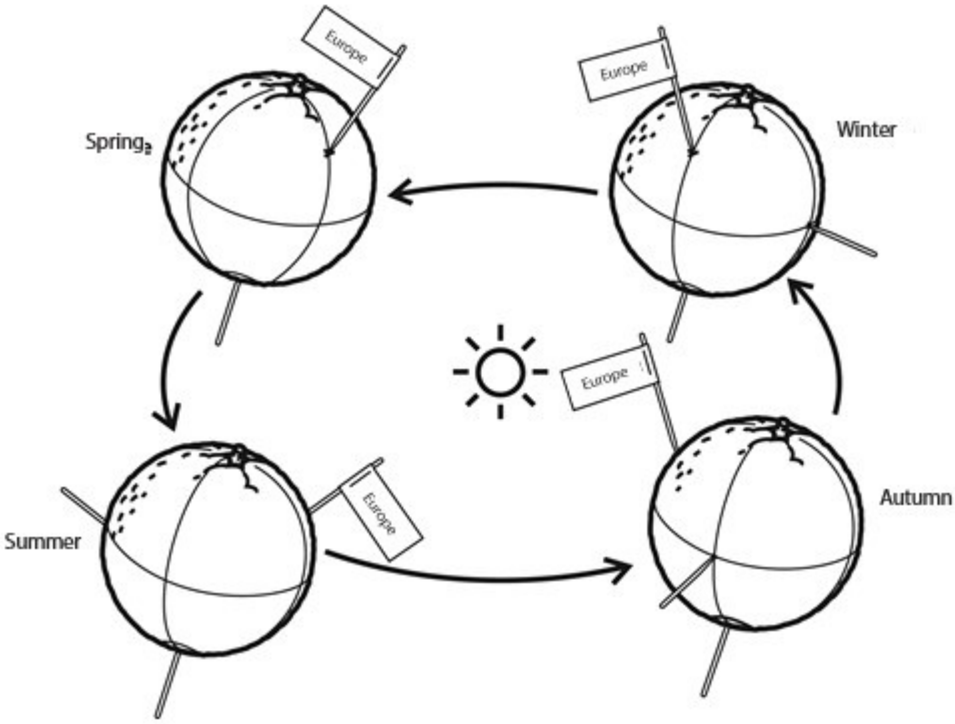
Show that the Sun shines more directly on the Northern Hemisphere when the North Pole is turned towards the Sun than when the North Pole is turned away from it. Explain that the seasons on Earth are caused by the different angles at which the Sun's rays hit the earth. This is why it is hotter in the summer than in winter. Discuss with the students that the sunlight never falls vertically on Europe. You can explain that this because there are always shadows. Even in the middle of the summer at noon when the Sun is highest on the sky, it is still not vertically above us.

Step 6:

The students complete the rest of Task 2 on the worksheet. Say that in Europe (or anywhere not on the Equator) the Sun shines for a shorter time in the winter than it does in the summer. Say that this is because of the angle of the Sun in relation to the surface of the Earth. Because the angle of the Sun shining on Europe changes throughout the year, we experience different seasons. This is because the amount of heat and light changes.

Activity 3: Seasons are not different everywhere

The students complete Task 3 on the worksheet. Ask them why we have such different seasons in Europe, while the countries on the Equator do not. Conclude that this is because of the changing angle at which the midday Sun shines on the Earth's surface in Europe, whereas it is more constant at the Equator. Refer back to the activity Vertical or shallow angle.



CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, seasons

National Curricula

UK, KS1:Year 1, science: seasonal changes UK, KS1:Year 5, science: seasonal changes UK, KS1, geography: Earth and space

ADDITIONAL INFORMATION

CONCLUSION

In three steps, this activity teachers how to build a model of the Earth and helps students understand the concept of seasons around the world. After completing the activity, students learn that seasons are determined by the angle at which the rays of the Sun fall on the Earth. So at the Equator there is very little difference between the seasons. Students observe that light falling on a surface diagonally covers a larger surface area than light falling from directly overhead and discover that the Sun warms a smaller area more quickly than a large area.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement nº 638653

BLUE MARBLE IN EMPTY SPACE

Students are taken on a virtual journey to outer space to experience that we live on a tiny planet that floats in a vast and empty space.

Erik Arends, Unawe, Leiden University

Curriculum topic
Earth, cultural and historical view

Big idea of science
Earth is a very small part of the universe.

Keywords
Earth, Atmosphere, Space, ISS, Orbit, Humans.

Age range
6 - 10

Education level
Primary School, Informal

Time
30min

Group size
Group

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Communicating information

Type of learning activity
Demonstration / Illustration

BRIEF DESCRIPTION

Using photographs and models, students are taken on a virtual journey to outer space. They can look back at the Earth as they travel further away and see it growing increasingly smaller, giving the experience that we live on a tiny planet that floats in a vast and empty space.

GOALS

- Experience the vastness of space and the relatively small size of Earth.
- Get a sense of scale for distances and sizes in the Solar System.

LEARNING OBJECTIVES

- Grasp the vastness of space by demonstrating models.
- Understand the Earth is just a tiny blue dot in the large emptiness of space and is very vulnerable indeed.
- Understand the importance of space exploration.

EVALUATION

- Ask students to recall how many times Earth could fit in the distance between the Earth and the Moon.
- Ask students what size Earth is compared to the size of the Solar System. Students should understand that as Earth appears only the size of a kernel of corn in the sky from Mars, which is relatively close by, Earth is very small compared to the size of the Solar System. Planets are very spread out with lots of empty space).
- Discuss with students whether it is important to look after the Earth, knowing that space is really big and a suitable alternative home is most likely very far away.
- Discuss with students whether their perspective of Earth has changed, and if so, how.

MATERIALS

- Earth Ball (inflatable globe 40 cm in diameter)
- Tiny sphere of 0.25 cm in diameter (peppercorn or kernel of corn)
- Computer with internet connection
- Styrofoam sphere (10 cm in diameter), or orange

BACKGROUND INFORMATION

The Earth

The Earth is the largest of four rocky planets (Mercury, Venus, Earth, Mars) in our Solar System, but smaller than the four gassy planets (Jupiter, Saturn, Uranus, Neptune).

Distances in the Solar System are very large compared to the sizes of the planets. More than 10,000 Earths fit in the distance Earth-Sun (The Earth's diameter fits more than 100 times in the Sun's, and more than 100 Suns fit in the distance Earth-Sun.). Astronomers call this distance an astronomical unit. The distance between Earth and our neighbouring planet Venus is 3,300 times the diameter of the Earth, and that is when the planets are closest to each other in their orbits. The distance between Earth and Mars is at least 6,100 times the diameter of the Earth. Usually our neighbours are much farther. Even to by far the closest celestial object, our Moon, you have to travel a distance of 30 Earths in a row. These large distances result in very small images of Earth when you look back from other planets.

The Earth is a finite sphere with finite resources that can be depleted by mankind. The Earth's atmosphere is very thin compared to its diameter. If the Earth were an apple, then the atmosphere would be thinner then an apple's skin. Humans can easily alter the composition of this thin atmosphere. If too much greenhouse gasses are put into the atmosphere, the Earth will warm because of a stronger greenhouse effect. This has dramatic consequences for our civilization, such as rising sea level, wider deserts, altering climates, and a runaway warming effect to increase the global temperature even more. With no known alien life to help us, or close-by habitable planets, we depend on the Earth.

Global citizenship

One of the primary goals of the educational project Universe Awareness (UNAWE) is to give children a sense of global citizenship. We all live on the same tiny blue planet floating around in the vast emptiness of space. When you are dealing with the extreme dimensions of planets, stars and the Universe in general, your perspective shifts from the local community you live in to the global community. Everyone on this planet sees the same Moon and the same Sun in the same sky. Dealing with astronomy is an identical experience for any human being. The realisation that we all share this one little sphere as our home bonds us as a species and makes us think about how we can work together to cherish the only safe haven in space that we have.

This video (https://vimeo.com/55073825) exactly embodies the message Universe Awareness wants to promote. When astronauts went into space for the first time in the early 1960s and looked back upon Earth, they saw something that no human had ever seen before: the Earth floating around in empty space, a bright blue ball standing out against the dark, infinite background. These astronauts experienced the ultimate sense of global citizenship, termed the 'overview effect'. They were able to communicate UNAWE's message like no-one else could, using a video of the Earth from space.

International Space Station

With advances in camera technology, astronauts nowadays are able to make extremely high quality movies of the Earth viewed from the International Space Station (ISS) as they orbit the planet every 90 minutes. This footage (http://goo.gl/uF2nd) shows our planet in amazing detail and depicts a thriving world without any borders.

Cosmology

As a species, we do not only share one home planet, but also one history. Of course, every culture has its own background, but humanity as a whole has one, too—that is, a 'cosmic history'. Cosmology tells the story of the Universe from its very beginning to the moment stars and planets formed. This story tells us that humans—despite their skin colour or culture—are all made of the same stuff: stardust. In fact, think of any person in the world, odds are that you carry some atoms in your body that were once in theirs!

FULL ACTIVITY DESCRIPTION

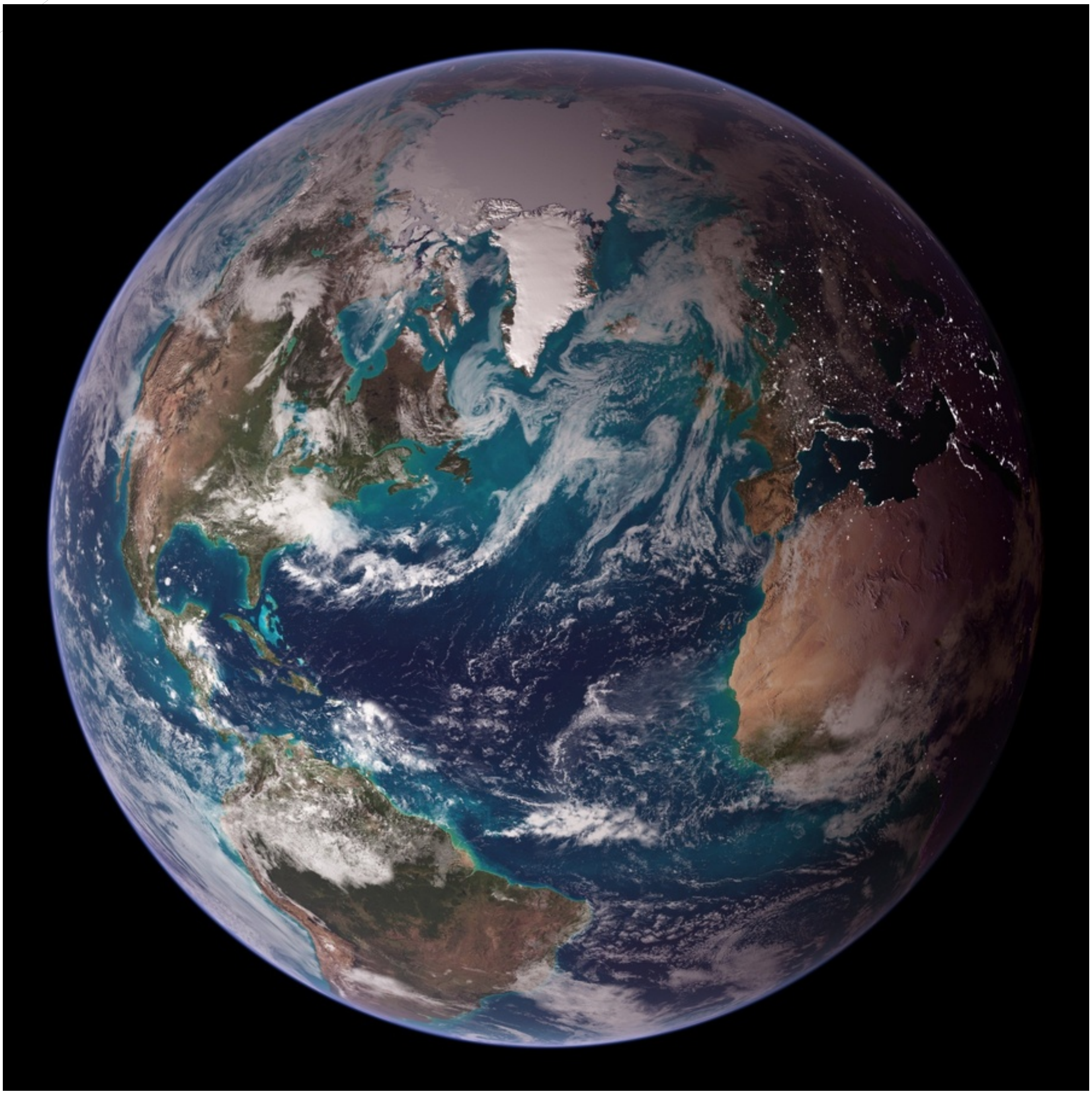
Step 1:

Show the students the video filmed from the ISS as it orbits the Earth every 90 minutes, looking down on the planet's surface from a height of 370 km.

Step 2:

Ask the students if they recognise Earth's atmosphere. Emphasise how thin and vulnerable this actually is, in comparison to the size of the Earth. If the Earth were an apple, the atmosphere would be thinner than its skin. Ask them what else they see.

Step 3:



The students have now had a first overview of Earth, although they didn't see it as just a sphere floating in space (for this, show them the 'Earth from Space' image) Explain how the border between day and night shifts from east to west (right to left) across the surface of the Earth.

The Earth rotates around its axis in the eastern direction—counter clockwise, if you look from space down on the North Pole—with the Sun as a fixed background light. If you look from space down on the South Pole, the Earth rotates clockwise (still in eastern direction).

Step 4:

Now, we travel even further outwards, to the Moon. Show the students the 'Earthrise' image (a photograph taken by the astronauts from the Apollo 8 mission in 1968.) These astronauts were the first people to ever orbit a celestial body other than the Earth, and when they looked back at their home planet, they experienced the so-called overview effect: everything they had ever known and loved was on that tiny blue marble, hanging peacefully in space.

Step 5:

At this point, you can make the shift from photos to model objects. Take the Earth ball and hand a Styrofoam sphere (10 cm in diameter) to one volunteer. If you don't have a ball of that exact size, then use a sphere that approximately fits on Australia on the Earth ball, for example an orange. If you use a globe instead of the Earth ball, adjust the sizes of the objects accordingly. For example, of you use a globe that is 20 cm in diameter, use a 5 cm moon and also divide the next sizes and distances in this activity in half.

Step 6:

Ask the volunteer to hold this model of the Moon at a distance from the Earth ball that he/she thinks is correct, according to this scale.

Step 7:

Ask the other students if they agree, and if not, let them stand at a distance they think is right. The correct answer is a distance of 30 Earth balls (or whatever globe you use) in a row. For the earth ball this is 12 meters, meaning all the way to the back of the classroom, or even outside. Let the students look at the earth ball from there and tell them that this is the size of the Earth as it would appear if they were to stand on the Moon.

Step 8:

We proceed on our virtual journey, now, to the other planets. Ask the students to remain at the back of the classroom. Now hold up a sphere of about 0.25 cm in diameter, for example a peppercorn or kernel of corn. The students will be looking at the Earth as viewed from Mars at its closest distance to Earth!

Step 9:

Show the students 'Pale Blue Dot' image, which is a photograph taken by Voyager 1, a spacecraft that was sent out into space in 1977 and has now long since passed the orbit of Neptune—the outermost planet of our Solar System. Of course, Voyager 1 is unmanned. In fact, no human has ever travelled farther than the Moon. In the picture, you can see a teeny tiny 'pale blue dot'. This is how small the Earth looks from 6 billion kilometres away, which is about the average distance to Pluto. Almost half a million Earths in a row fit in this distance. It would take an airplane more than 600 years to fly there! The stripes in the picture are just 'noise'.

Step 10:

Ask the students if their perspective of Earth has changed. Do they think the Earth is big enough to provide us with inexhaustible resources? Explain that the Earth is a sphere with a finite atmosphere and finite resources. If we pollute our planet, there is no-one in space that can help us. We have nowhere to go. The Earth is the only home we have.

Note: For students aged 9–10 years, you can extend this activity by getting into the subject of searching for life on exoplanets, which are planets outside our Solar System. So far, thousands exoplanets have been discovered. For the current count, check out https://exoplanets.nasa.gov/. From this activity, the students have learned that the Earth looks very small from outside the Solar System. This demonstrates that from Earth's perspective, exoplanets must seem very small indeed and are very difficult to see. Therefore, it's hard to determine whether life has developed on them. Even with very strong telescopes, astronomers can rarely see the planet, never mind zoom in far enough to look for living organisms! However, methods are available to examine exoplanets.

Ask the students to think of ways to find out if a planet is hospitable to life, or even to check for actual life. The most important requirement for life is the presence of liquid water. The planet should be far enough from its host star so that water, if present, won't evaporate. But it shouldn't be too far, otherwise the water would freeze. Also, an atmosphere is probably necessary to protect life from harmful radiation and large temperature variations. In the future, astronomers might have developed such high-quality telescopes that they can see an exoplanet's colour, from which they could deduce whether it has vegetation.

So far, however, we haven't found a planet that is just like Earth. If we do, it will probably be very far away, meaning it will be difficult to study with our telescopes. Emphasise that lots of work still needs to be done in this area: if the students grow up to be astronomers, they might make a breakthrough discovery—they might even find life!

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Our fragile planet, Earth, cultural and historical view

National UK

KS2: Year 5, Science, Earth and Space

National Dutch

Kerndoelen, 28, 33, 38, 39, 46

ADDITIONAL INFORMATION

- The shift in awareness about the world the astronauts experience is also known as the overview effect: http://goo.gl/OuH9v
- Frank White's blog on The Overview Institute (author of "The Overview Effect: Space Exploration and Human Evolution"): http://www.overviewinstitute.org/blog/bloggers/frank-white
- "Overview" video by the Planetary Collective which documents astronauts' life-changing stories of seeing the Earth from the outside – a perspective-altering experience often described as the Overview Effect: http://goo.gl/t8l0R
- "Further Up Yonder: A Message from ISS to All Humankind", a video by Italian videomaker, Giacomo Sardelli, about the International Space Station, its inhabitants, and its role in space exploration: http://goo.gl/uF2nd
- Frank White wrote a book about this topic: The Overview Effect

CONCLUSION

The activity should help students learn about scale and distance of the solar system and how important yet small the Earth is. It should give students a sense of global citizenship that we all live on the same tiny blue planet floating around in the vast emptiness of space.

ASTROEDU

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

COMA CLUSTER OF GALAXIES

Learn the basics of galaxy classification and grouping, using actual Hubble Space Telescope images.

Keely Finkelstein, McDonald Observatory

Curriculum topic
Galaxies

Big idea of science
Earth is a very small part of the universe.

Keywords
Galaxies

Age range
14 - 19

Education level
Secondary School, Informal

Time
1h

Group size
Group

Supervised for safety
Unsupervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Planning and carrying out investigations, Analysing and interpreting data, Constructing explanations, Communicating information

Type of learning activity
Full enquiry

BRIEF DESCRIPTION

This classroom activity for high school students uses a collection of Hubble Space Telescope images of galaxies in the Coma Cluster. Students study galaxy classification and the evolution of galaxies in dense clustered environments.

GOALS

- Students will learn the basics of galaxy classification by making use of real astronomical data from the Hubble Space Telescope. Classification is a scientific practice important in many different fields of science; by simplifying a diversity of objects into a smaller number of categories, it becomes easier to see what characteristics are shared by many objects, and study these properties of representative objects, rather than each object individually.
- Students will discover a "morphology-density effect" and then make hypotheses about the causes of this effect.

LEARNING OBJECTIVES

- Students will be able to classify different galaxy types based on astronomical images.
- Students will explain the importance of classifying objects.
- Students will propose ideas for why galaxies might have different shapes.
- Students will practice asking questions and planning investigations.
- Students will discuss the ideas that there are physically different environments throughout the universe that galaxies live in, that galaxies interact, and that there is a relationship between environment and galaxy morphology (called the "morphology-density effect").
- Students will make hypotheses about the cause of the morphology-density effect.

EVALUATION

The teacher could discuss the answers with students, encouraging them to share their calculated values of the different types of galaxies found in both the field and the cluster as well as their answer to the final question about the morphology-density effect. Student understanding can be assessed by discussion as detailed throughout the activity and by collecting scripts to mark. As these activities assess student understanding, additional evaluation tasks are unnecessary. Suggested grading is detailed below.

Suggested Grading

- Table 1: 5 points - students provide clear explanations of the classification scheme they create.
- Table 2: 2 points each - Answers (E/S0/SB0 - 2, 6, 9), (S - 1, 8, 12), (SB - 3, 4, 10), (IR - 5, 7, 11).
- Tables 3, 4 and 5 (counting galaxies): not graded - based on student's subjective interpretation.
- Table 6 and Calculations: 30 points - Graded for completion, not accuracy. Students will get different numbers, but math should be correct. Answers for percentages are typically in the following range: (Cluster: E 50%, L 30%, S 20%) (Field: E 20%, L 10%, S 70%). Students usually find a higher percentage of spirals in the field. Hypothesis Question: 30 points – Student's hypothesis should mention the effects of interactions and ram-pressure stripping in changing past gas-rich spirals into current gas-poor ellipticals and lenticulars in clusters.

MATERIALS

- Image of 40 galaxies.
- Galaxies cards A to D.

BACKGROUND INFORMATION

Galaxy Classification

Astronomers classify galaxies based on their appearance into three main classes: elliptical, spiral, and irregular galaxies. Edwin Hubble first came up with this classification scheme. Hubble originally thought that the 'tuning fork' sequence represented the evolutionary progression of galaxies. This concept turned out to be wrong, but astronomers still use these general categories and labels to describe galaxies.

The Main Galaxy Types

Elliptical (E), Lenticular (S0), Barred Lenticular (SB0), Spiral (S), Barred Spiral (SB) and Irregular (IR). More detail can be found in the activity description section.

An additional type of galaxy category

Interacting: Consists of two or more galaxies that are so close together that they are affecting each other's shape.

Data provided in this activity

The data used in this activity is Hubble Space Telescope data of the Coma Cluster of galaxies. It was taken in 2006 using the Advanced Camera for Surveys (ACS) instrument on the Hubble Space Telescope.

Galaxy Environments

Galaxies are found throughout the universe, and live in a variety of environments. Galaxies can be found in clusters, groups, or in isolation.

Groups

Sometimes galaxies are found in smaller numbers called groups, with just a handful of galaxies being members of the group. The Local Group contains our Milky Way galaxy, and our next door neighbours the Magellanic Clouds and the Andromeda galaxy, along with a few dozen smaller galaxies.

Field

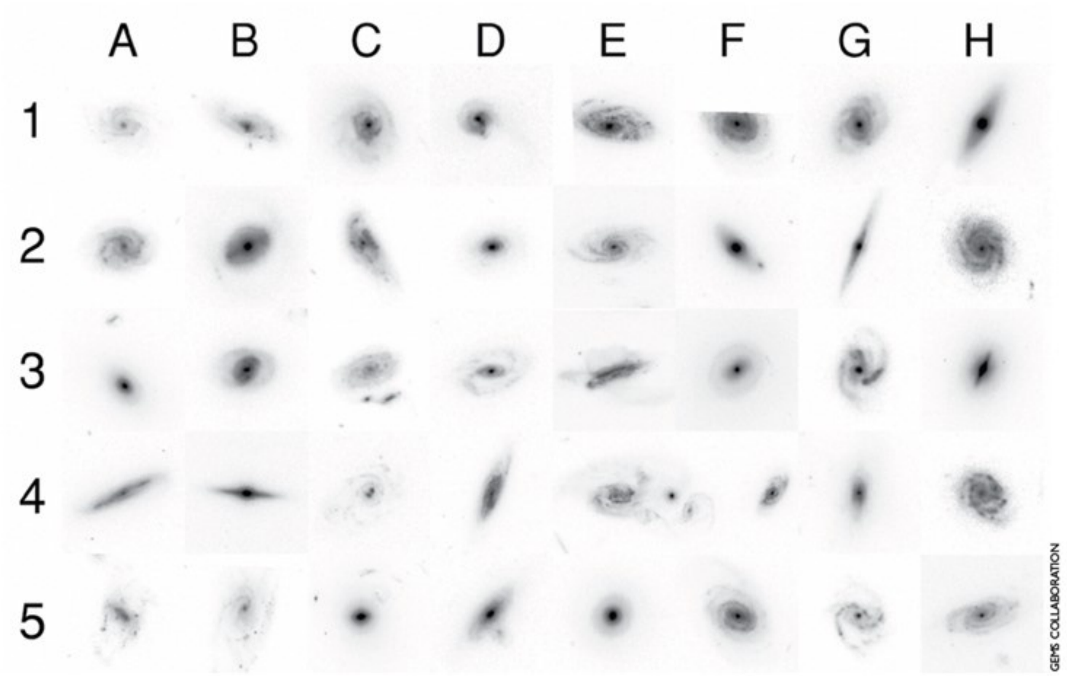
At other times, galaxies can be isolated and be far from another in the field. These are called field galaxies.

Clusters

A galaxy cluster is a large structure in the universe consisting of hundreds or thousands of galaxies that are gravitationally bound together. The large number of galaxies in a cluster are all packed close together, such as in the Coma Cluster. Clusters make some of the largest, and densest structures in the universe. Clusters, groups, and some isolated galaxies can all be part of even larger structures called superclusters; at the largest scales in the visible universe, superclusters are gathered into filaments and walls surrounding vast voids. This structure is often referred to as the 'cosmic web'.

FULL ACTIVITY DESCRIPTION

Students will first investigate images of 40 galaxies to become familiar with how galaxies appear and are shaped differently. They will come up with their own classification scheme for galaxies, and then explore how astronomers actually classify galaxies into four main groups.



Step 1

Tell students: the above diagram shows a mosaic of 40 galaxies. These images were taken with the Hubble Space Telescope and show the variety of shapes that galaxies can have. When astronomer Edwin Hubble first started studying these various types of galaxies in the 1920s, he developed a way to organize and categorize them. He created a classification scheme in which he grouped similar galaxies together.

Your job is to do the same thing. In the following chart, invent your own galaxy types and provide a description of these galaxy types and three examples for each one.

Fill in the table in the worksheet.

Step 2

Discussion: Ask students to share their classification schemes with each other. Suggested points of discussion:

- What are significant similarities between schemes?
- Significant differences?
- Arguments about how to classify particular galaxies?
- Why did students decide to design their schemes the way they did?
- What are other completely different types of schemes you could devise, e.g., if you had different data on the same galaxies?
- Why is it important (or not) to classify objects we discover?
- Might classification schemes be changed over time?

These discussion points can be re-visited later in the activity as well. (Presumably at least some students will come up with classification schemes based on shape---but if they do not, after discussing their schemes, encourage them to come up with other schemes that are based on shape.)

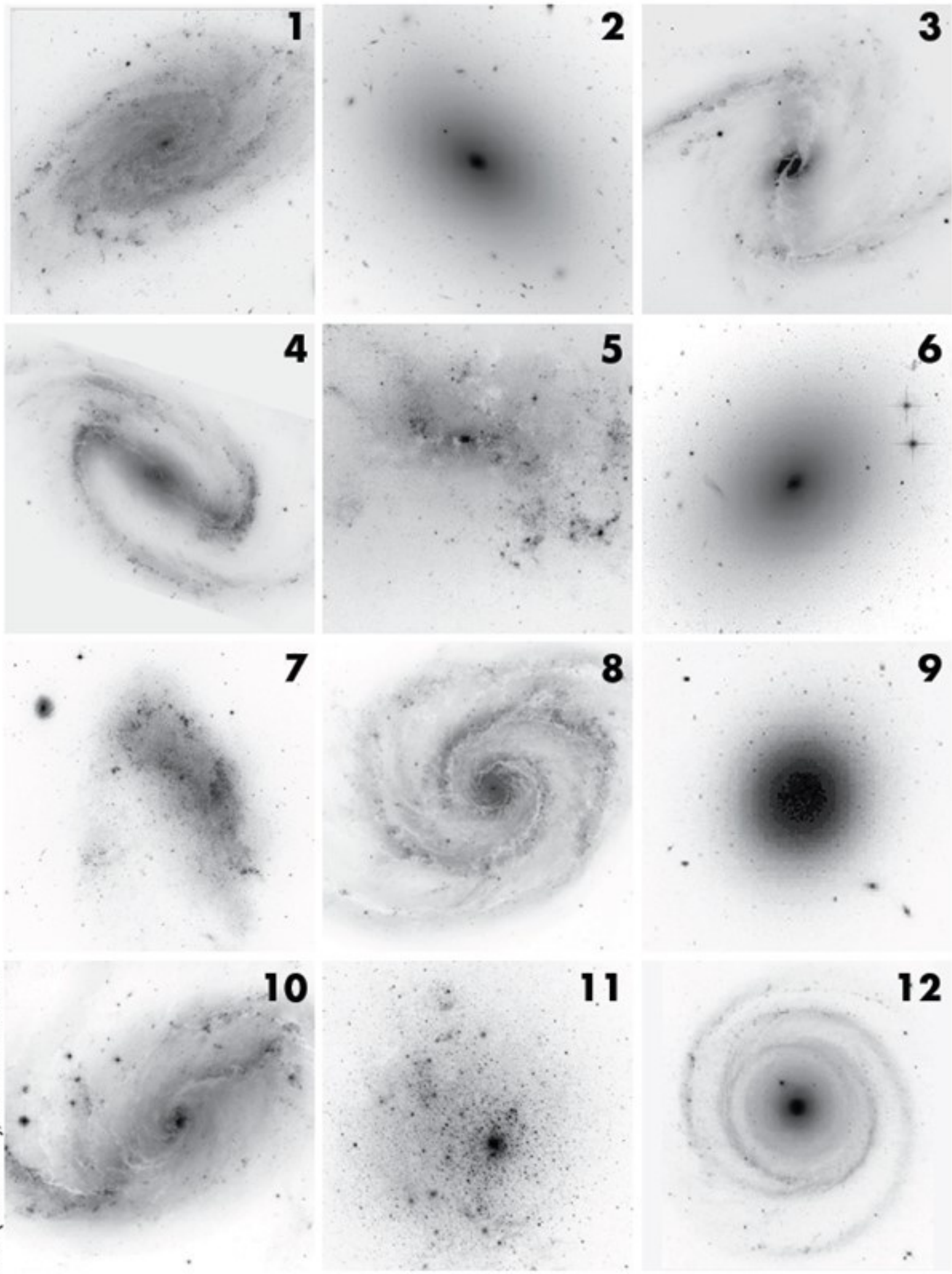
Prompt students to make observations and ask questions based on their analysis of the image so far, discuss them in groups, and write them down. The goal is for them to ask, "Why do different galaxies have different shapes?" Then, prompt students to discuss and write down questions and ideas about why galaxies might have different shapes---for example

- Did the galaxies form in different shapes, or did they all form in the same shapes and then evolve into different shapes?
- What different histories could different galaxies have (especially, that could affect their shapes)? (encourage students towards the idea of galaxies interacting with each other)
- Could the evolution of galaxy shape be due to internal processes or driven by external processes? (e.g., something that happens to all galaxies over time no matter what, or something driven by an interaction with another galaxy)
- Could the shapes be related to the size of the galaxy when it forms?
- Are the shapes we observe transient or long-lasting?

While students are thinking of these kinds of ideas, encourage students to discuss how they could investigate the answers to these questions. (Perhaps some students will think of the idea that interactions with other galaxies could be important, and that looking at regions where there are many galaxies so many interactions take place might be a way of investigating this. Whether they come up with this idea or not, this previous discussion will help them to be in a better position to think through this idea later in the activity.)

Step 3

Tell students: Astronomers have developed their own classification scheme for galaxies, based on the galaxy shape (often called "morphology"). The definitions of the main galaxy types which astronomers use are listed below. Using these definitions, place the 12 galaxies shown in the above figure into their commonly-used categories. Fill in the table in the worksheet.

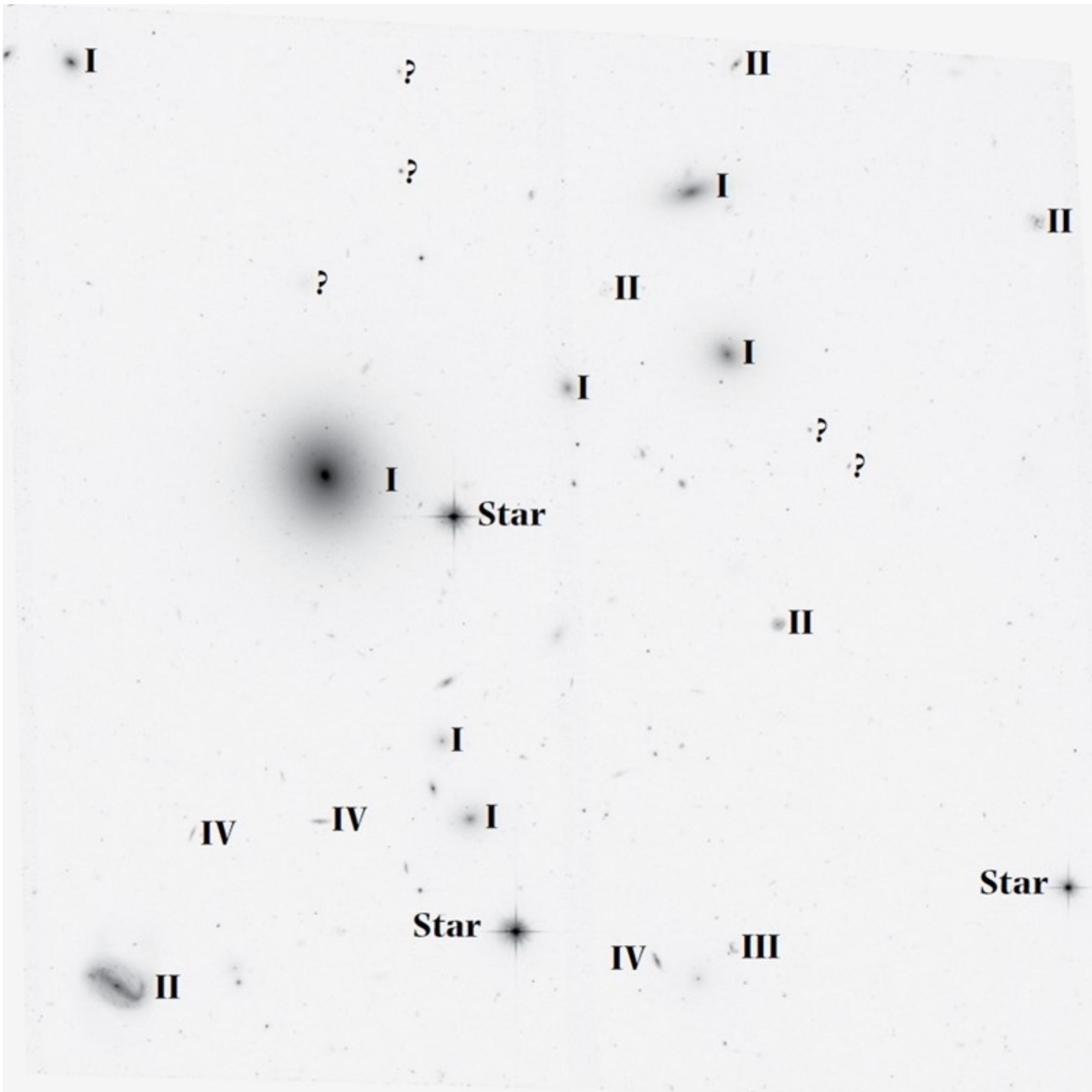


ESO (TOP RIGHT); ALL OTHERS NASA

Note: The smallest galaxies are often called dwarf galaxies (No. 5 and No. 7 are dwarf galaxies). These contain only a few billion stars — a small number compared to the Milky Way's 200 billion. The largest ellipticals contain several trillion stars. Discuss: How does the classification scheme used by astronomers compare with the classification schemes designed by members of the class?

Step 4

Tell students: Use the image below and guidelines to help decide how to identify and count the galaxies.



Guidelines:

- I) Ellipticals or Lenticulars: it can be hard to tell these apart. If you know it's either an E or S0 / SB0, it is okay to guess between these two.

- II) Spirals and Barred Spirals: it can be hard to tell these apart. If you know it's either an S or SB, it is okay to guess between these two.
- III) Irregular galaxy.
- IV) Uncertain: an edge-on view of a galaxy that could possibly be an S0, SB0, S, SB, or IR. There are too many possibilities, so do not count these.
- Star) any object that has 'crosshairs' sticking out of it is a foreground star in the Milky Way galaxy, so do not count these.
- ?) Don't count small, faint objects like these that are too hard to classify.

Step 5

Download the images "Galaxies Cards" A-D to count the types of galaxies seen in each image. Count the number of galaxies of each morphological type and write down the number in the correct spot in the table.

Step 6

Tell students: Galaxies are found throughout the universe, from our next door neighbours — the Magellanic Clouds and Andromeda — all the way out to the visible universe 13 billion light years away. Galaxies live in a variety of environments. Sometimes large numbers of them are packed close together in clusters, such as the Coma Cluster; sometimes they gather in smaller numbers called groups, like the Local Group that contains the Milky Way; and sometimes they are isolated far from one another in the field. The table below shows the different properties for the different types of galaxy environments. In the previous step, Galaxy Cards images A and C show the dense central core of the Coma Cluster, and images B and D show galaxies out in the field. (NB Astronomers sometimes use the term "field" to mean the area outside galaxy clusters.) Fill in the tables using the numbers you wrote down in the table from step 5 of the activity.

See tables in the worksheet.

Step 7

Ask students to think about and discuss in groups: What trends do you notice from the data you've analysed above? Do you notice anything about where different types of galaxies tend to be found? (Extra prompt: Do you tend to see more spirals in the dense cluster or in the field? What about ellipticals?) Students should notice that spiral galaxies are more common in the field, and ellipticals are more common in dense clusters. Follow-up question: Does that seem surprising? The goal here is to get students to ask "Why does the number of spiral galaxies (or elliptical galaxies) depend on where the galaxy is located?" Ask students to discuss and write down ideas for why galaxy type seems to be affected by where the galaxy is located. Ask students how they could investigate their ideas: What predictions would their ideas make? What additional observations or information would they want to have?How could they quantify this trend using the data?

Step 8

The following steps explain how students can investigate this trend, first by quantifying it, and then by reading more information about how galaxies form and evolve. You can tell them exactly what to do as below. Better yet, have them discuss in groups how they could investigate their question, starting with how to quantify the trend and then determine the procedure themselves for making the calculations below.

Using a calculator, find the percentages of each galaxy type in the cluster versus the field (Ignore IRs and INTs).

Use your numbers from the table above to calculate the percentages and fill in each of these blanks below: In the Cluster:% of Ellipticals (e / h) = **% % of Lenticulars (f / h) =** % % of Spirals (g / h) = *% In the Field:% of Ellipticals (i / m) =* % % of Lenticulars (j / m) = _ *% % of Spirals (k / m) =* %

Question: Where did you find a higher percentage of spirals - in the Cluster or in the Field? Answer: _ Tell students:The percentages that you just found tell us which types of galaxies are common in the Coma Cluster versus which types are common in the field.

Astronomers have done this same experiment on hundreds of thousands of galaxies in the nearby universe, and discovered that the following percentages are pretty typical:

- In dense clusters, 40% of the galaxies are ellipticals, 50% are lenticulars, and 10% are spirals.
- In the field, 10% of the galaxies are ellipticals, 10% are lenticulars, and 80% are spirals.

When galaxies are found very close together there are more ellipticals and lenticulars. When galaxies are far apart there are more spirals. Astronomers call this the "morphology-density effect." This term basically means that in crowded galaxy neighbourhoods, like clusters, there are different types of galaxies than are found in open areas, like the field.

Step 9

Students should by now (from Step 7) have asked the question, "Why do we see more elliptical and lenticular galaxies in clusters and more spirals in the field?" (This question can also be phrased, "Why do we observe the morphology-density effect?") They should also have had the idea that interactions could be involved, and maybe even the idea that more interactions take place in denser environments, like the center of a cluster. Below is information that can be used to answer this question. You can give students this text to read, then ask them to discuss and write down an explanation for this effect; or you can continue to prompt students to brainstorm and discuss ideas for possible explanations, then potentially have them do research in textbooks / on the internet on their own or in groups, and then have them share their explanations with each other.

Explanation: Many galaxies contain what astronomers call "gas," which generally means hydrogen gas, sometimes mixed with the gases of other elements, and sometimes mixed also with dust. Gas clouds can collapse by gravity, which leads to the formation of stars.Astronomers have observed many spiral galaxies (S and SB) and find that most of these galaxies contain a lot of gas, and are currently forming lots of new stars. Elliptical and lenticular galaxies (E, S0, and SB0) are gas-poor and are not making many new stars. Galaxies that are very close to each other, such as those in clusters, often undergo many violent interactions with each other. When a gas-rich spiral galaxy interacts with another galaxy, it tends to quickly use up most of its gas to make new stars, leaving little gas behind. Galaxy-galaxy interactions often change gas-rich galaxies into gas-poor galaxies. Many lenticular galaxies are the remains of old spirals that have lost their gas, and many elliptical galaxies are the remains of several spiral galaxies that have collided. Galaxy clusters are usually filled with a lot of extremely hot gas that is spread between galaxies throughout the cluster. However, there is no hot gas like this out in the field. When the radiation from this hot gas hits a spiral galaxy, it strips the spiral galaxy of its much cooler gas in a process called "ram-pressure stripping." This process quickly converts a gas-rich spiral galaxy into a gas-poor lenticular galaxy. Spiral galaxies have a hard time surviving in the superheated gas environment.

As you see, galaxies change and evolve over time, and galaxies we observe in the nearby universe today have had a very long history already.

Additional activity

Once students know about the shapes of galaxies, they can contribute to a real scientific research project by exploring the Galaxy Zoo citizen science programme: http://www.space-awareness.org/en/games/galaxy-zoo/

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Galaxies

National Curricula USA

Next Generation Science Standards, content Standard in 9-12 Science as Inquiry (Abilities necessary to do scientific inquiry, Unders and Content Standard in 9-12 Earth and Space Science (Origin and evolution of the universe)

National Curricula UK

GCSE, KS3 ,A level: Physics - Edexcel; OCR A; WJEC

CONCLUSION

Students identify the galaxies by making calculations, working through the worksheets and drawing a hypothesis about the morphology-density effect.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

MEET OUR NEIGHBOURS: MOON

Explore the tactile version of our moon made with household materials.

Lina Canas, Núcleo Interativo de Astronomia

Curriculum topic
Sun-Earth-Moon

Big idea of science
Earth is a very small part of the universe.

Keywords
Moon, Solar System

Age range
6 - 12

Education level
Primary School, Middle School, Informal

Time
2h

Group size
Group

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Analysing and interpreting data, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

Converting a visual experience to a tactile one, this activity lets visually impaired students learn and explore our Moon and its characteristics.

GOALS

- To create a tactile version of the Moon using low cost household materials.
- To explore our moon through a tactile model.

LEARNING OBJECTIVES

- Students will be able to recognise and describe lunar features using the tactile Moon.
- Students will be able to explain the importance of building models, identify strengths and limitations of this model, and suggest ways they might improve aspects of the model.

EVALUATION

Ask students to point at a feature on their model as soon as they know which one it is. First give a description and a couple of seconds to think about it. Then give the name and a couple more seconds to point it out. e.g.:

- This is the main overall surface of the Moon, it is not smooth.
- These are called the seas of the Moon, although there was never water on the Moon. Instead this was caused by lava on the surface a long time ago. They are smooth and dark (the dark coloured Maria).
- This bowl shaped part or feature of the Moon is caused by rocks hitting the surface (Crater). -These are the bumpy features on the Moon at a greater height (Mountains).

Evidently the Moon is not made of fabric and sequins. Ask students to discuss the importance of building models, strengths and limitations of this model of the Moon, and how they might improve the model.Ask students in their groups to write down two things they learned from the activity, and two things they want to learn more about.

MATERIALS

- Fabric, e.g. grey felt, for surface of Moon
- Thick fabric (for different mountains)
- Thin fabric (for mare features)
- Curved sequins (for craters)
- Glue (for the fabric)
- Pen (to write on the fabric)
- Scissors
- Print out Moon Features PDF
- Print out Moon Featureless PDF (two copies)

BACKGROUND INFORMATION

Moon

The Moon is the only natural satellite of the Earth. It orbits our planet in 27.3 days at a mean distance of 384,400 km. Its diameter of 3,474 km makes it the fifth largest satellite in the solar system. It is thought that the Moon was formed at the same time as the Earth, 4.55 billion years ago, from the debris of a giant collision between the Earth and a Mars-size object. The Moon is in on a synchronous orbit around the Earth, which means that it makes one turn around itself as it makes one turn around the Earth. So, it is always showing the same face to us. All we know about the 'hidden' face of the Moon comes from the records taken by astronauts or automatic probes that went around to the other side. There is no rising or setting of the Earth on the horizon of the Moon. If you were standing on the near side of the Moon, the Earth would appear immobile in the sky. During its revolution around the Earth, the disk of the Moon is not always completely lit by the Sun. This variation in the appearance of the lunar disk is called the "phases of the Moon", and is characterized by a well-known cycle. The apparent diameter of the Moon as seen from Earth is almost exactly that of the Sun. This is why the Moon can sometimes completely mask the solar disk and produce total solar eclipses. Another important influence of the Moon on Earth is the phenomenon of tides, which is due to the Moon's gravitational pull on the seas and oceans of Earth. The Moon is the only celestial object that has been visited by human beings. The first visit was on 21 July 1969 when two members of the Apollo 11 mission set foot on our satellite: they were Neil Armstrong and Edwin Aldrin. As many as 12 astronauts walked the surface of the Moon between 1969 and 1972, and they returned with 382 kg of lunar soil to be analysed on Earth.

Tactile features:

The tactile model of the Moon includes a number of features that represent real features of the moon. You can find more information about these features below.

Mountains and Maria

The visible surface of the Moon shows bright and dark areas. The bright areas are generally hills or mountains (represented by thick fabric on the tactile image), while the dark ones are flat lands, called “mare” (represented by thin fabric in relief on the tactile image). These low altitude areas were filled with lava during an ancient period of volcanic activity, around 3 billion years ago. Most of them were named by ancient astronomers after common phenomena encountered on terrestrial seas and oceans: Oceanus Procellarum (‘Ocean of Storms’), Mare Imbrium (‘Sea of Rains’), Mare Serenitatis (‘Sea of Serenity’), Mare Tranquilitatis (‘Sea of Tranquility’), etc.

Craters

The whole face of the Moon is dotted with craters, with diameters from a few meters to hundreds of kilometres (curved sequins). They are the result of impacts by asteroids, since the Moon does not have any atmosphere to prevent them from reaching the surface (a few of them are represented by buttons on the tactile image: Plato and Aristoteles at the top, Aristarchus on the left, Copernicus near the centre, and Clavius at the bottom). Copernicus has a diameter of 93 km and is located in Mare Imbrium at the end of a chain of mountains called Apennins (represented by the thick fabric on top of the thin fabric on the tactile image).

FULL ACTIVITY DESCRIPTION

Introducing the Moon:

- Ask students what they know about the Moon. Discuss information included in the first half of the background information section, up to but not including the tactile features. Tell students that they will be making a model of the Moon and investigating its features.
- Put the students in groups of 5 (ideally 3 non-visually impaired to 2 visually impaired).
- Distribute materials, including the printouts, to each group.

Making the Model:

- Close supervision is important. Follow each group and explain each of the tactile elements and their correspondence to each object feature.
- Understand the different needs of each group of students to promote interaction between the students during the building of the tactile image. Visually impaired students need to be familiarized with the different materials involved.
- Allow enough time to follow instructions and build the tactile image.

Step 1

Cut the outer round shape of the Moon from one of the printed 'Moon Featureless PDF'.

Step 2

Place it on top of the thick fabric and draw a circle.

Step 3

Cut the circle you just drew out of the thick fabric.

Step 4

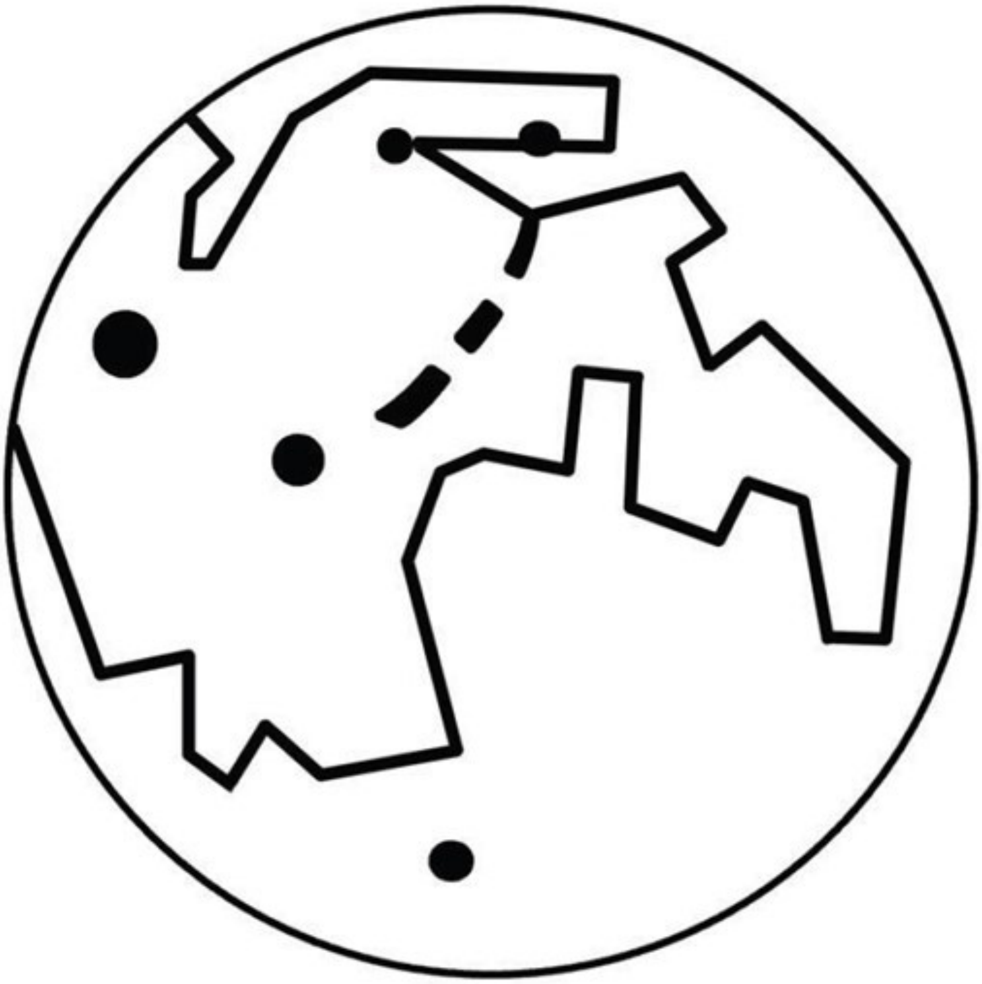
Apply glue on the surface of the Moon on the other Moon Featureless PDF.

Step 5

Place the circular fabric cutout on top of the glued area of the printed paper.

Step 6

Take the 'Moon Features PDF' and cut out the inner section which has several black dots.



Step 7

Place the inner section on top of the thin fabric and draw the outline of the shape.

Step 8

Cut out the outlined shape.

Step 9

Glue this piece of fabric on top of your fabric moon.

Step 10

Cut a small piece of the thick fabric and glue it in place so it matches the dashed line on the Moon Features PDF.

Step 11

Glue the thick fabric piece on top of the previously glued thin fabric.

Step 12

Place glue on the flat section of the sequins and glue them on top of the fabric, in the same places as the small circles on the Moon Features PDF. Wait for the model to dry before you start exploring.

Exploring the tactile image:

There are several ways in which you can explore the scientific content of the tactile schematic images. If you're presenting the final tactile image to the students, first let them explore and feel the different textures. Questions will arise as the students explore; encourage them to write their questions down and share them with the other groups. Read "Background Information" to understand the different features present in the Moon's schematic tactile model, and share with the students as they ask about them, or (if you have more time), prompt each group to choose a feature to learn more about and then have them present their findings to the other groups in the class.

- The Moon's overall surface is represented by the round shaped thick fabric;
- The second higher layer of fabric depicts the Maria;
- Curved sequins depict cratered surfaces;
- Mountains are depicted by the higher layer of thick fabric.

Discuss the idea of models with the students. Suggested discussion points:

- What is a model? Why is it useful to build models?
- What are the strengths of this model?
- What are limitations?
- How could the model be improved?

Ask students in their groups to write down two things they learned from the activity, and two things they want to learn more about.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Our fragile planet, Sun-Earth-Moon

National UK

KS3 - Chemistry, Earth and Atmosphere KS2: Year 5 - Science, Earth and Space KS2 - Art and Design

ADDITIONAL INFORMATION

Explore the rest of the planets through 'Meet Our Neighbours' in tactile form at http://nuclio.org/astroneighbours/resources/

CONCLUSION

This low-cost tactile version of the Moon is a great resource to explore lunar features for both visually impaired and normal vision students.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

SPACE awareness

MEET OUR HOME: PLANET EARTH

Explore a tactile version of our home, the Earth, made with household materials.

Lina Canas, Núcleo Interativo de Astronomia

Curriculum topic
Sun-Earth-Moon, the Earth

Big idea of science
Earth is a very small part of the universe.

Keywords
Earth, Tactile, Visually Impaired

Age range
6 - 12

Education level
Primary School, Middle School, Informal

Time
1h30

Group size
Group

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models, Analysing and interpreting data, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

Converting a visual to a tactile experience, this activity lets visually impaired students learn about and explore some of the characteristics of our home planet, the Earth.

GOALS

To explore our home, the Earth, through a tactile hands-on experience for visually impaired students and their non-visually impaired peers.

LEARNING OBJECTIVES

- Students will be able to recognise and describe features of the Earth using the tactile model.
- Students will be able to explain the importance of building models, identify strengths and limitations of this model, and suggest ways they might improve aspects of the model.

EVALUATION

Use the descriptions below or ask students to volunteer their own description of a feature on Earth. Ask students to point at the feature on their model as soon as they know which one it is. First give a description and a couple of seconds to think about it. Then give the name and a couple more seconds to point it out. Encourage students to ask questions about different characteristics of Earth represented by the different textures.e.g.:

- The part of the world where nearly all humans live. (Land).
- These cover nearly three quarters of the Earth's surface and are very wet. (Seas and oceans).
- These are very cold parts of the world, made of ice. (Polar caps).
- These are in the sky and where rain comes from. (Clouds).

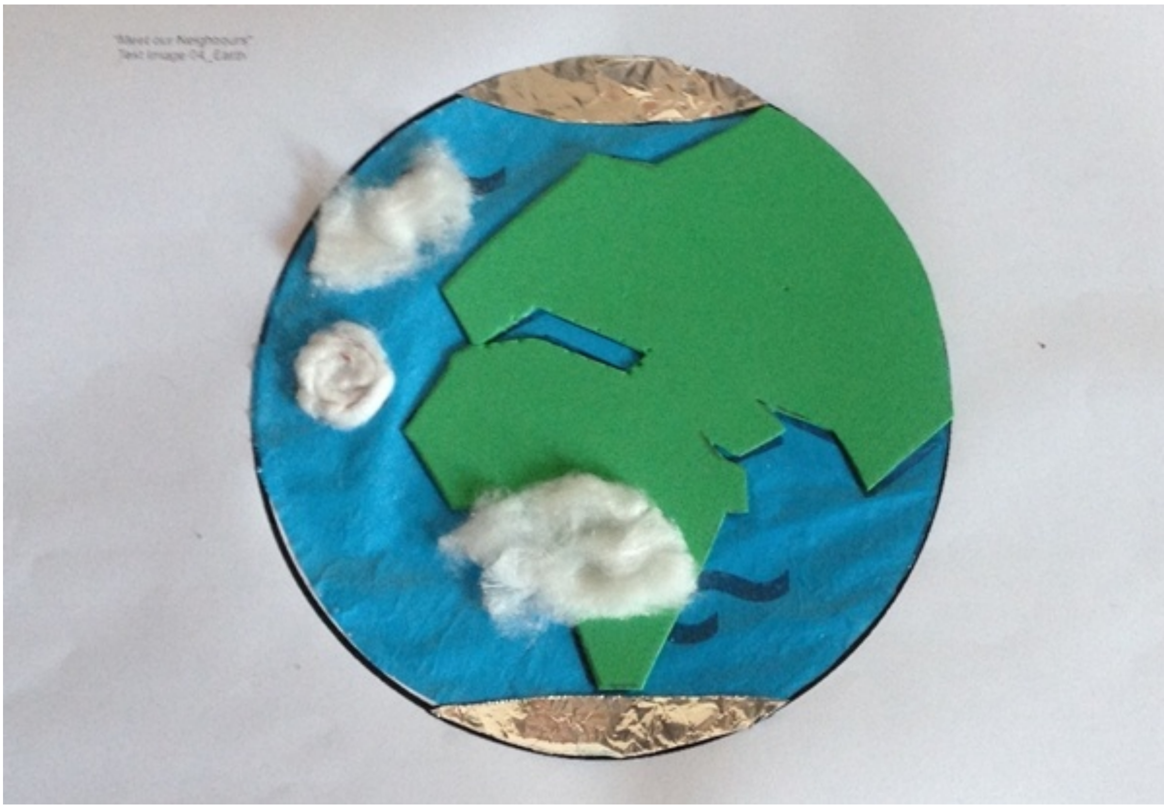
- These are huge storms where the wind is really strong (Hurricane).

Ask students to discuss the importance of building models, strengths and limitations of this model of the Earth, and how they might improve the model.

Ask students to write down two things they learned from the activity in their groups, and two things they want to learn more about.

MATERIALS

- Thin wire (for hurricane feature)
- Cotton (for clouds and hurricane)
- Aluminium foil (for polar caps)
- Thick fabric (for continents)
- Plastic (for liquid water)
- Glue
- Scissors
- Pen
- Earth Features PDF print out
- Earth Mold PDF (two copies) print out



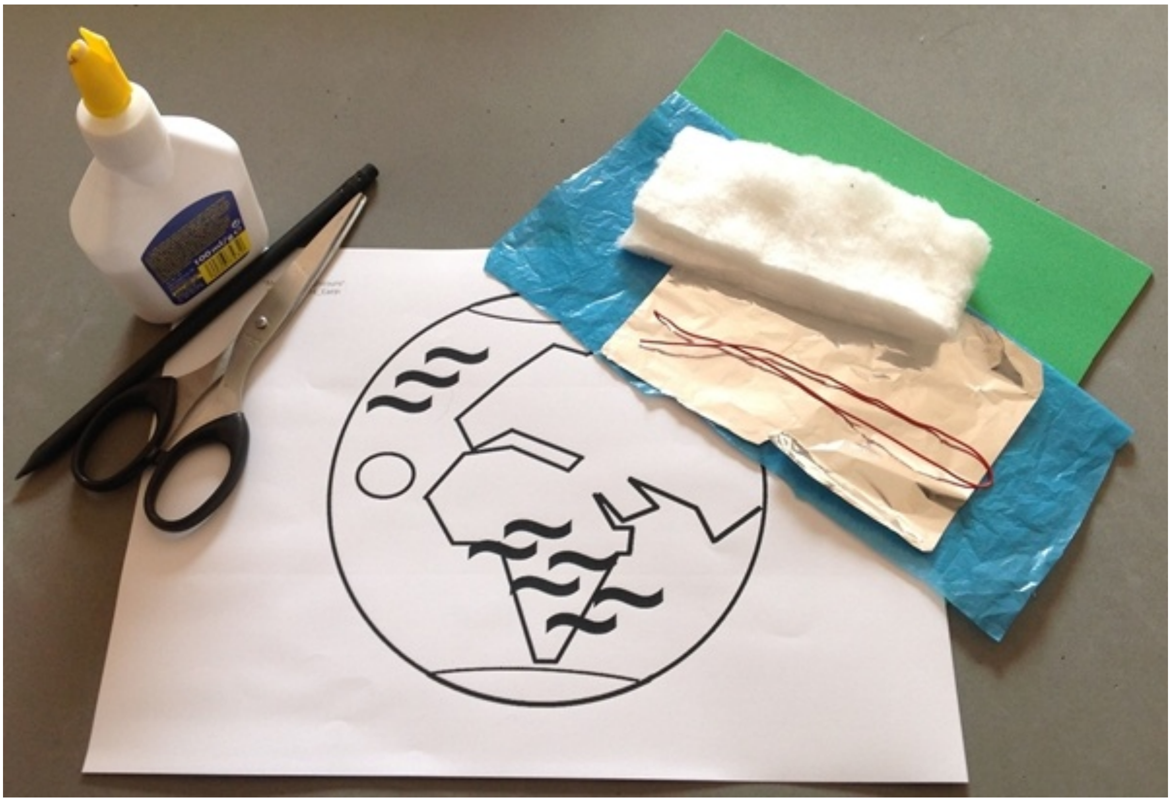
BACKGROUND INFORMATION

Earth

Earth is our home and the third planet from the Sun. With a mean distance between the Sun and Earth of 150 million kilometres, the average surface temperature is above the freezing point of water (0 degrees C). Unlike on Venus or Mars, whose surface temperatures are either much warmer or colder, this means that liquid water can exist freely on Earth. This has played a fundamental role in the development of life on our planet. The shape of the Earth is very close to a sphere. Because of its slow rotation — once every 24 h — the distortions are small, the difference between the equatorial radius (6,378 km) and the polar radius (6,357 km) being only 21 km. Earth only has one natural satellite, the Moon, which is thought to have played a major role in stabilising the axis of rotation of the Earth. Once again, this may have been a favourable element in the emergence of life.

Tactile features

The tactile model of the Earth includes a number of features that represent real features of Earth. You can find more information about these features below.



Liquid water, continents and polar caps

On Earth, 71% of the surface is covered by liquid water (represented by plastic on the tactile model), so the area occupied by seas and oceans is more than twice that occupied by land. The distribution of lands and seas is unequal and peculiar: the majority of land masses are in located in the Northern hemisphere, as three major continents (Europe, Asia, and North America).

Continents are represented by the thick fabric on the tactile model. The poles of the Earth are also quite different: there is an ice-covered continent at the South Pole (Antarctica), but an ocean at the North Pole (the Arctic Ocean), which forms an ice cap in winter (both represented by the aluminium foil on the tactile model). On Earth, surface elevations are measured with respect to the mean sea level. They vary between a height of 8,848 m (Mount Everest) and a depth of 11,000 m (the Mariana Trench in the northwest part of the Pacific Ocean). The average depth of the oceans is 3,800 m, and the average altitude of land is 840 m.

Clouds and hurricanes

Earth has a relatively thin atmosphere extending to less than 200 km altitude. Dry air is mainly composed of nitrogen (N_2: 78.08%), oxygen (O_2: 20.95%), and argon (Ar: 0.93%). The remaining 0.04% is a mixture of “trace” gases, mostly carbon dioxide (CO_2), but also rare gases such as neon (Ne), helium (He), and krypton (Kr). On average, water vapour (H_2O) accounts for 0.25% of the mass of the atmosphere, but its concentration varies a lot depending on the local temperature: it can be anywhere between 0.01% and 5%. When lifted to the upper parts of the atmosphere (above 3000 m on average), water vapour condenses to form clouds of very diverse densities and shapes (represented by clumps of cotton on the tactile model); some of these clouds can develop into powerful hurricanes over the oceans (represented by curled wire and cotton on the tactile model). Earth’s climate has recently begun undergoing an unprecedentedly fast warming phase due to the action of “greenhouse gases”, such as carbon dioxide and methane, that humans have been releasing in large quantities since the beginning of the industrial era. These gases tend to trap infrared radiation from the Earth's surface, causing the Earth's surface to heat up; we call this phenomenon the "greenhouse effect."

FULL ACTIVITY DESCRIPTION

Prior to the activity:

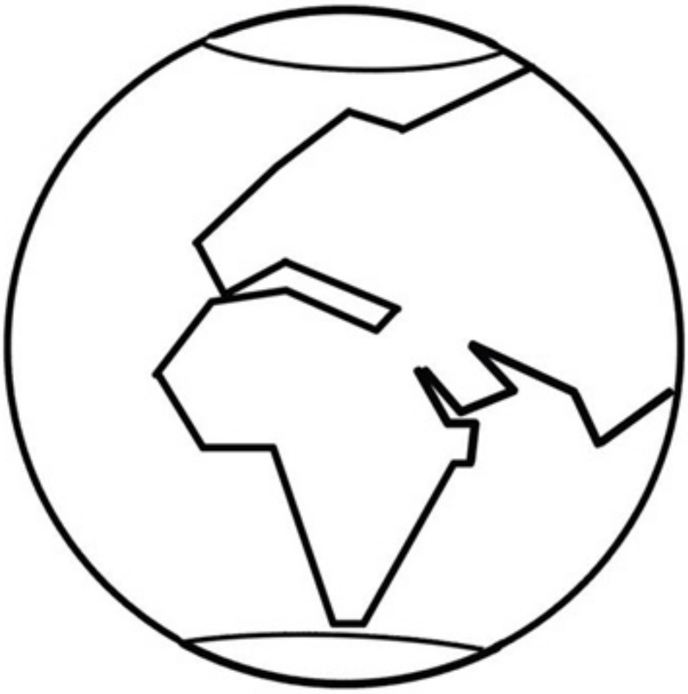
- Print both Earth mold and Earth features PDFs for each group, and prepare the materials listed above.
- Ask students what they know about the Earth, and how it looks from space. Tell students they will be making models of the Earth to investigate its different features.

During the activity:

- Put the students in groups of 5 (ideally 3 non-visually impaired to 2 visually impaired).
- Distribute materials accordingly.
- Close supervision is important. Follow each group and explain each of the tactile elements and their correspondence to each object feature.
- Understand the different needs of each group of students to promote interaction between the students during the building of the tactile model. Visually impaired students need to be familiarized with the different materials involved.
- Give enough time to follow instructions and build the tactile image.

Step 1

Print two copies of the 'Earth Mold PDF.'



Step 2

Cut the outer round shape of the Earth from one of the printed papers.

Step 3

Place the paper cutout on top of the plastic and draw the outline.

Step 4

Cut the plastic according to the drawn section.

Step 5

Apply glue on the surface of the Earth in the other printed paper.

Step 6

Place the circular plastic cutout on top of the glued area.

Step 7

Cut the shape of the polar caps on the previously cut 'Earth Mold PDF.'

Step 8

Place the polar caps on aluminium foil and draw the outline.

Step 9

Cut the aluminium foil along the outline.

Step 10

Glue the aluminium foil (polar caps) on top of the previously glued plastic circle on the paper.

Step 11

Print the 'Earth Features PDF' and cut the shapes of Earth's continents.

Step 12

Place the paper cutout (continents) on top of the thick fabric and draw the outline.

Step 13

Cut the thick fabric according to the drawn section.

Step 14

Apply glue on the cutout and paste it on the plastic circle.

Step 15

Curl the cotton around the thin wire to produce the hurricane feature.

Step 16

Curl the wire into a spiral that fits in the round shape of the hurricane.

Step 17

Apply glue and paste the hurricane on the model.

Step 18

Apply glue on the regions denoted by the curved lines.

Step 19

Place cotton on top of the glue to produce the clouds feature. Wait for the model to dry. This may take a while.

Exploring the tactile model:

There are several ways in which you can explore the scientific content of the tactile model.

If you're presenting the final tactile model to the students, first let them explore and feel the different textures. Questions will arise as the students explore; encourage them to write their questions down and share them with the other groups.

Read "Background Information" to understand the different features present in Earth's schematic tactile model, and share with the students as they ask about them, or (if you have more time), prompt each group to choose a feature to learn more about and then have them present their findings to the other groups in the class.

- Water is represented by the plastic texture.
- The continents are represented by the thick fabric.
- The polar caps are represented by aluminium foil.
- The hurricanes are represented by cotton and wire curled up.
- The clouds are represented by cotton.

Discuss the idea of models with the students. Suggested discussion points:

- What is a model? Why is it useful to build models?
- What are the strengths of this model?
- What are the limitations of this model?
- How could the model be improved?

Ask students in their groups to write down two things they learned from the activity, and two things they want to learn more about.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Our fragile planet, Sun-Earth-Moon, the Earth

National UK

KS3 - Chemistry, Earth and Atmosphere KS2: Year 5 - Science, Earth and Space KS2 - Art and Design

ADDITIONAL INFORMATION

Explore the rest of the planets through ‘Meet Our Neighbours’ in tactile form at http://nuclio.org/astroneighbours/resources/

CONCLUSION

Students build a tactile version of Earth using cheap household items and use it to identify the different tactile characteristics of Earth.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement nº 638653

MEET OUR NEIGHBOURS: SUN

Explore the tactile version of our star, the Sun, made with household materials.

Lina Canas, Núcleo Interativo de Astronomia

Curriculum topic
Sun-Earth-Moon

Big idea of science
Earth is a very small part of the universe.

Keywords
Sun, Solar System

Age range
6 - 12

Education level
Primary School, Middle School, Informal

Time
1h

Group size
Group

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Developing and using models, Communicating information

Type of learning activity
Fun learning

BRIEF DESCRIPTION

Converting a visual experience to a tactile one, this activity lets visually impaired students learn about and explore our star, the Sun, and its main characteristics.

GOALS

To explore our star, the Sun, through a tactile hands-on experience for visually impaired students and their non-visually impaired peers.

LEARNING OBJECTIVES

- Students will create a tactile version of the Sun using low cost household materials.
- Students will explore characteristics of the Sun using the tactile model.
- Students will be able to list the different features present on the Sun.

EVALUATION

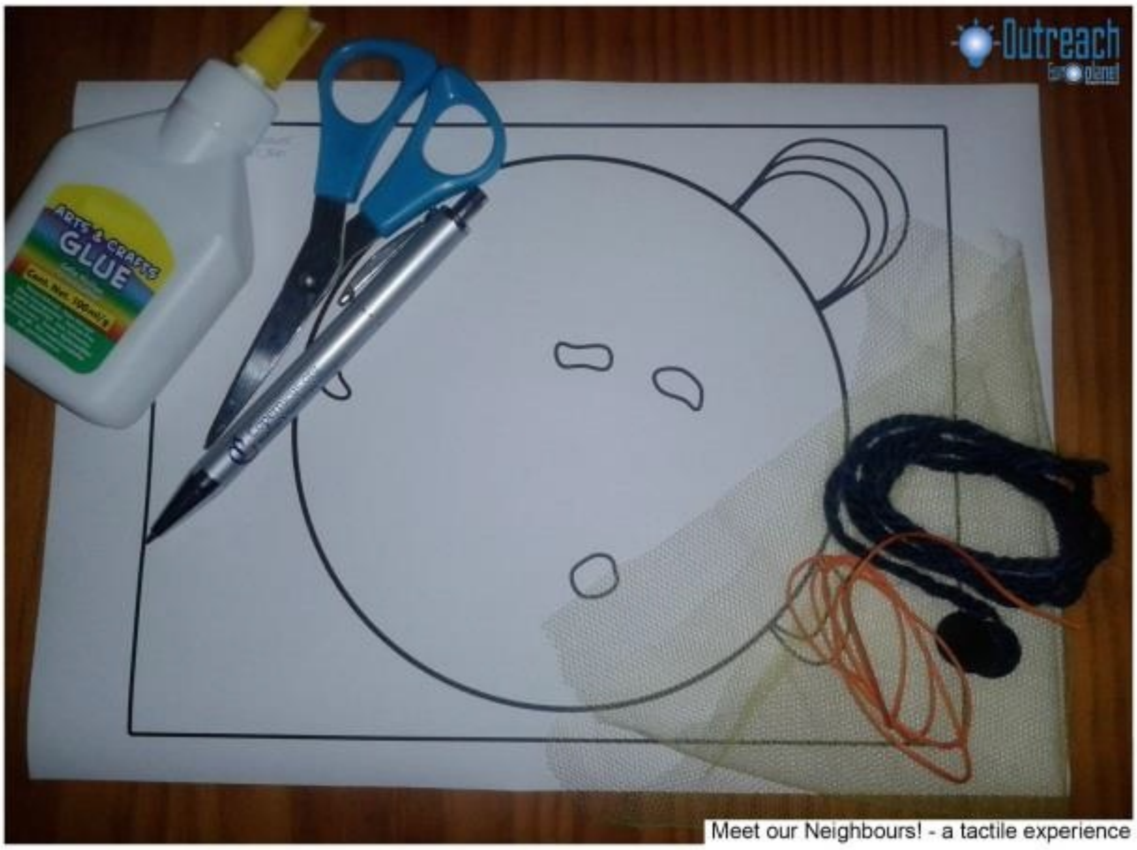
Call out a feature on the Sun (sunspot, solar surface, solar prominence) and ask the students to point it out on their model. For each feature give a brief description.e.g.:

- These are small, dark, cool areas on the Sun surface (Answer: sunspot).
- These are long loops of solar material held above the sun's surface by a magnetic field (Answer: prominence).
- We see light coming from this part of the Sun. It has a temperature of over 5000˚C! (Answer: solar surface)

Ask the class to suggest how the Sun affects us and helps life on Earth. (Ideas to include: the Sun provides us with a) heat which keeps us warm b) heat which keeps the oceans warm enough to be water rather than ice and c) light to see and give plants energy to grow. The Sun also produces solar flares- very large outbursts of energy which leave the Sun. When these flares reach the Earth, they can disrupt Earth satellites, interrupting GPS and mobile signals.)

MATERIALS

- Flat black sequins (for sunspots)
- Yellow thread or wool (for solar prominence and outline)
- Fabric of granular texture (bubble wrap or netting) (for surface of the Sun)
- Print out 'Sun Features 1 PDF'
- Print out 'Sun Features 2 PDF'



BACKGROUND INFORMATION

The Sun is a "yellow dwarf" star of average dimension and mass. Its diameter is about 1,400,000 km, which means that more than 100 Earth could be lined up along the Sun's equator, and its mass is more than 300,000 times that of Earth. But compared to other types of stars, the Sun is quite average: the radius (mass) of the smallest type of stars, called "brown dwarfs", can be as low as 0.05 solar radius (0.01 solar mass) whereas that of the largest type of stars, called "supergiants" or "hypergiants", can reach 1000 solar radii (200 solar masses). The Sun produces its energy from thermonuclear reactions taking place at its very centre, where the temperature reaches 15 million degrees. This process, which involves "burning" hydrogen and transforming it into helium, has been going on for the last 4.5 billion years and is expected to last about the same amount of time.

The surface of the Sun, called "photosphere", is much cooler than its core, with a temperature of 5500°C. At certain locations on the photosphere, called "sunspots" the temperature is lowered by about 1000°C due to the action of the magnetic field which "punctures" the photosphere at these locations. This makes them appear darker than the surroundings. The spots always appear in pairs with opposite magnetic polarities (the four irregular shaped areas on the tactile model). The activity of the Sun can be measured by the number of spots appearing on the photosphere during a particular year. This activity varies periodically along a cycle of about 11 years. The last minimum occurred in 2014 and the next maximum is expected in 2019-2020. However, between two consecutive cycles, the magnetic field reverses itself; so a complete cycle is actually 22 years long.

Other remarkable features of the sun are the "solar prominences" (represented by loops of thin thread at the edge of the tactile model). They are actual bridges of matter between solar spots, shaped by the powerful magnetic field of the sun. Some of them can be lifted above the photosphere by as much as 350,000 km, which is almost the distance between the Earth and the Moon. They can also be completely disrupted by violent explosions before all the matter has time to fall back onto the surface, in which case some of the matter is sent flowing throughout the solar system.

The sun has an atmosphere, called the "chromosphere" because of its dark orange colour. It can only be seen during natural or artificial eclipses as a thin orange layer around the much brighter photosphere. Finally, above the chromosphere, lies the "corona", a region containing very rarefied gas heated up to one million degrees by a process which is still poorly understood. Like the chromosphere, it can only be seen during an eclipse as a shiny halo with bright streaks of hot plasma.

FULL ACTIVITY DESCRIPTION

Prior to the activity:

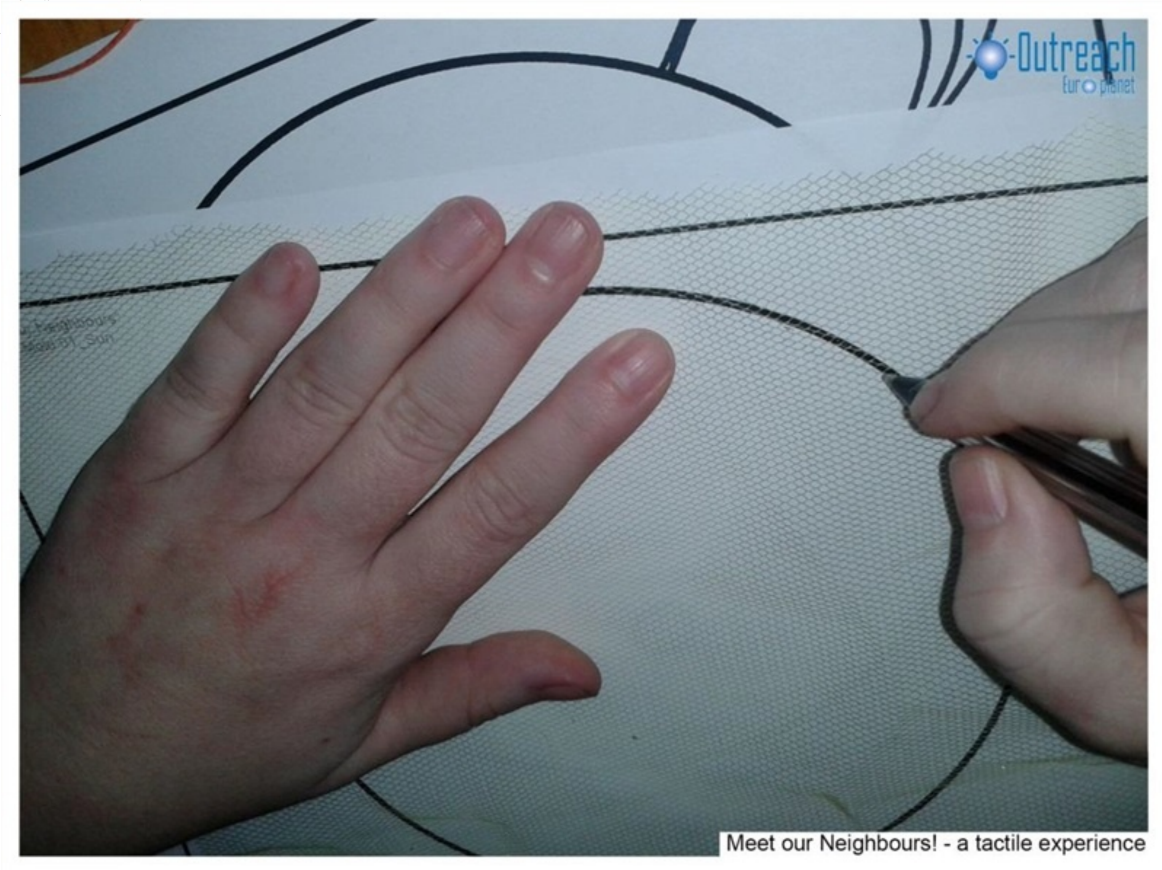
- Print both Sun mold and Sun features PDFs for each group, and prepare the materials listed above.
- Ask students what they know about the Sun, introducing it as the star closest to Earth and a hot ball of "burning" gas. Tell students they will be making models of the Sun to investigate its different features.

During the activity:

- Put the students in groups of 5 (ideally 3 non-visually impaired to 2 visually impaired).
- Distribute materials accordingly.
- Close supervision is important. Follow each group and explain each of the tactile elements and their correspondence to each object feature.
- Understand the different needs of each group of students to promote interaction between the students during the building of the tactile image – visually impaired students need to be familiarized with the different materials involved.
- Give enough time to follow instructions and build the tactile image.

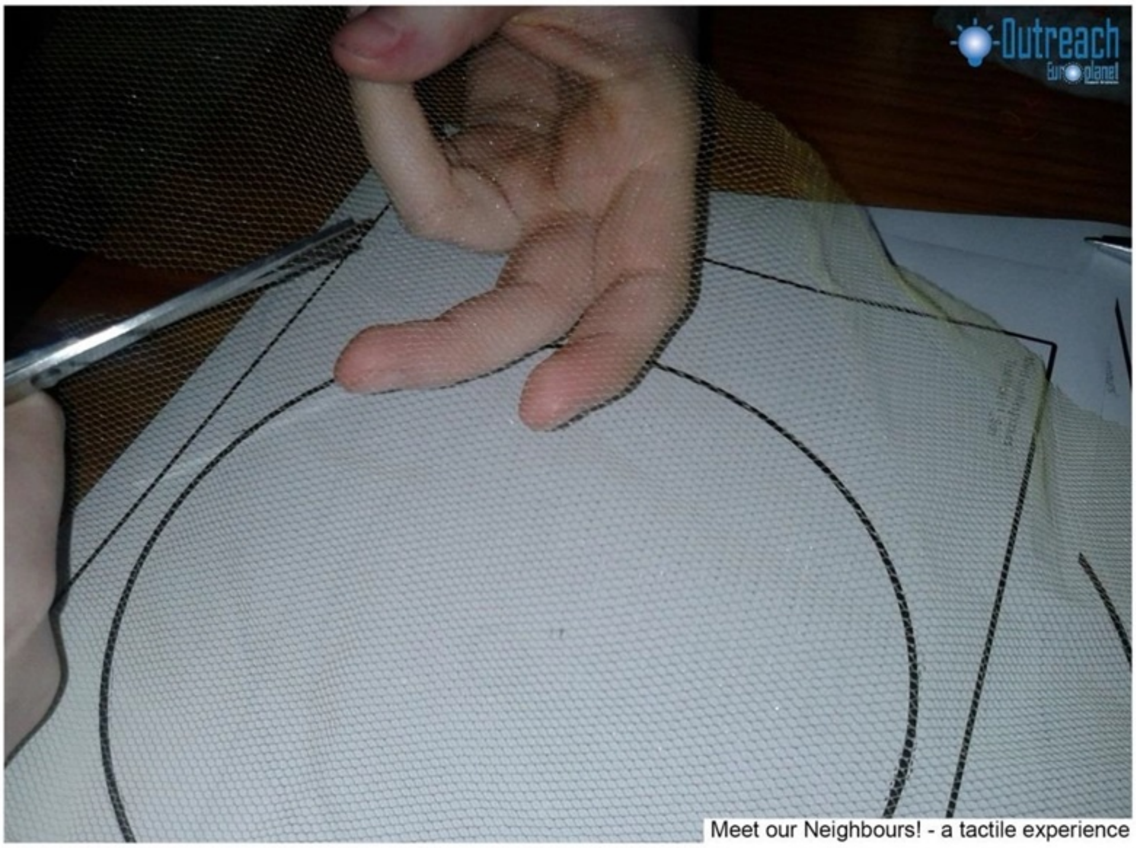
Step 1

Place the fabric on top of Sun mold sheet and draw the outline.



Step 2

Cut the fabric along the drawn outline.

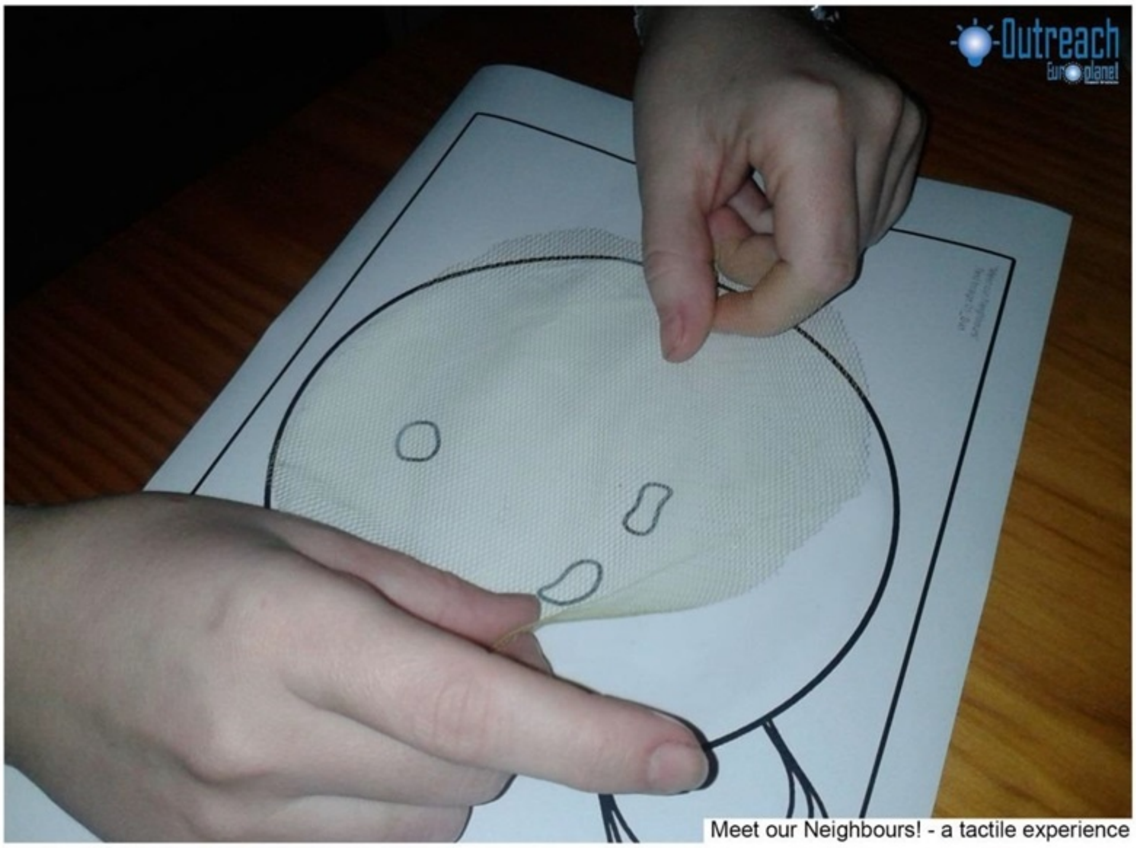


Step 3

Apply glue on the surface of Sun on the Sun features sheet.

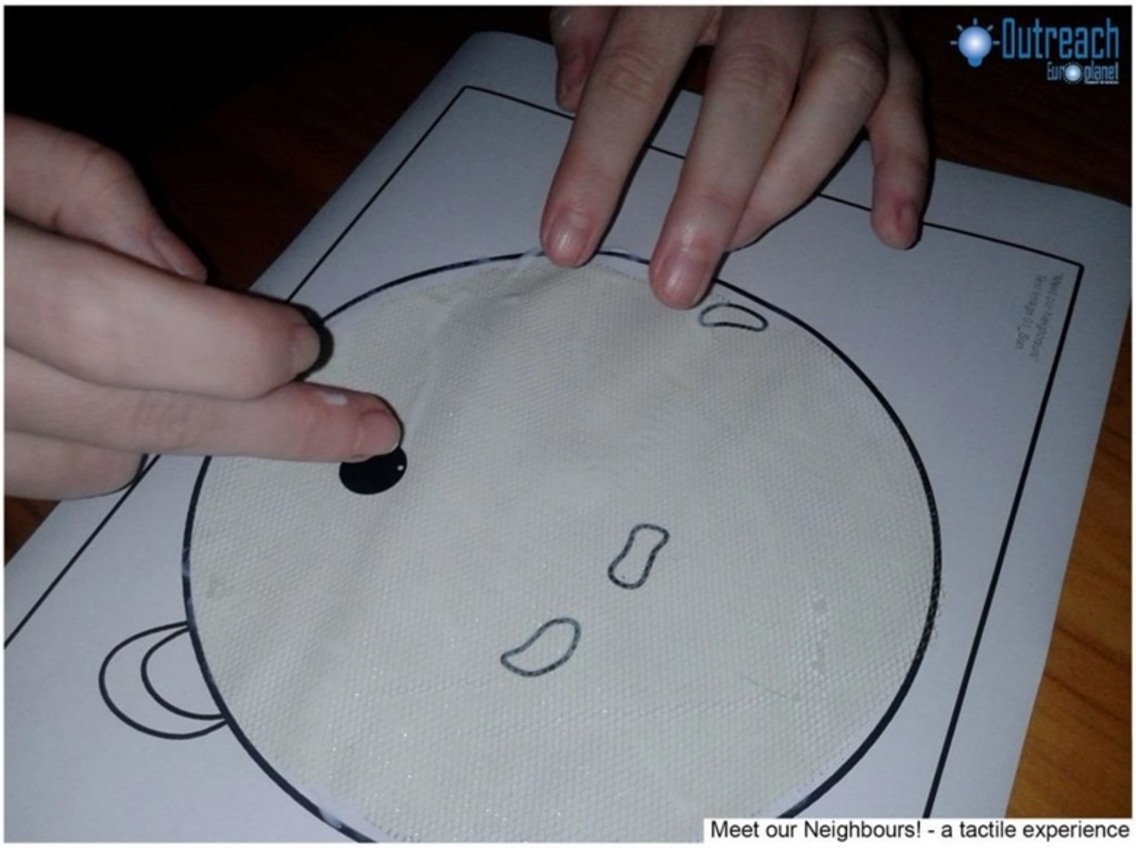
Step 4

Place the fabric on top of the glued area and wait for the model to dry.



Step 5

Glue the different sequins on top of the glued fabric.



Step 6

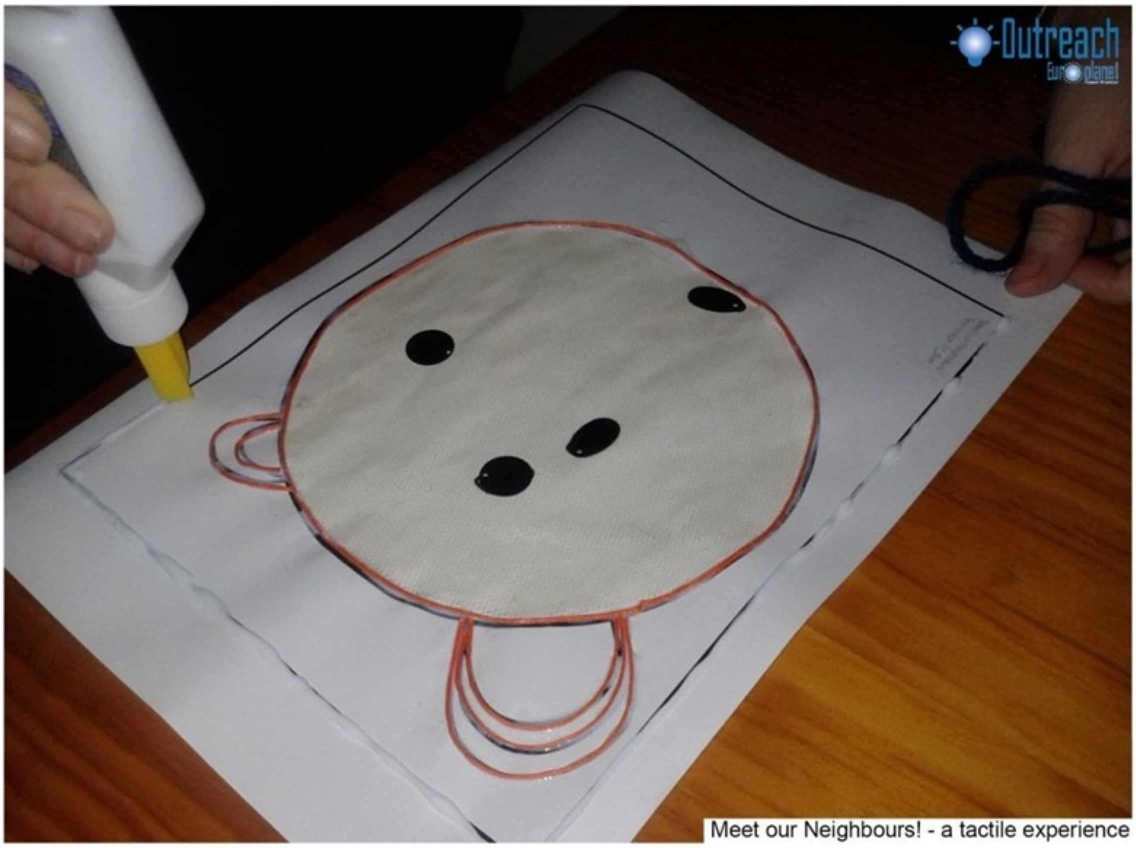
Glue the thin thread to the outer shape of the sun.

Step 7

Glue the thin thread to the prominence features.

Step 8

Wait for the model to dry (it might take a while before you can explore the model).



Exploring the tactile model:

There are several ways in which you can explore the scientific content of the tactile model. If you're presenting the final tactile model to the students, first let them explore and feel the different textures. Questions will arise as students explore and it is important to guide them. Read "Background Information" section to understand the different features present in the Sun's schematic tactile model.

The star's outer shape is outlined by a thin thread (2). Follow the thread until you find (3) the solar prominence.The interior of the thin thread (2) is the fabric showing the sun's surface (4). There are several sunspots (5) present.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Sun-Earth-Moon

National UK

KS3 - Physics, Space Physics: Our Sun as a Star KS2: Year 5 - Science, Earth and Space KS2, Art and Design

ADDITIONAL INFORMATION

Explore the solar system planets through "Meet Our Neighbours" in tactile form at http://nuclio.org/astroneighbours/resources/ Follow up discussion: How long does it take Sun light to travel to Earth? (take students outside during the day time to feel the sunshine). Answer: approximately 8 minutes (can be calculated from time= distance /speed = 150 million km / 300,000,000 metres per second = 150,000,000 m/300,000,000 m/s).

CONCLUSION

The activity concludes when the students have explored and experienced the tactile Sun and are able to identify the characteristics of the Sun.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

MEASURE THE SOLAR DIAMETER

Hands-on activity to measure the Sun by using household materials.

Edward Gomez, LCOGT

SPACE awareness

Curriculum topic
Solar System

Big idea of science
Earth is a very small part of the universe.

Keywords
Sun, Observation, Measurement, Maths, Physics

Age range
12 - 19

Education level
Middle School, Secondary School, Informal

Time
30min

Group size
Group

Supervised for safety
Supervised

Cost
Low (< ~5 EUR)

Location
Outdoors

Core skills
Using mathematics and computational thinking, Constructing explanations, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

The Sun moves across the sky at a constant rate because of the rotation of the Earth. By measuring how fast the Sun moves, you can work out how big the Sun appears in the sky. All you need are some household items and about 30 minutes on a sunny day.

GOALS

- Students will have an appreciation of the relative and actual size of the Sun.
- Students will have an appreciation of how fast the Sun moves across the sky.

LEARNING OBJECTIVES

- Students will be able to describe perspective which makes the Sun appear smaller in the sky than it is in reality.
- Students will be able to describe why the Sun appears to move across the sky when in fact its apparent motion is produced by Earth’s rotation.
- Students will be able to convert between different time units, angles and calculate an accurate diameter for the Sun.

EVALUATION

- Make sure each of the objectives is reached.
- Ask students to describe what is happening as Sun moves across sky by using a ball and globe (representing the Sun and Earth).

- Ask students to explain their measurements in terms of the ball and globe model.

MATERIALS

- a small mirror (it needs to be covered by the thick paper, so it must be between 5 and 20 cm)
- a piece of thick paper or card to cover your mirror
- a tripod or a lump of Plasticine or playdough
- something to use as a screen (a piece of A4 or A3 white paper with a cardboard backing will do)
- a pencil or marker pen to write on the screen
- masking/electrical/duct tape
- a stop watch

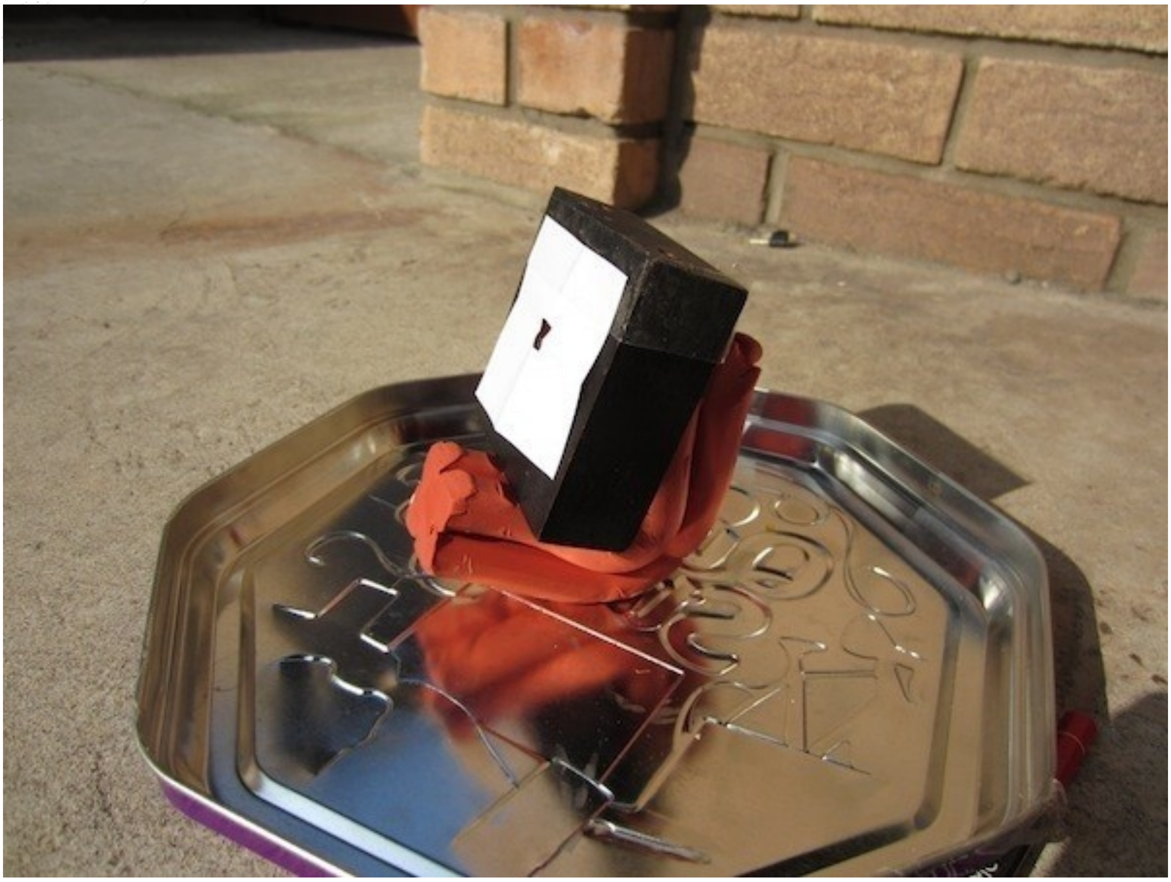
BACKGROUND INFORMATION

- Understanding of the concept of angles and angular distance
- Understanding of the concept of velocity
- Appreciation that the sun's movement is apparent, and caused by the Earth's rotation, and
- Awareness of the dangers of looking directly at the Sun.

FULL ACTIVITY DESCRIPTION

Setup:

- Cut a small hole (something between a pinhole and 5mm diameter hole) in the centre of the piece of thick paper.
- Tape this piece of paper to the front of your mirror, so that you can only see the mirror through the small hole you made.
- Attach the mirror to the tripod, so that the paper faces upward.
- If you don't have a tripod, put the plasticine/playdough on the floor and embed the block on it so that the mirror is at about a 40 degree angle (facing the Sun).
- Stand your screen up and make sure it cannot move during the experiment: if it does move, you will have to start all over again.



Method:

- Angle the mirror so the Sun is reflected onto the screen.
- The projected image of the Sun must be circular, so angle your mirror and screen until it is.
- Trace around the image of the Sun on the screen.
- Start your stopwatch.
- Wait until the Sun has moved to just outside the circle you drew.
- Note the time on the stopwatch and reset.
- Repeat steps 2–5 a few times (repeat 3–4 times for more accurate results).
- Take the mean (average) of all your timings (in seconds).

Discussion and Results

In this activity, you have been measuring how long it takes the Sun to move a distance equal to its own diameter across the sky. The Sun will take 24 hours to travel 360 degrees all the way around the sky and return to the same position it was in on the previous day. The speed it travels at is:

360 degrees/24hours: = 360 deg/(24x60) minutes
= 0.25 deg per minute
= 0.00416 degrees per second or 1/240 degs per second

Calculate the size of the Sun as an angle:Average duration (in seconds) × 1/240 (degrees per second) = _ degrees

Congratulations! You have calculated the angular size of the Sun.

Calculate the physical size of the Sun

You can use your value for the angular size of the Sun to calculate the physical size of the Sun.

Your number for angular size converted into radians × distance from Earth to the Sun = size of the Sun

Angular size × (pi/180) × 92 955 887.6 miles = _ miles OR

Angular size × (pi/180) × 149 598 000 km = _km

Congratulations! You have measured and calculated the diameter of the Sun in miles/kilometers!

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, Solar System

National Curricula UK

GCSE, physics: AQA Science A, Edexcel, OCR A, OCR B, WJEC GCSE, astrophysics: Edexcel (1.1.3: a, b) KS3, phyics: space physics

ADDITIONAL INFORMATION

Make sure you are getting an image of the Sun reflected from the mirror and not just a reflection of the mirror itself. The small hole in the thick paper is essential in this regard. If the hole is too big or the paper is too far from the mirror, you will not get a good projection. This will take some experimentation.

Make sure the screen does not accidently get moved.

Make sure the screen is face on to the mirror so the projected image is circular.

The Sun does not take exactly 24 hours to return to the same place in the sky because in that time, the Earth has moved a 1/365th of its journey around the Sun. This phenomenon is masked by the measurement accuracy of this activity, but you might like to discuss it with the students.

When performing the calculation we convert 360° into 2pi radians. Radians allow us to make calculations involving angles and distances. It can be explained to the students by saying that degrees are a unit. When you walk in a circle, although you have moved 360° you have also walked 2pi x radius of the circle. You can prove this by drawing a small circle on paper, wrapping a piece of string around the edge and then measuring the string. The measurement will be the same as 2pi x radius of the circle you drew.

You can see a full calculation of the diameter worked through as an interactive pencast on the LCOGT website http://lcogt.net/education/activity/measure-diameter-sun

Image of the Sun: NASA STEREO Captures Huge Eruptive Prominence 304 April13

CONCLUSION

The activity concludes when all the steps have been completed and a size for the Sun has been calculated (and compared with a value listed in a text book). If there are multiple groups doing this activity, collect all the answers and see how much variation there is.

This activity can be used to start a discussion about many other astronomical concepts, such as size scales in the Solar System or unit conversions.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653

MODEL OF A BLACK HOLE

Understand the mystery of black holes through a hands-on activity.

Monica Turner, UNAWE

SPACE awareness

Curriculum topic
the origin and structure of the Universe

Big idea of science
Earth is a very small part of the universe.

Keywords
Black hole, Universe, space

Age range
8 - 12

Education level
Primary School, Middle School, Informal

Time
1h

Group size
Group

Supervised for safety
Unsupervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Asking questions, Developing and using models

Type of learning activity
Demonstration / Illustration

BRIEF DESCRIPTION

Many children may have heard of black holes and already have the understanding that they are 'bottomless wells'. If something falls into a black hole, it is impossible for it to escape—even light cannot escape and is swallowed. The lack of light is how black holes get their name. These objects are mysterious and interesting, but they are not easy to explain. This activity will allow children to visualize, and therefore help them decompose, the concepts of space-time and gravity, which are integral to understanding these appealing objects.

GOALS

To gain a basic understanding of what a black hole is and how its gravity affects space-time by building an interactive model of a black hole.

LEARNING OBJECTIVES

- Use an interactive, hands-on activity to introduce students to the important astronomical concepts of black holes, gravity and space-time.
- Students will build a physical model of the space curvature around a massive object and observe the effect on a less massive object.
- Students will be able to describe what happens to an object passing a gravity well, if its velocity is not high enough or if the gravity well is too deep.

EVALUATION

During (or after) the activity, ask students to describe what they observe: how do objects with different mass (and gravity) affect space-time? Example of questions you can ask are:

- If a less massive ball was used, how would the behaviour of the marbles change? (Answer: The less massive ball has less gravity so will distort space-time less. Therefore the path of the marbles will bend less towards the ball as they travel slower.)

- If the marble and ball were the same mass, how would they behave? (Answer: With the same gravity they would equally distort space-time, so would orbit each other, losing energy until they 'fall' into each other.)
- If you rolled the marbles with more force, what would happen? (Answer: The marbles would have more energy and travel faster. If they do not pass too close to the ball they will travel past it rather than 'fall' in. Their path will still be slightly distorted from a straight line.)

MATERIALS

- Light elastic bandage used for muscular injuries (i.e., Tubifix)
- Small marble
- Very heavy ball (such as those used in games of boules, bocce or pétanque)

BACKGROUND INFORMATION

Gravity

Gravity is a force of attraction between two objects. All objects with mass (weight) have gravity. Gravity acts like a magnet, pulling objects together. What causes gravity is not really known. The Earth has gravity, which holds everything close to the planet so that it does not float into space: trees, water, animals, buildings, and the air we breathe are all held here by gravity. All of the planets, the stars and the moons of the Universe also have gravity. Even our own bodies exert gravitational forces on other objects. The Earth's gravity is far stronger than our own, so the gravity our bodies possess is not noticeable. Gravity is affected by the size and proximity (closeness) of objects. The Earth and the Moon have a stronger pull on each other than the Earth and Jupiter because the Earth and Moon are closer to one another. Earth has a stronger pull than the Moon because it is larger, so there is more pull on our bodies here on the Earth than the pull on the bodies of astronauts visiting the Moon. That's why astronauts can jump higher on the Moon than on Earth. We don't actually 'feel' gravity. We only feel the effects of trying to overcome it by jumping, or when we fall. Actually, the man who thought of the 'Universal Law of Gravitation' was inspired by an apple falling on his head as he sat thinking in the garden. The apple was being pulled to Earth by gravity!

Black Holes

A black hole is a region in space where gravity is so strong that nothing that enters it can escape, not even light! Black holes form when a massive star runs out of fuel and becomes unable to support its heavy outer layers of gas. If the star is large enough—approximately 25 solar masses—then gravity pulls on the gas and causes the star to grow smaller and smaller until its density reaches infinity at a single point. This is called a 'singularity'.

After the black hole forms, it can continue to grow by absorbing mass from its surroundings, such as other stars and other black holes. If a black hole absorbs enough material, growing to over one million solar masses, it becomes a 'supermassive black hole'. It is believed that supermassive black holes exist in the centres of most galaxies, including the Milky Way.

A black hole is made up of three parts: the singularity (the collapsed star), the 'inner event horizon' (the region around the singularity where nothing, not even light, can escape), and the 'outer event horizon' (where objects will still feel the gravity of the black hole but do not become trapped).

Astronomers usually observe objects in space by looking at the light. However, since black holes don't emit any light, they can't be observed in the usual way. Instead, astronomers have to observe the interaction between the black hole and other objects. For example, as black holes pull material in, like water being sucked down a plughole, the material forms a disc around the black hole. As the disc spins faster and faster, it heats up to extreme temperatures, causing enormous amounts of light and material to be emitted into space as dazzling jets. If they're pointed towards us, these jets are extremely bright and can easily be picked up by our telescopes on Earth. For black holes that are not 'feeding', one way to detect them is to observe the motions of stars around the black hole, since their orbits will be altered by its presence.

Space-time

Space is made up of three dimensions (up-down, left-right and forward-backward). If you add the fourth dimension, time, then you have what's called the space-time continuum. This might sound strange, but imagine you are meeting somebody; you need to know which location (place in space) to meet them at, but you also need to know which time!

Albert Einstein was the first person to propose the idea of the 'fabric of space' (space-time), in his 'General Theory of Relativity'. Before Einstein's theories, it was believed that gravity was a force, as explained by Isaac Newton. But Einstein's general theory of relativity explains gravity as the 'curvature of space-time'. This concept can be pictured by imagining space-time as a rubber sheet. The balls on the rubber sheet bend the sheet around them, similar to the way matter bends space-time.

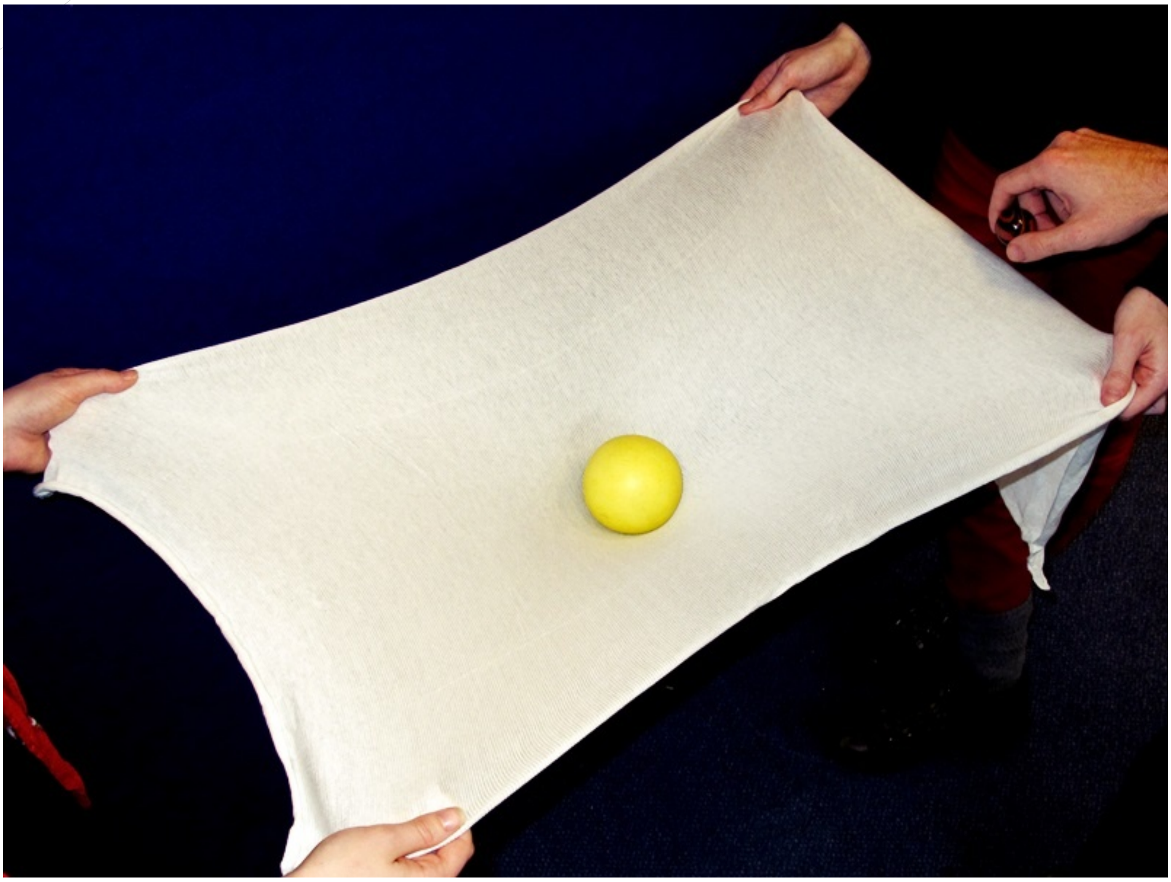
FULL ACTIVITY DESCRIPTION

In the following activity, students will build a model of a black hole, which is intended to help them visualize how exactly a black hole can 'bend' space and time and affect nearby objects. The activity should take about one hour.

Step 1

Before you begin the activity, use the 'Background Information' section to introduce children to the concept of gravity. You can do this by telling the story of Isaac Newton and the apple tree, and having all the children jump up and feel gravity pull them back to Earth.

Step 2



Cut a 40 × 40 cm piece of elastic bandage. If it is tubular, you will need to cut it through one side to make it flat.

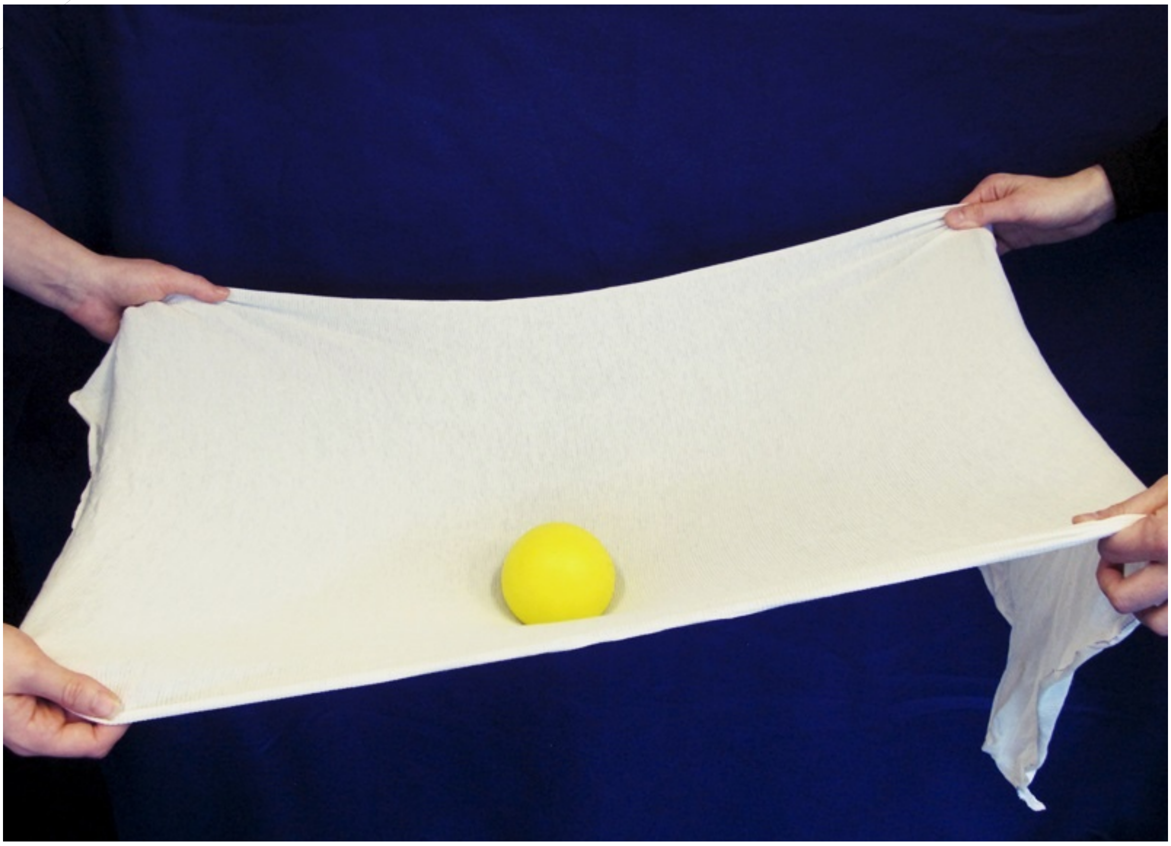
Step 3

Ask several students to stretch the bandage horizontally until it becomes taut to represent two-dimensional 'space'. Note that the students must hold the bandage still so that their movements do not affect the experiment.

Step 4

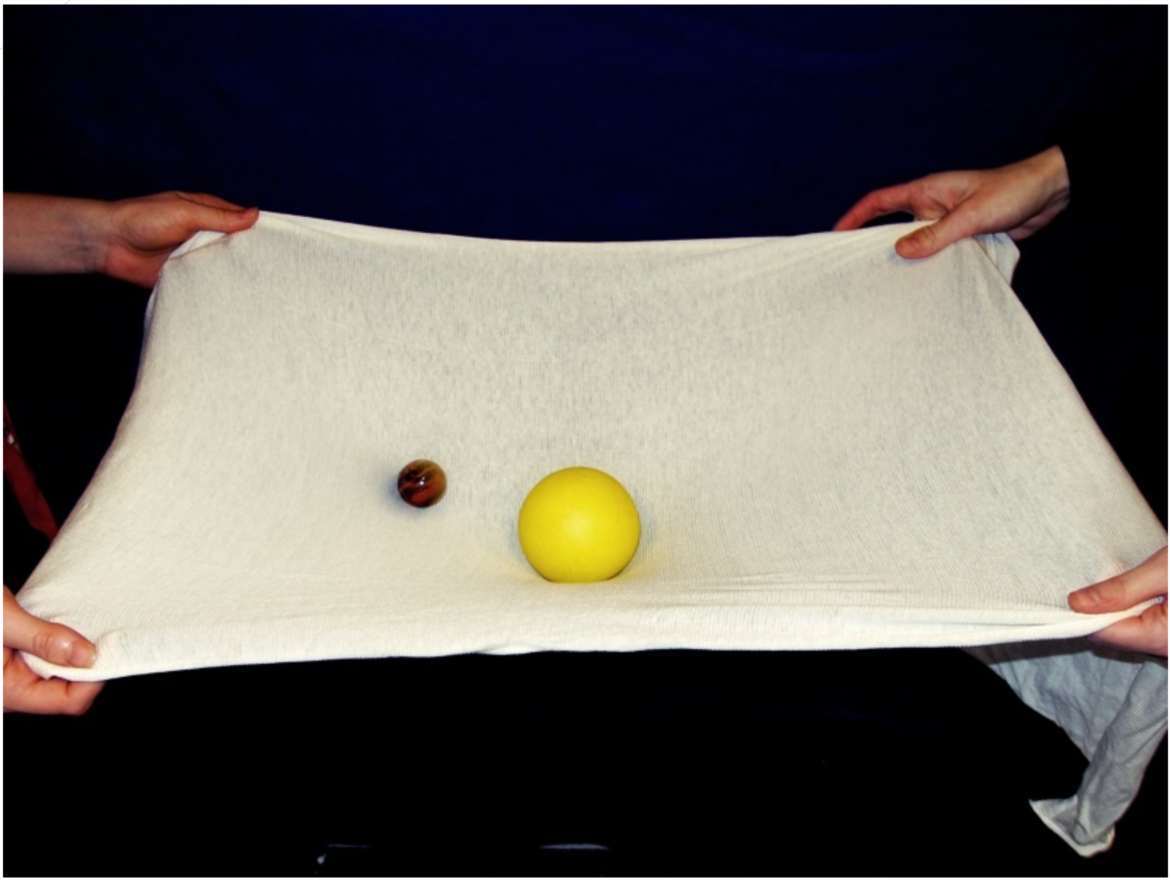
Place the marble on the bandage and make it roll across its surface. The marble's path should follow a straight line, similar to that of a ray of light travelling through space.

Step 5



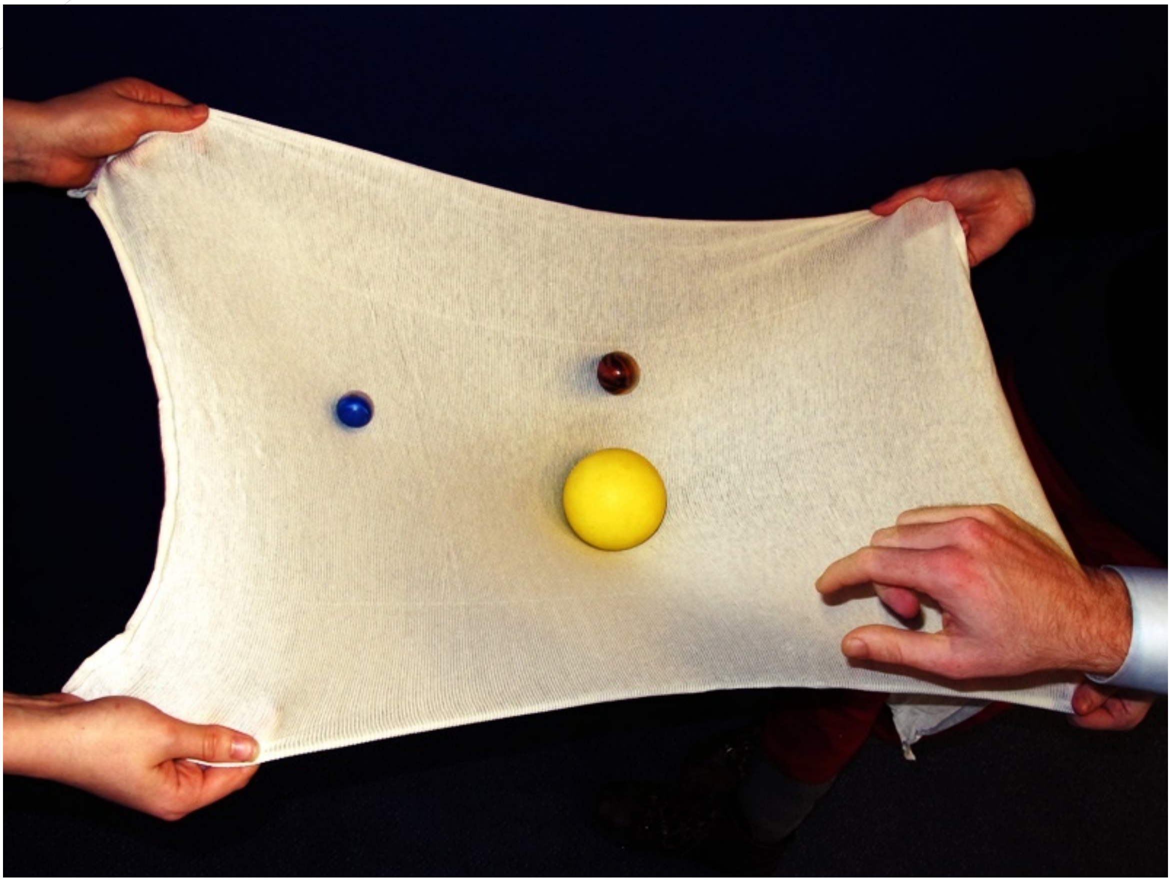
Swap the marble for a heavy ball. When you place it on the bandage you will see how it deforms the fabric of 'space'. 'Space' becomes curved around the heavy object.

Step 6



Make the same little marble roll close the heavy object. Its trajectory should now be altered by the deformation of the bandage. This is similar to what happens to light passing close to a massive object that deforms the space surrounding it. Try varying the speed of the marble to see how its path changes.

Step 7:



The more concentrated the central mass (i.e., the heavier the large ball), the more curved the bandage will be. This increases the depth of the 'gravitational well' from which the marble will not be able to escape.

Step 8:

As the marble passes close to the large ball, it starts to revolve around the 'black hole' and eventually falls in. You can now see how things may easily fall into a black hole but cannot come back out. This is what happens with black holes: their gravity deforms space in such a way that light or other objects fall in and cannot escape.

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, the origin and structure of the Universe

National UK

KS3 - Physics, Motion and Forces: Forces (gravity) KS2: Year 5 - Science, Forces and Magnets

ADDITIONAL INFORMATION

Accessible information about black holes from the ‘Ask an Astronomer’ site at Cornell University. It provides answers to many different questions and specifies difficulty level: beginner, intermediate, advanced http://curious.astro.cornell.edu/component/tags/tag/black-holes

A video by the European Southern Observatory showing real data taken of stars orbiting around a black hole: http://www.eso.org/public/videos/eso0846a/

A great interactive site from the Space Telescope Science Institute with extensive information about black holes as well as online activities and experiments:http://hubblesite.org/explore_astronomy/black_holes/

Follow up questions:

- What happens when you decrease the speed of the marble? Why?
- What happens when you use a heavier ball? What about a heaver marble?
- How would you be able to know if there is a black hole somewhere by observing the motions of the stars?

This resource was developed by Unawe and peer-reviewed by astroEDU.

CONCLUSION

The activity concludes when the black hole model has successfully been created and used to demonstrate the object’s behaviour. Teachers should then discuss the demonstration with the children to evaluate what they have learned.

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STAR IN A BOX

Explore the life-cycle of stars with the Star in a Box activity.

Edward Gomez, LCOGT

Curriculum topic
stars

Big idea of science
Earth is a very small part of the universe.

Keywords
Stars, Lifecycle of stars, Evolution, Interactive

Age range
10 - 19

Education level
Middle School, Secondary School, Informal

Time
30min

Group size
Group

Supervised for safety
Unsupervised

Cost
Average (5 - 25 EUR)

Location
Indoors (small, e.g. classroom)

Core skills
Constructing explanations, Engaging in argument from evidence, Communicating information

Type of learning activity
Partial enquiry

BRIEF DESCRIPTION

Have you ever wondered what happens to the different stars in the night sky as they get older? The Star in a Box application lets you explore the life cycle of stars. It animates stars with different starting masses as they change during their lives. Some stars live fast-paced, dramatic lives; others change very little for billions of years. The app visualises the changes in mass, size, brightness and temperature for all these different stages.

GOALS

- To understand the differences in the lifecycle of stars with different starting masses.
- To demonstrate the use of graphing as a tool for exploring different physical aspects of a complex system.

LEARNING OBJECTIVES

- Describe the relationship between a star's mass and its life span.
- State that stars above a certain mass end their lives in a supernova.
- Name the major stages of a star's life cycle, in order, for several masses of star.
- Describe the relationship between a star's mass, its age, and its position on the Hertzsprung-Russell diagram.

EVALUATION

The accuracy of their answers to the question can form the basis of the evaluation of students' understanding. However, more detailed feedback can be obtained by talking to individual students about their understanding.

- Ask students to talk through what is happening to a 1 solar mass star as the star marker moves around the graph.

- Ask students why different initial masses of star lead different life cycles; what are the main differences and happens at the end of these stars lives?

MATERIALS

- Computer with internet
- Star in a Box worksheets

BACKGROUND INFORMATION

- Students should understand what a star is in broad terms before starting this activity.
- Students should be familiar with the concept of hydrogen burning/fusion.
- Students should be familiar with using graphs to display and discern information.
- Teachers can use the Powerpoint presentation provided to give students a full lesson about the life cycle of stars before attempting the activity (available at http://lcogt.net/education/starinabox).

FULL ACTIVITY DESCRIPTION

Star in a Box app is available at http://lcogt.net/starinabox

Secondary School Level

Step1

- Open the lid of your 'Star in a Box'.
- The graph is a Hertzsprung-Russell diagram, where a star's luminosity is plotted against its temperature.
- The information panels allow you to compare the Sun with your star. It compares the relative radius, surface temperature, brightness (luminosity) and mass of the star to the Sun.

Step2

The Sun's Evolution during its lifetime.

Click the play button below the Hertzsprung-Russell diagram to show the Sun's evolution.

Name the three stages of the Sun's life shown on the Hertzsprung-Russell diagram.

- Stage 1:
- Stage 2:
- Stage 3:

Use the table below to describe the changes the Sun will go through between stages.

- Label 'Increase', 'Decrease' or 'Stay the same' for each of the quantities in the table along with the values they change from and to.

	Radius	Luminosity	Temperature	Mass
Stage 1 to Stage 2	. . . Increase From: . . . R_{sun} To: . . . R_{sun}	. . . Increase From: . . . L_{sun} To: . . . L_{sun}	. . . Increase From: . . . K To: . . . K	. . . Increase From: . . . M_{sun} To: . . . M_{sun}
Stage 2 to Stage 3	. . . Increase From: . . . R_{sun} To: . . . R_{sun}	. . . Increase From: . . . L_{sun} To: . . . L_{sun}	. . . Increase From: . . . K To: . . . K	. . . Increase From: . . . M_{sun} To: . . . M_{sun}

Look at the light bulb tab:

- At which stage in its life cycle will the Sun be at its brightest?
- How old will the Sun be at this point? (in Myr)

Look at the thermometer tab:

- At which stage in its lifecycle will the Sun be at its hottest?
- What is its maximum temperature? (in K)

Look at the pie chart tab:

- In which stage of its life will the Sun spend most of its time?
- How long will it spend in this stage? (in Myr)

Look at the mass tab:

- What happens to the mass of the Sun as it gets older?
- What type of star will the Sun be at the end of its life?
- What is the total lifetime of the Sun?

Step3

Using the ‘Star Properties’ banner, explore the evolution of stars with different starting masses.

- Select a different starting mass for your star in the ‘Star Properties’ banner.
- Using the Hertzsprung-Russell diagram tab, click play to watch your new star's evolution.
- Try out a few different masses then answer the following questions.
- Using the Hertzsprung-Russell diagram:
- Where on the main sequence do the lower mass stars start?
- Where on the main sequence do the higher mass stars start?
- There are three possible outcomes for the final stage of a star's life depending on its initial mass. Name these 3 possible final stages.

Step4

Follow the evolution of five stars of different masses. Complete the table below, filling in a row for each of the different masses. Hint: You may find it easier to use the data table on the ‘Star in a Box’ to find the exact values.

Mass of Star (M_{sun})	Maximum Radius (R_{sun})	Maximum Luminosity (L_{sun})(Brightness)	Maximum Temperature (K)	Name of Final Stage	Total Lifespan (Myr)
0.2					
1					
6					
20					
40					

Step5

Study the data for the different stars in your table above.

- Comparing the temperatures:
- Which mass star reaches the highest temperature?
- At what stage in its life does the star reach this temperature?
- Comparing the luminosities:
- Which mass star gets the most luminous (brightest)?
- Is this the same mass of star that reaches the highest temperature?

Step6

Multiple choice questions. Choose the correct answer.

What type of star will the Sun become after it leaves the Main Sequence?

- Neutron Star
- Red Dwarf
- Red Giant
- Red Supergiant

What main factor determines the stages a star will follow after the main sequence?

- Mass
- Luminosity
- Temperature
- Radius

The mass of the star Betelgeuse is much greater than the mass of the Sun; therefore, its total lifetime will be:

- Greater than the Sun
- The same as the Sun
- Less than the Sun

Compared to when it joins the Main Sequence, a star's mass at the end of its life will:

- Be greater
- Be the same
- Be less

- Depend on the type of star

The Sun will spend most of its life in what stage?

- Main Sequence
- Red Giant
- Red Dwarf
- White Dwarf

(solutions at: http://goo.gl/tlaEH1)

CURRICULUM

Space Awareness curricula topics (EU and South Africa)

Our wonderful Universe, stars

National Curricula UK

GCSE, physics: AQA Science A, Edexcel, OCR A, OCR B, WJEC

GCSE, astrophysics: Edexcel

A level, physics: AQA, Edexcel, OCR A, OCR B, WJEC

KS3, physics: space physics

KS2, year 5, science: Earth and space

ADDITIONAL INFORMATION

- If you would like to know more about how stars evolve, take a look at our SpaceBook pages about the life cycle of stars. https://lco.global/spacebook/life-cycle-stars/
- You can also learn more about Hertzsprung-Russell diagram on SpaceBook http://lcogt.net/book/h-r-diagram
- Questions in the exercise workbook could be made into a multiple choice quiz using a website or an app such as Socrative https://itunes.apple.com/au/app/teacher-clicker-socrative/id477620120?mt=8.

CONCLUSION

The activity finishes when the students have completed the worksheets. The teacher should discuss the range of answers the students had for some of the later questions on each worksheet.

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