Orienting & Asking questions

Orienting: Provide contact with the content and/or provoke curiosity:

- Did you ever wonder how huge Earth is compared to us?

- Since Earth is so big, do you thing it is possible to measure the size of the Earth without using satellites?

- How about doing it here in our school by just using a stick, do you think it's possible?

Teacher Guideline

Use "Google Earth " to make a small demonstration to the children. The purpose of this demonstration is to impress children by showing them how small we are in comparison to Earth's size.

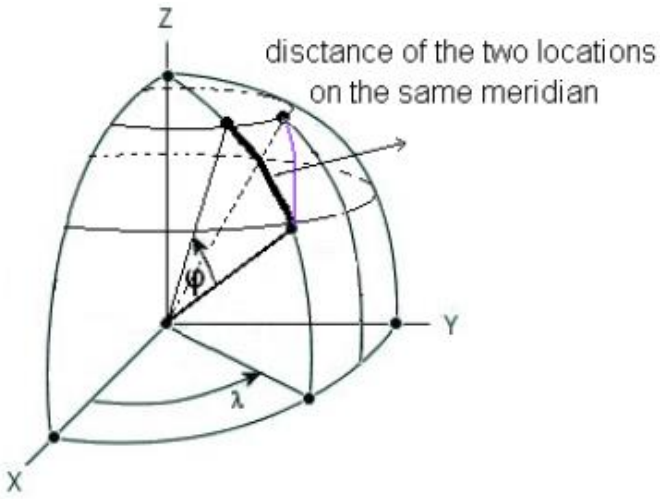
Inform the students that Eratosthenes measured the Earth's circumference 2,200 years ago by just using a stick and the Sun's location.

Define goals and/or questions from current knowledge

- So how do we know the Earth is round?

Since Earth is round, its perimeter corresponds to a circle.

- How many degrees are there in a full circle?
- What is the arc of a circle?
- Can we calculate the whole perimeter, if we know the length of the arc that corresponds to a given angle?
- If we have two locations on Earth, what does the angle between them correspond to
- How can we measure it?



Teacher Guideline

Explain to the students, how Aristotle came to the conclusion that Earth is a sphere by looking at the shadow it casts on the moon.

Present how the angular distance between two locations can be measured. Students need to understand the main idea that if we now the angle and the arc corresponding to this angle, we can calculate the whole circumference.

Students need to understand that in order to do the calculation we need to define the angular distance between the two locations.

If we place one car (assuming that the approximate length of a car is 4m) behind another along the Earth's circumference we will end up using

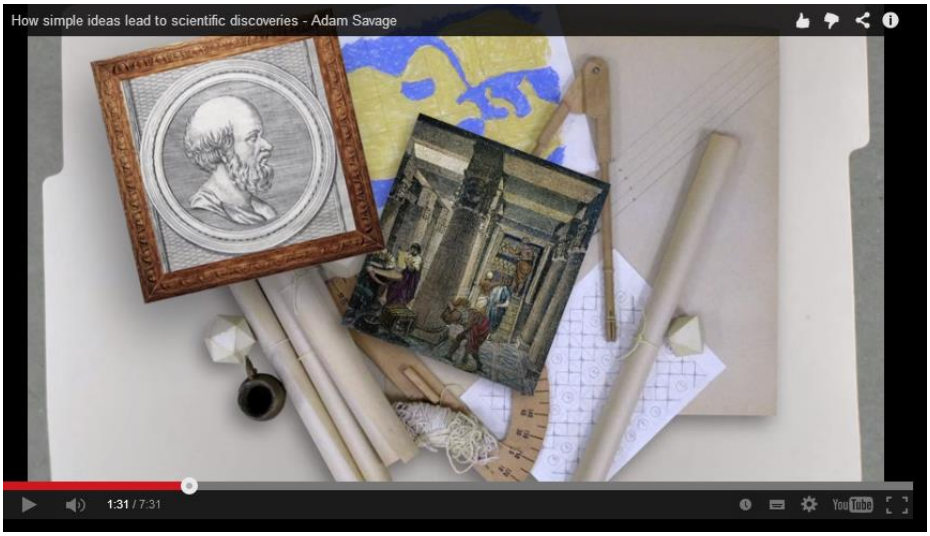
a) 1 million
b) 10 million
c) 100 million
d) 1 billion

Hypothesis generation & Design

Generation of Hypotheses or preliminary explanations

Following the ideas we discussed above, can you come up with a plan on how to measure Earth's circumference:

Let's see how Eratosthenes did it!



Eratosthenes` experiment was based on a chance observation that in Syene the sun was reflected on the surface of a deep well at midday, while at the same time an obelisk in Alexandria projected a small shadow.

Since Eratosthenes knew that Earth is a sphere, why was he puzzled by this observation?

Teacher Guideline

If the earth is a sphere, this observation could be possible because sunrays that reach the earth are parallel.
Ask students to write down their ideas.
https://www.ted.com/talks/how_simple_ideas_lead_to_scientific_discoveries
01:31 - 03:40

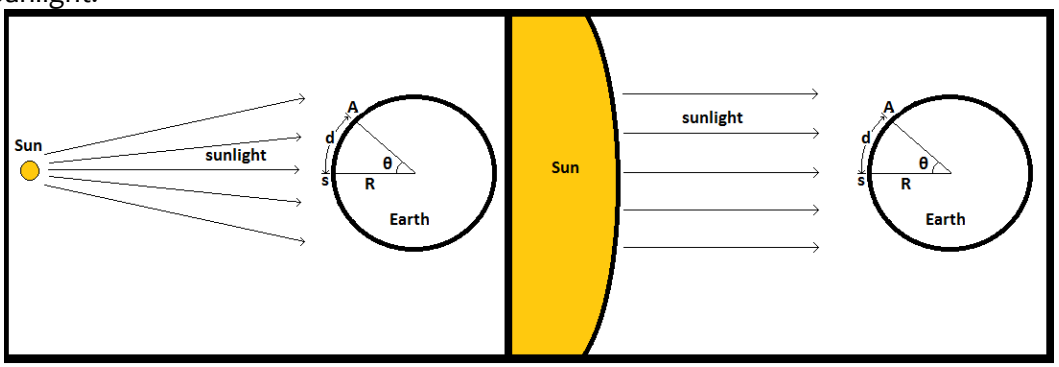
Design/Model

Let's build some models to see how we can do the same observation.

The shape of the Earth:

The left model represents the case of a flat Earth. The model on the right represents the case of a round Earth.

Sunlight:



The left model represents the case of non-parallel sunrays. The model on the right represents the case parallel sunrays. Which one do you think is correct?

After having observed the models, look back at the question and check your answer. Is your answer correct or do you wish to change it?

Answer the following Questions:

Assuming that the sunlight comes from a very long distance away, Eratosthenes experiment can be the basis to prove that:
a) the Earth is a sphere
b) the Earth is not flat
c) the Earth rotates around itself
d) the Earth rotates around the sun

Eratosthenes experiment was originally performed
a) on the 20th of March during the spring equinox
b) on the 21st of June during the summer solstice
c) at the time of the year when the length of day and night are equal
d) around the hottest days of the summer

If Eratosthenes lived in Europe then would he be able to see the image of the sun in the bottom of the well as he did in Syene? If yes, when or where would he observe that?
a) No, he wouldn't be able to see the image of the sun in the bottom of a well
b) Yes, he would have seen the image of the sun in the bottom of a well if he lived near the North Pole
c) Yes, he would have seen the image of the sun in the bottom of a well if he made his observation on March 20th
d) Yes, he would have seen the image of the sun in the bottom of a well if he made his observation at a place (in Europe) that has the same longitude as Syene.

If the sun rays are considered parallel when reaching the Earth then during the winter solstice (21/12) they are
a) perpendicular to the ground during local noon at any location on the Tropical of Sagittarius
b) perpendicular to the ground during local noon at any location on the Tropical of Cancer
c) perpendicular to the ground during local noon at any location on the Equator
d) perpendicular to the ground during local noon at the South and North Pole

Two cities on the same longitude
a) will have a local noon at the same time only if they both are on the same hemisphere
b) will have a local noon at the same time
c) will have a different local noon depending if they are in the north or south hemisphere
d) will have different local noon depending on the season at that location

If I place a 1m stick at two different locations on the same latitude then
a) they will have the same shadow length at local noon measured on the same day
b) they will have different shadow length at local noon depending on their longitude
c) they will have the different shadow length at local noon measured on the same day
d) they will have the same shadow length at local noon measured only on 20th of March

If we place one car (assuming that the approximate length of a car is 4m) behind another along the Earth's circumference we will end up using
a) 1 million cars
b) 10 million cars
c) 100 million cars
d) 1 billion cars

Two people decide to measure the shadow length of a 1m stick at local noon. One person performs the experiment during the spring equinox (20/3) and the other during the autumn equinox (21/9). After that they decide to share their data. Can they measure the Earth's circumference?
a) Yes, as long as they are on the same longitude and know the distance between their two locations
b) No, because they have made their measurement at different times and the earth is not at the position it used to be
c) Yes, as long as they are on the same location
d) No, except if they are both on the equator at different locations and know the distance between these locations

If your school has the option of matching with another school on the same longitude in order to exchange data and perform Eratosthenes experiment on 20/3, what matching school would you prefer so to minimize the error on your calculations
a) a school that is very far from yours so the distance between the two schools corresponds to a greater central angle measured more accurately
b) a school that is very close to yours so the distance between the two schools is not large and thus can be measured with greater accuracy
c) it doesn't matter as long as both schools share the same longitude
d) a school that is as close as possible to equator because its stick shadow will be very small and thus it can be measured with greater accuracy

Note: All the knowledge questions provided here will be also available online

Planning & Investigation

Plan investigation

Let's see what factors are important for our investigation.

For the time of the experiment we need to:

a) bear in mind the local time of the partner school and to carry out the experiment at the same time
b) bear in mind the local time of the partner school and carry out the experiment when the sun is on the same position at the sky for each school.
c) use sticks of the same length
d) the same number of students carry out the experiment

To measure the distance between the two schools we'll have to:

a) Measure the direct distance between two schools.
b) Measure the distance based on the road network
c) Measure the distance of the schools on the same meridian.

To get good results, the stick should be:

a) hold by hand
b) stick into ground
c) fixed into ground
d) lean on a wall

For the shadow of the stick we need to:

a) take many measurements and calculate the mean value to avoid errors
b) take the shortest value because it has the shortest error
c) take the shortest value because that is when the sun is at its zenith
d) take many measurements and calculate the mean value because I can't know when exactly the sun is at its zenith.

→ Use Stellarium to define the local time of carrying out the experiment. To make your planning easier, you can choose to perform the experiment when the sun is at its zenith
→ Use Google Earth to find out the distance between the two collaborating schools

Teacher Guideline

→ Use Stellarium (http://www.stellarium.org) to define the local time of carrying out the experiment. To make your planning easier, you can choose to perform the experiment when the sun is at its zenith.
→ Use Google Earth to find out the distance between the two collaborating schools.

The experiment needs to be performed when the sun in on the same location for each school. So each school will make the experiment when the sun is at its zenith. To define when the sun is at its zenith for each location use.

Students need to calculate the distance on the same meridian. For guidance see here: Consider Other Explanation.pdf

To define the distance check: Measure the distance.pdf

Perform investigation

- Place the stick in the Sun and make sure it is vertical to the ground.
- Measure the length of the stick (H) and note down your measurement in the table below.
- At the time scheduled to conduct the experiment, measure the length of the stick's shadow. Repeat the measurement 5 times and write your values down in the table.

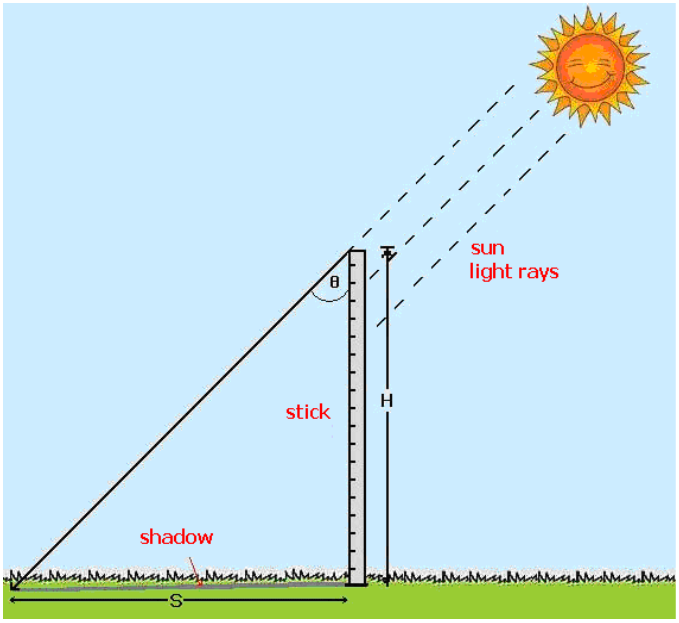


Table of measurement	
Stick length	
Shadow length (1st measurement)	
Shadow length (2nd measurement)	
Shadow length (3rd measurement)	
Shadow length (4th measurement)	
Shadow length (5th measurement)	
Mean shadow length	
Length of triangle's 3rd side	
Distance between schools	

Analysis & Interpretation

Analysis and Interpretation: Gather result from data

1. Find the shortest value for the length of the shadow (S).

2. Use the length of the stick (H), the length of the shadow (S) and the tangent formula below, to calculate the angle between the sunlight and the vertical to the ground axis.

$$tan\theta = \frac{S}{H} \Rightarrow \theta = arctan\left(\frac{S}{H}\right)$$

   *Angle (ϑ):*_____

   This θ angle is also equal to the angular distance between the location of the experiment was performed and the equatorial.

3. Note down the angle measured by your fellow students at the other school. Angle (φ): _____

4. Subtract the two angles. The value you'll find corresponds to the angular distance between the two schools.

   Angular distance between the two schools:_____

5. Using proportions calculate the Earth's circumference.

$$\frac{\text{distance between the schools}}{\text{angular distance between the schools}} = \frac{\text{Earth's circumference}}{360^0}$$

   Earth's circumference:_____

Conclusion & Evaluation

Conclude and communicate result/explanation:

- What is the Earth's circumference according to your calculations?
- Compare your measurement to the real value for Earth's circumference. Did you get it right?
- Do you think your experiment was successful?

Evaluation/reflection:

- What sources of error are there? Have they been taken into consideration?
- Is Eratosthenes method accurate?

- If you could repeat the experiment, what would you change?

Consider other explanations

If the Eratosthenes experiment is carried out from one school in Greece and one in Finland whose longitudes are very close, the result would be better than from two schools only in Greece. This is:

a) correct, because the weather in Greece is much better
b) correct, because the greater the distance between the two schools the better the measurement.
c) not correct, because the mountains in between will interfere with the measurement
d) not correct, because the accuracy of the measurement is not affected.

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Assessment using provided assessment questions

After students finished the last learning activity they answer a set of multiple choice assessment questions. These questions measure the problem solving skills of the students.

According to the 'Big Idea' that is focused in the Demonstrator it is possible to pick at

least one matching Assessment Question out of the official catalogue of ISE assessment questions and to create up to three (minimum two) Assessment Questions by your own in order to investigate the problem solving competency of your students. It is possible to immediately compare the results of the students with average PISA results.

There are several ways to assess students' performance in the Eratosthenes project.

a) Students can prepare a written or oral presentation to a younger student on Eratosthenes' measurement of the circumference of Earth.
b) Students can prepare a written or oral presentation to a younger student on Eratosthenes' measurement of the circumference of Earth.
c) Students can prepare a written or oral presentation to a younger student on Eratosthenes' measurement of the circumference of Earth.