GOSTEAM Hands-on Activity Template *(Inquiry-based)*

Title:

Scale of the Solar System in a nutshell

Short Description (Max 500 words):

The best way to appreciate the size of our solar system and the size of the planets is by creating a scaled model of them that shows how far from the sun the eight planets are located (scaled distance). Students will have the opportunity to make these estimates and attribute their findings inside (using digital mapping tools) and outside the classroom (experimentation). Thus, if the sun has the size of your school, where is the earth placed inside your city? Or maybe outside?

Keywords (Up to 5):

Solar system, Size, Scale, Distances

Information about the Implementation

Age and language of the students:

		9-12	12-15	15-18	18+
Language: Greek	Age:	☑	☑	☐	☐

Number of Lessons – Duration (per lesson):

Number of Lessons: 1 Duration per Lesson: 45’

Subjects:

For which subject(s) the activity is usable, is it an interdisciplinary activity?

Science ☑

Physics ☑ Chemistry ☐ Biology ☐ Geosciences ☑ Environmental ☐ Other ☐

Technology ☑

Engineering ☑

Arts ☐

Mathematics ☑

Information about the Scenario

Curriculum and country:

Link of the current activity to the curriculum:

Country:	Greece	Class:	Secondary	Grade:	5 - 9

Topic: Physics, Mathematics

Objectives (Max 100 words):

Description of the learning objectives

Students will actually complete two activities focusing on:

1. comparing the size of the objects (Sun, planets, moons) of our Solar System, and,
2. comparing the distances between the objects in our Solar System at different scales inside and outside classroom

In this way, students will gain an understanding of the comparative size of the objects in our Solar System and the great distances between them.

Materials (Max 100 words):

Which resources and materials (software, hardware) are needed?

Material: Search Engines

Software: Spreadsheet app., FreeMapTools

Spatial concepts, skills, and abilities:

Which spatial concepts and skills are covered by the activity?

Spatial concepts:

Primitives: Identity/Name ☐ Location ☑ Space/Time ☐

Simple: Distance ☑ Direction ☐ Connectivity ☐ Movement ☐ Boundary ☐ Shape/Area ☐ Adjacency ☐

Difficult: Overlay ☐ Buffer ☐ Topology ☐ Coordinate ☐ Map ☐ Scale ☑ Shortest Path ☐ Navigation ☐ Surface ☐ Slope/Gradient ☐ Aspect ☐ Contour ☐

Complex: Interpolation ☐ Map Projection ☐ Spatial Dependency ☐

Other:

Spatial skills:

- [ ] Map literacy
- [ ] Navigation/orientation
- [x] Estimating distances and directions
- [ ] Recognizing and understanding patterns/Understand and identify models of spatial organization
- [ ] Select an ideal location based on the given spatial features
- [ ] Visualization
- [ ] Understand and identify spatial correlations/ dependencies
- [ ] Categorize spatial entities/ geographic features and identify hierarchies
- [x] Compare spatial entities and draw analogies among them
- [ ] Identify/determine connections/relations
- [x] Understanding scale in space and time
- [ ] Delineation of spatial regions/ zones based on given features/ properties

Short Description

Navigation/orientation: Finding one's way in unfamiliar environments, interpreting and giving walking and driving directions.
Estimating distances and directions: Measure paths, weighted distances, angles.
Map literacy: Using, interpreting/understanding, learning from, and communicating acquired spatial knowledge from maps, comprehension of geographic features represented as points, lines, or polygons.
Recognizing and understanding patterns/Understand and identify models of spatial organization. Delineation of spatial regions/zones based on given features/properties: Regionalization processes, pattern recognition and clustering identification in the 2d and/or the 3d world.
Select an ideal location based on the given spatial features: Single or multi-criteria siting and optimal areas identification.
Visualization: Visualizing spatial entities from written/oral verbal descriptions, from their 2d or graphical representations or through mental transformations; such as axis rotation or perspective taking.
Understand and identify spatial correlations/ dependencies: The ability to realize, identify and explain patterns, clusters and relevant spatial dependencies.
Categorize spatial entities/geographic features and identify hierarchies: Identify the hierarchical form of data and gradients between spatial entities.
Compare spatial entities and draw analogies among them: Calculate and compare different geometric objects' shapes, area and boundaries.
Identify/determine connections/relations: The ability to identify links and common characteristics among spatial entities and between humans and spatial entities.
Understanding scale in space and time: The understanding of changes/transitions through space and time for different spatio-temporal scales.

Geospatial concepts and spatial abilities documentation (see Section 3.2):
http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf

Description of the activity in detail

Question Eliciting Activities

Provoke curiosity

Describe ways and materials that teachers will present to their students to attract their attention to the topic investigated.

Usually, the most effective way to provoke students' curiosity is by presenting an exciting video or a series of photos

Our solar system is the Sun and everything that travels around it. Traveling around the Sun are eight official planets, at least five dwarf planets, nearly 200 moons (or natural satellites of the planets), and a large number of comets and asteroids.

Our solar system is so big it is almost impossible to imagine its size if you use ordinary units like kilometers or miles. The distance from Earth to the Sun is 149 million kilometers (93 million miles), but the distance to the farthest planet Neptune is nearly 4.5 billion kilometers (3 billion miles). Compare this to the farthest distance you can walk in one day, the distance covered by a vehicle in his entire life-cycle (approx. 300000 km.) or that the International Space Station (ISS) travels in 24 hours 643720 kilometers (400000 miles).

To trigger student's interest you can show the following video or you can visit the following online games explaining the solar system distances and planets' size.

https://youtu.be/DMZ5WFRbSTc **(Solar System distances video)**

http://www.bbc.com/future/bespoke/20140304-how-big-is-space-interactive/ **(Space Race game)**

https://joshworth.com/dev/pixelspace/pixelspace_solarsystem.html **(Solar System scroll)**

http://omgspace.net/#sun **(Solar System distances and Planets' size)**

Propose preliminary explanations or hypotheses

Formulate the scientifically oriented questions that teachers will present to the students to trigger their engagement in thinking about the topic investigated based on their existing knowledge. Make these questions digitally available and easily usable, e.g., by integrating them in the materials described in the previous step.

It is best to ask these questions in the context of a relative discussion.

- Can you imagine these vast distances and sizes scaled on the Earth's surface?
- If the Sun has a size of 1 meter and is located at the center of your school, how far are located from your school the other planets orbit?

Active Investigation

Plan and conduct simple investigation

Provide the teachers with a specific plan of the investigation that will take place. Offer instructions about the activities they students will need to perform and what kind of materials they may need. Describe ways that the teachers can use to facilitate the students to focus on evidence.

This is the phase in which students are being prepared for the subsequent phase of evidence gathering during observation.

Students should be familiar with the names of all the planets in the solar system and the order in which they appear. To succeed this, students can copy of the radius (or diameter) and distance from the Sun for each planet and the Sun. You can make this into a worksheet for each student or in groups of 2 students.

See Figure 1

	A	B	C	D
1				
2		**Solar System objects**	Distance from the Sun (Km.)	Planets' radius in Km.
3		**Mercury**	57000000	2439
4		**Venus**	108000000	6051
5		**Earth**	149000000	6371
6		**Mars**	228000000	3389
7		**Jupiter**	780000000	69911
8		**Saturn**	1437000000	58232
9		**Uranus**	2871000000	25362
10		**Neptune**	4530000000	24662
11				
12		**Moon**	150000000	1737
13		**Sun**	0	696340

Figure 1: Solar System objects' distance from the sun (ascending order) and their radius in Km.

Moreover, students have to be familiar with the terms of "**scale**" and "**scaled model**". They must further investigate how they can scale the size of an object or/and the distances among objects or even the geographical scaling (in a map).

https://en.wikipedia.org/wiki/Scaling_(geometry) **(Scaling - Geometry)**

https://en.wikipedia.org/wiki/Scale_(map) **(Scaling - Map)**

https://study.com/academy/lesson/uniform-non-uniform-scaling-definition-examples.html#quiz-course-links **(Uniform scaling video - Advanced)**

https://www.mathsteacher.com.au/year8/ch06_ratios/06_scale/draw.htm **(Scaling examples)**

Creation

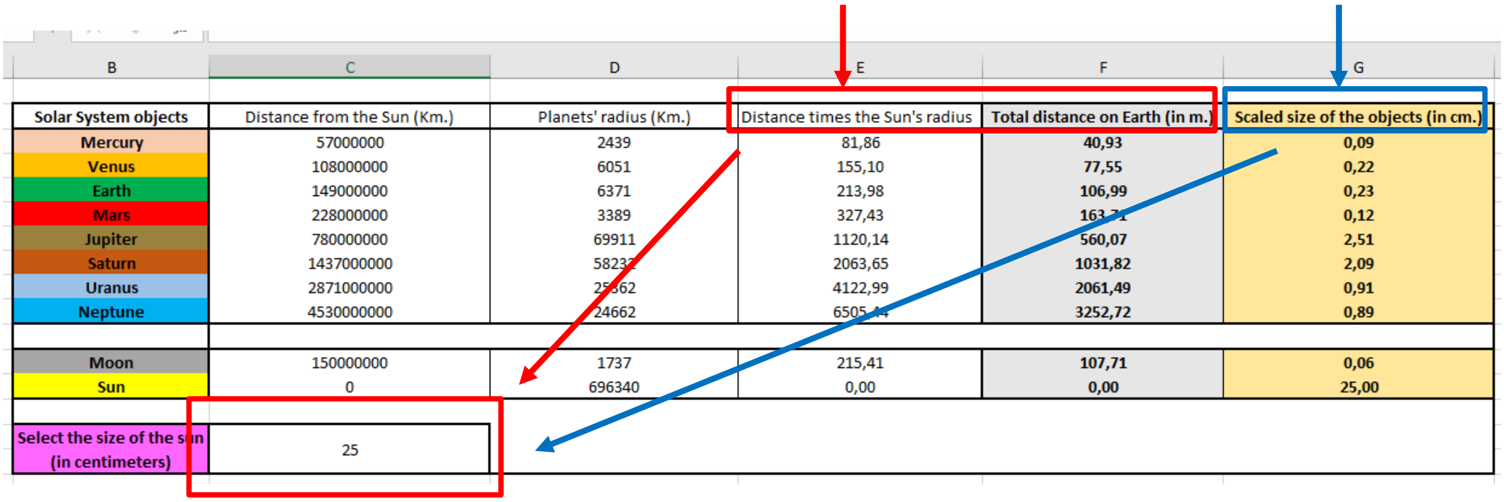
Gather evidence from observation

The selected resource (e.g., a simulation, an experiment, an animation, a graph, or other exhibit of similar nature) must provide students with an opportunity to collect evidence addressing the scientific questions presented in previous stages through direct or indirect observation.

> ***Remind students of the model idea if they don't mention it? "Let's make a model that accurately represents the size and distance from the Sun and of all planets. This model will give us a better idea of the sizes and distances in our solar system."***
>
> **Show them the basketball and ask them how big each of the planets would be if the Sun was the size of the basketball.**
>
> You can draw a basketball on the board. Ask from students if they can imagine how can we estimate the size of each planet compared to the Sun (actually, the basketball)?
> When this drawing of the solar system is complete, ask students how far apart each of these planets would be if the sun were a basketball. Would they fit in this room? Would they fit in the school? In their city/village?

To answer these questions, we have to make some calculations first! Open the excel worksheet (you can download the Solar Scale Calculator HERE).

Focus on columns E, F and G. In order to scale the size of each object, students must focus on each planet's radius compared to the radius of the Sun (blue box). Moreover, for estimating the total scaled distance on Earth (in centimeters or meters, Column F), students have to consider how many times the Sun's radius fits on the distance of each planet (column E).



B	C	D	E	F	G
Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	40,93	0,09
Venus	108000000	6051	155,10	77,55	0,22
Earth	149000000	6371	213,98	106,99	0,23
Mars	228000000	3389	327,43	163,71	0,12
Jupiter	780000000	69911	1120,14	560,07	2,51
Saturn	1437000000	58232	2063,65	1031,82	2,09
Uranus	2871000000	25362	4122,99	2061,49	0,91
Neptune	4530000000	24662	6505,44	3252,72	0,89
Moon	150000000	1737	215,41	107,71	0,06
Sun	0	696340	0,00	0,00	25,00
Select the size of the sun (in centimeters)	25				

Figure 2: The fields that the students have to set-up and fill, including the scaled distances and sizes of each planet compared to the Sun's radius

In order to estimate the aforementioned scaled values, you will need the following formulas (embedded at an excel file, estimate by hand or even by using a programming language).

$$\boldsymbol{Size_{scaled}} = Sun_{cm}(Planet_{radius}/Sun_{radius})$$

$$\boldsymbol{Distance_{scaled}} = ((Planet_{dist}/(2 * Sun_{radius}))Sun_{cm})/100)$$

, where Sun_{cm} is the scaled size of the Sun on Earth, $Planet_{dist}$ is the distance of each object from the Sun, $Speed_{light}$ is the speed of light and finally, $Planet_{radius}$ and Sun_{radius} are the radius of each solar object and the Sun's radius respectively.

Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	**40,93**	**0,09**
Venus	108000000	6051	155,10	**77,55**	**0,22**
Earth	149000000	6371	213,98	**106,99**	**0,23**
Mars	228000000	3389	327,43	**163,71**	**0,12**
Jupiter	780000000	69911	1120,14	**560,07**	**2,51**
Saturn	1437000000	58232	2063,65	**1031,82**	**2,09**
Uranus	2871000000	25362	4122,99	**2061,49**	**0,91**
Neptune	4530000000	24662	6505,44	**3252,72**	**0,89**
Moon	150000000	1737	215,41	**107,71**	**0,06**
Sun	0	696340	0,00	**0,00**	**25,00**
Select the size of the sun (in centimeters)	25				

Figure 3: Scaled distances and objects' size based on the Sun's radius and the scaled size of the Sun

Finally, to draw our scaled model on the Earth's surface, we have to select a central point (as the Sun) and then we can add all of the remaining circles (orbits) for each planet or the moon using a different color (see **Figure 4**).

In order to select the position of the Sun, we can either type the name of a country, city or region or we can insert the exact coordinates (in lat-lon) of our school etc.

Note: During this step you can introduce to the classroom the geographic coordinates concept. For instance, you can ask from them to explain *"The **latitude** of The Eiffel Tower in* Paris, *France is 48.858093, and the **longitude** is 2.294694."* What does it mean and how Lat-Lon is estimated?

Lat-Lon explanation:
https://gsp.humboldt.edu/olm/Lessons/GIS/01%20SphericalCoordinates/Latitude_and_Longitude.html

Follow the Steps described in **Figure 4** in order to draw your scaled Sun and planets using FreeMapTool! Draw each orbit on different color!

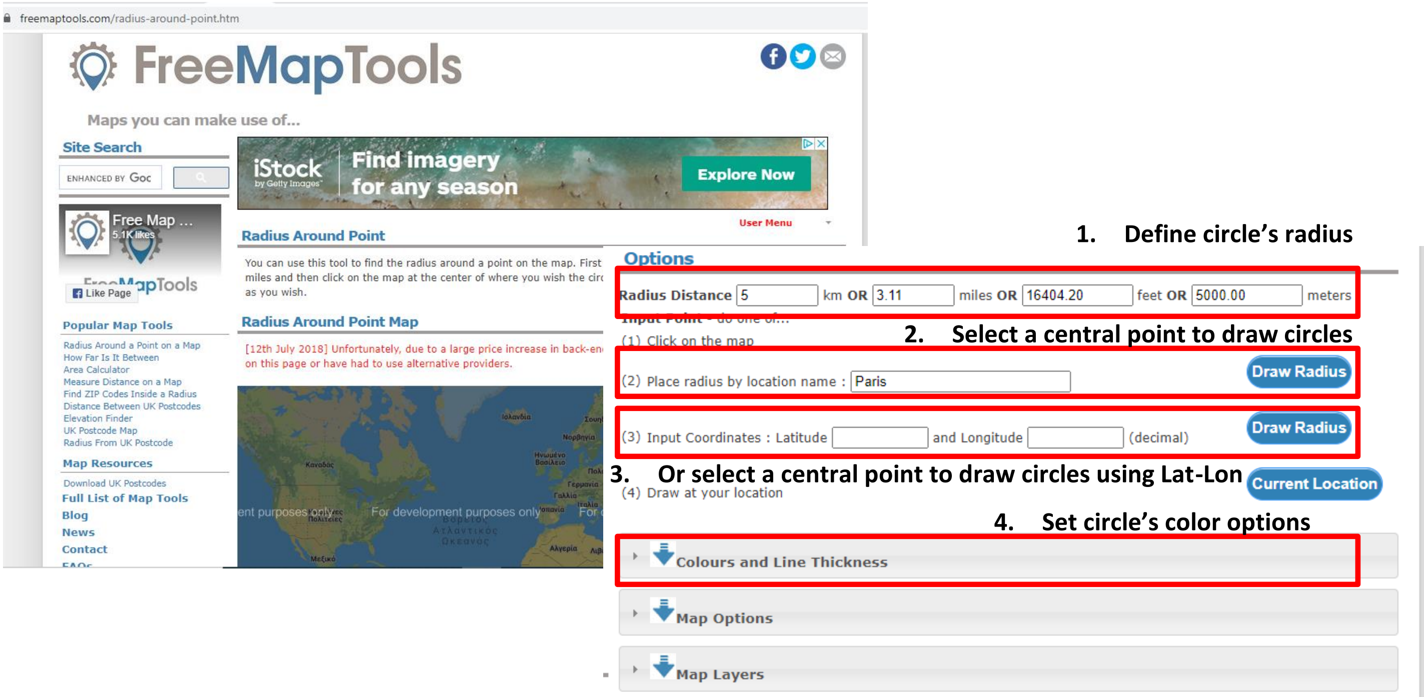


Figure 4: FreeMapTool to draw planets' orbits with different colors and size

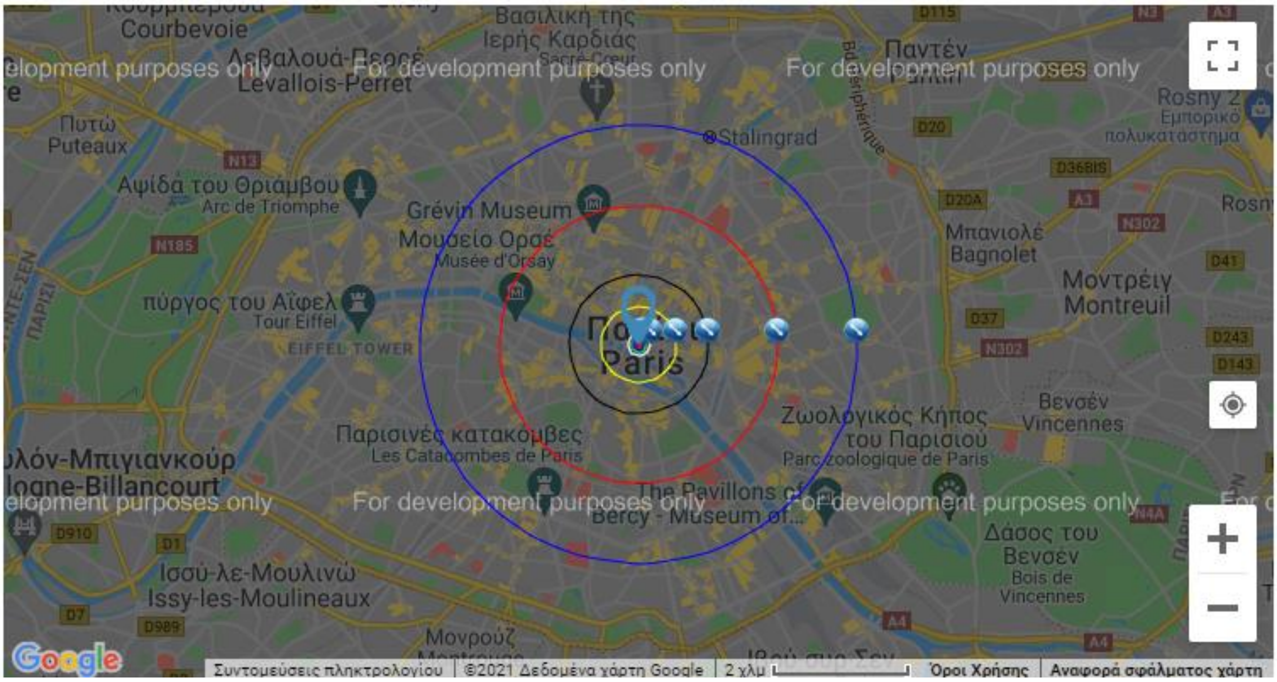


Figure 5: The scaled planets' orbits considering that the Sun's position is located on the center of Paris

You can also draw the Sun (i.e 25 centimeter radius) for realizing the vast differences considering the size of the Sun and the distance of each planet (covering the entire Paris center)!

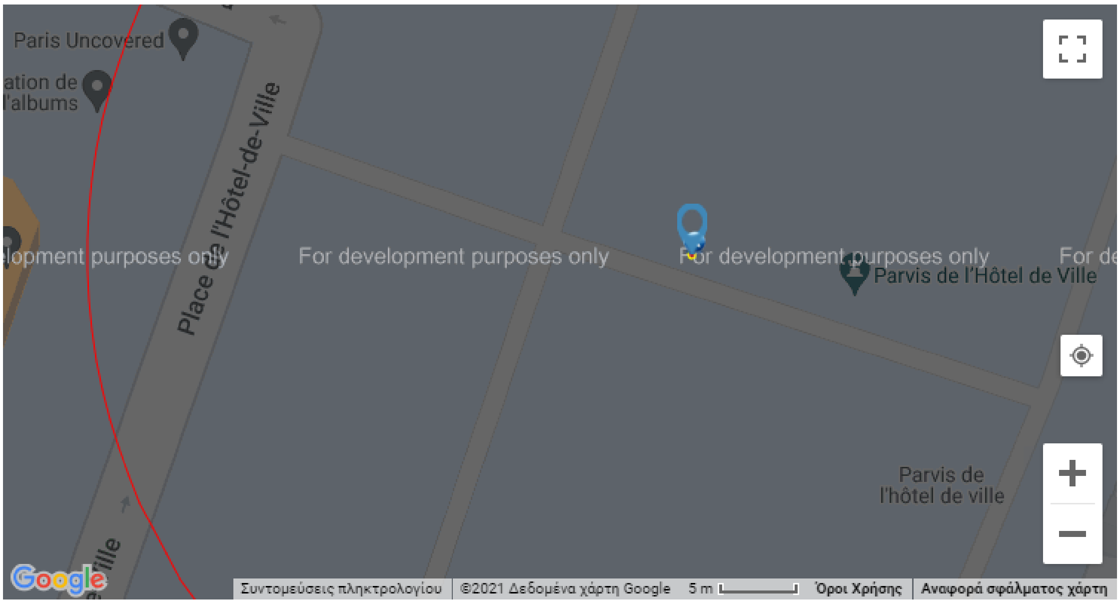


Figure 6: The Sun is merely illustrated at a building block level

Of course, you can force students to test this experiment for different Sun radius, for example, what if the size of the Sun was 50 meters?

Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	8185,66	17,51
Venus	108000000	6051	155,10	15509,66	43,45
Earth	149000000	6371	213,98	21397,59	45,75
Mars	228000000	3389	327,43	32742,63	24,33
Jupiter	780000000	69911	1120,14	112014,25	501,99
Saturn	1437000000	58232	2063,65	206364,71	418,13
Uranus	2871000000	25362	4122,99	412298,59	182,11
Neptune	4530000000	24662	6505,44	650544,27	177,08
Moon	150000000	1737	215,41	21541,20	12,47
Sun	0	696340	0,00	0,00	5000,00
Select the size of the sun (in centimeters)	5000				

Figure 7: Scaled distances and objects' size based on the Sun's radius of 50 meters (5000 cm.)

Discussion

Explanation based on evidence

Guide the teachers to encourage their students to provide correct explanations for the topic(s) investigated.

Describe ways and they can use to this end and give them directions how to discover them.

Discuss the difficulties you encountered during your investigation.
Did you understand the method of scaling?

Why scaling is important and where can we use it?

Consider other explanations

Direct teachers to facilitate the student groups to evaluate their own explanations in the light of alternative explanations, particularly those reflecting scientific understanding. Illustrate examples they can use and give them instructions how to locate them.

Estimate the one-way travel time from the Sun to each of the solar system planets. Use that fact that the travel time from the Sun to Earth is 8 ½ minutes in order to validate their results. They can fill their answers in the excel form, in units of seconds, minutes or hours depending on the adjustment that the teacher wants for the students to learn (i.e. how to estimate arrival time in seconds, minutes or hours).

Explain the formula: Time = distance/speed (in minutes)

Some further explanations and examples related to the light travelling around the universe:

https://www.pbs.org/seeinginthedark/astronomy-topics/light-as-a-cosmic-time-machine.html (Time for the light to reach different planets, stars or galaxies)

You can conclude with the following question:

"What do you think aliens could see right now from the Orion Nebula if they looked towards Earth?"

Reflection

Communicate explanation

Guide teachers to facilitate each student group to reflect on the previous experiences and to produce a report with its findings, presenting and justifying the proposed explanations to the other groups and the teacher.

Provide content which the teacher can use to help the students to get familiarized and to become efficient in scientific writing.

Think about how we could use the method of scaling objects or distances in other aspects of everyday life.

You can ask from students to write a short report with the results occurred during this activity (including tables, images from the FreeMapTool etc.). Also, students can provide some relevant examples and why is important to scale down some physical entities or to think of an example of scaling up! (for example, scale up the size of ants, humans and mammals).

Follow-up activities and materials

Describe and direct the user to any follow-up activities or materials that can be used to wrap-up the hands-on activity.

These could include appropriate learning assessment and/or reminder materials (e.g., quizzes, games, other user-friendly tests), hints for further activities etc.

If you have ever wondered where we fit in the universe, then this interactive is for you. The Scale of the Universe takes you on a ride down to the smallest thing theorized by scientists and then out to the vastness of the universe. The interactive opens with a variety of objects shown on the screen, from a Giant Earthworm to a hummingbird.

Try the following game

https://htwins.net/scale2/

Sustainable contact

Loukas Katikas (Email: lkatikas@ea.gr)

References (if any):

Assessment (if any):