

Título: Study of the movement of the sun through the analysis of a shade.

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Abstract

The aim of this scientific project is to explore the sun shade along the academic year. The sun is a constant presence in our lives, but we normally don't pay attention to its movement neither to the changes in its positions in the different seasons. This research projects will allow the students to answer apparently easy questions of celestial mechanics, such as where does the sun come up? Where will it come up on 24th June? Where is exactly the East? The changes on its shade along one, differences between summer and winter.

The analysis of the shade is carried out in three days in different seasons. After the data are taken, they are analyzed in detail at the classroom, where the basic concepts of celestial mechanics are also explained. Finally, the results are compared with the initial hypothesis and interpreted by the academic contents. Moreover, the students design and create models and minatures of the translation movements and of the observations done. The activity is completed with the construction of a sundial.

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Development

1. Aim of the study.

The goal of this scientific project is to investigate some basic concepts of celestial mechanics related with the sun movement and Earth's orbit. The aims are:

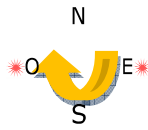
- To investigate the Sun movement and the Earth's orbit by analyzing the sun shade in an object in different seasons of the year.
- To learn and consolidate basic theoretical concepts of celestial mechanics, such as, cardinal points, North-South line, magnetic North, Earth's orbit, inclination of the Earth's axis, seasons, and so on.
- To acquire the first contact with Astrophysics by prolongating the acquisition of the data till the sunset. The students could observe and identify the first stars after sunset and the visible planets, specially the polar star and Jupiter. In addition, a telescope was used to observe the moon.

Beyond these scientific goals, an important motivation of this project was to involve all the students in the classroom. Our aim was to show that scientific research is within the reach of all the students, independently of gender, social background, and, at this early stage, even of performance at school. In our opinion, this could be achieved by involving all the students in the class, and making them to play a crucial role in the design and organization of the activities needed to develop the scientific project.

Formulation of the initial question.

- We know that the sun position changes along the day.
 - The sun rises in theEast
 - The sun sets in theWest
 - The sun moves fromEast.... toWest..... going through the ...South.....

Thus, the sun movement in one day is



➤ **Highschool location.**

The students prepared a sketch of the high school plan and indicated on it where the cardinal points are located. A satellite image of the school taken from Google Maps was used to create this sketch.

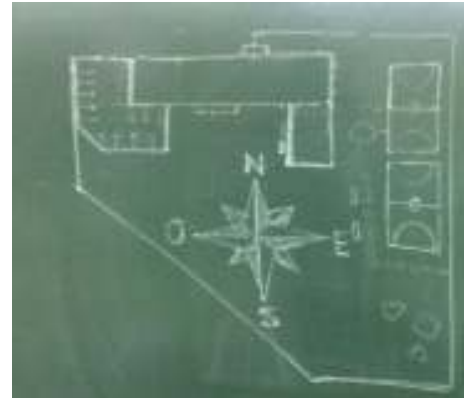
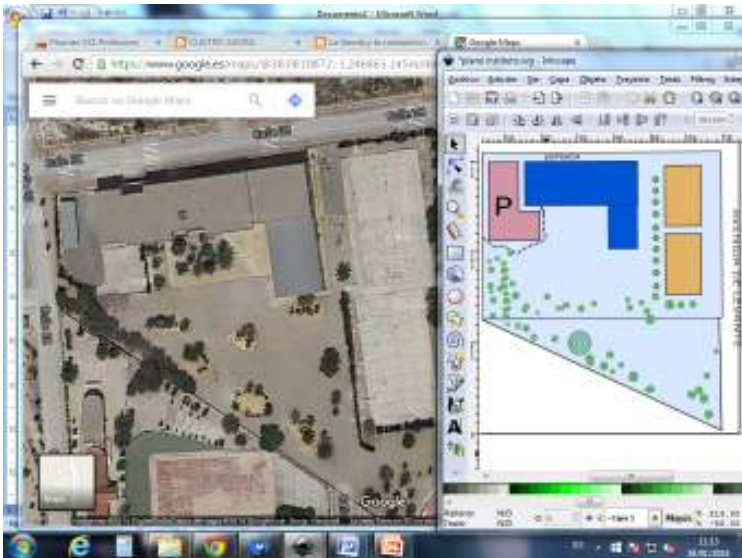


Image.: On the left, the satellite image from Google and the sketch drawn by the students and used to get spatial orientation. / On the right, the same map drawn on the blackboard.

Initial hypothesis

A globe is used to mimic the celestial sphere, there the pupils draw the horizon line and the location of the cardinal points. Next, we plot the hypothesis of the Sun movement

Hypothesis 1: Sun movement in January. See blue line in the Figure.

Hypothesis 2: Sun movement in March. See red line in the Figure

Are these two movements similar?

These two movements are drawn in the globe.



Picture 1. Students plotting the Sun movement (I)



Picture 2. Observing and analyzing the relation between the shade and the sun position.



Picture 3. AI Students plotting the Sun movement (II)

Picture 4. Drawing details

2. Experiments to check the hypothesis.

Measurements of the length of an object's shadow created by the sun, in a full day from the sunrise till the sunset.

- a. In Winter.
- b. In early Spring
- c. In late Spring.

For a more pedagogical experience we have choose the equinoxes and solstices

The students organized themselves in groups, and create a timetable and the groups shifts to perform the measurements.

- They decided to measure every half an hour.
- The day for the data acquisition was decided taking into account the weather forecast aiming for a clear and sunny day without wind.
- The measurements were taken in a continuous paper, which is fixed along the day.
- The data, which were taken in three days in winter, early and late spring, were collected in the same paper, which was kept in the classroom.



Picture 5. Measuring: students mark the final shade point.



Picture 6. Two objects were made to measure the shade. In the end one of them was rejected.



Picture 7. Stones were located for a better view of the results of the measurements taken up to that moment.



Picture 8. Along with other group students they observe and comment on the results.

3. Demonstration of the hypotheses.

Once the measurements were performed, the students analyzed these results and proved if the theoretical hypotheses agree with their observations. These first observations allowed them to make new hypothesis about the sun movement during the next measurement day.

4. Theoretical aspects related to the activity.

In the classroom, all the pupils studied under the supervision of the teacher, the basic theoretical aspects of celestial mechanics associated with this activity:

- Earth's orbit.
- Inclination of the Earth's axis
- The four seasons
- The equinoxes and solstices.
- Orientation by the sun.
- Orientation by the star during the night, celestial navigation, and the pole star.

5. Model construction

Some of the students completed the activity constructing two miniatures related with this scientific project. The first one simulates the Earth's orbit around the Sun, whereas the second one mimics this experiment which measures the shade of an object to trace the sun movement. Finally, the third model draws the sun movement measured by days in a plastic sky globe, where, we can follow the shadow of an object with a flashlight

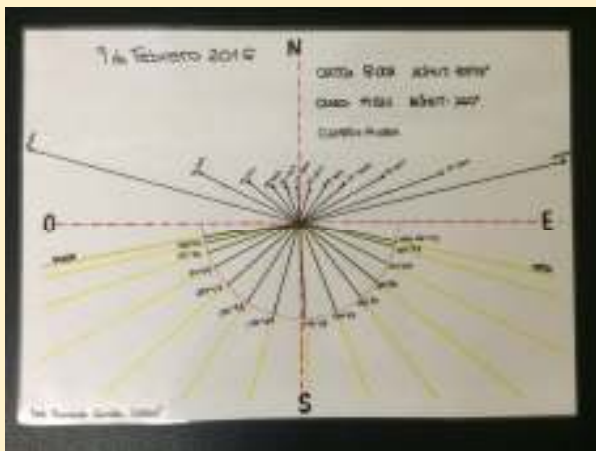
Model simulates the Earth's orbit around the Sun



This experiment measures the shade of an object to trace the sun



Time	Altitude	Distance	Shadow
7:30	45°	100	141.4
7:45	40°	120	169.7
8:00	35°	140	214.1
8:15	30°	160	270.6
8:30	25°	180	343.9
8:45	20°	200	439.9
9:00	15°	220	574.4
9:15	10°	240	759.7
9:30	5°	260	1000.0
9:45	0°	280	1300.0
10:00	5°	300	1671.4
10:15	10°	320	2125.6
10:30	15°	340	2677.8
10:45	20°	360	3342.0
11:00	25°	380	
11:15	30°	400	
11:30	35°	420	
11:45	40°	440	
12:00	45°	460	



The final miniature draw the sun movement in the measurements days in a plastic sky globe. With a flashlight, we can follow the shadow of an object.



6. Final results of the activity.

At the end of this scientific project, the pupils were able to correctly draw the Sun trajectory in their hometown in different seasons along the year, and to plot it in a Earth globe. They have learned and understood the basic concepts of Celestial mechanics needed along the project.

As final activity, all the students were involved in the construction a sundial in the High school playground.

In addition, the students have understood that research and science is within the reach of all of them. The importance of working in a group and organization skills. And last but not least, that science is fun.

7. Timetable, place and public (tipo de publico).

The activity was carried out by the 40 students attending the subject "Introduction to research" ("Iniciación a la investigación") from the school year 1ºESO. The program developed for this scientific project was:

- **Last week of January:** The students planned and prepared the activity. They developed the initial hypotheses, constructed a extended long sheet of paper to take the measurements. They organized themselves into groups to perform the measurements, created the timetable and the group shifts for the data acquisition date. 3h
- **February 2nd.** First day of measurements.
- **February 3rd.** Analysis of the experimental data.
- **Second week in April** Preparation and execution of the second measurement day.
 - o *In the second day of measurements, all the students within 1ºESO were invited to join. The aim of the project as well as the results of the two measurements were presented and explained to the new students. Due to the pleasant weather, the experimental hours prolonged till sunset, which the students enjoyed while observing the first stars appearing in the sky. The activity was completed with the identification these first stars and the planets, for instance the pole star and Jupiter, respectively, and the observation of the moon with a telescope.*
- **Third week in April.** Analysis of the data, prove the initial hypotheses, and study of the theoretical aspects of celestial mechanics related to the experiment. 3 hours.
- **At the end of May.** Construction of the miniatures 3 hours (estimated)
- **June.** Dissemination of the activity and construction of the sundial 5h (estimated)

These activities were performed within the facilities of the high school (IES), either in the playground or in the classroom.

All the students attending the subject "Introduction to research", 40 in total, were involved in all the stages of this scientific experiment. They were split in two groups for the measurements taken at the playground. The data analysis and study of the basic concepts of celestial mechanics was performed by the full group at the classroom and supervised by the teacher. The dissemination day was open to the rest of students within the same school year, around 120 of them were involved in the activities.

Image Gallery



First measurement in the morning



Second measurement in the morning



Measurements with different students continue



A great distance among the first measurements in the morning is observed.



The students themselves organise the exits to measure in pairs.



During the break, the measurement awakes other students' curiosity and interest.



Measuring at noon



Sharing the activity with other 1st eso groups.



Some extra measuring to avoid mistakes.



Another groups fulfill a different measuring during the day. Due to strong wind the paper has to be fixed.



The wind makes measurements difficult



After sunset we all wait for the stars to come out as we observe the moon. When night fell we could observe Jupiter and the polar star. The observation was open for all the students.

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References

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CNICE <http://recursos.cnice.mec.es/biosfera/alumno/1ESO/Astro/contenido12.htm>

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