Teaching seasons with a hands-on activity

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ABSTRACT

Through a simple experimental activity with the students' participation, the seasons of the year can be studied in different latitudes. It is easy to explain phenomena such as the midnight sun, the apparent motion of the Sun, and the influence of the tilt of the Earth's axis using the experimental apparatus. Also, why the equatorial region has a more temperate climate, whereas the temperatures near the poles tend to be more severe.

Keywords: teaching physics; astronomy; seasons; practical activity.

1. INTRODUCTION

Since ancient times, astronomy has attracted great interest. Means of Communication, especially television, have been increasing the availability of space for this science. In elementary school, astronomy represents the gateway to the study of Physics, especially in the final years.

All levels of education should offer astronomy instruction in a broader level. To make this possible, teachers must receive training in astronomy topics and education. Generally, astronomy is taught in school curricula. However, if students are not exposed to practical activities, such as observational experiences, there is a high probability that they will be restricted to uninteresting calculations. It is necessary to promote astronomy teaching in elementary and high school teachers [1, 2].

In this regard, we intend to provide support material to be used by Science and Physics teachers, which presents a simple but correct language and is easy to use. However, it should be emphasized that the material does not replace the adopted textbooks, but rather constitutes a complement.

To clarify the main doubts students and teachers may have, the produced material contains information about the apparent movement of the Sun, the inclination of the earth's axis, and the seasons of the year. As well as correcting some misconceptions found in some didactic publications.

A simple experimental activity is presented that facilitates the understanding of phenomena and objects. In this sense, this work was constructed as a reference in a series of books and articles reported in the literature [1-10].

2. INTRODUCTION TO ASTRONOMY

In space, the planet Earth moves continuously in several directions. Two of these movements stand out: rotation and the revolution (also called translation). The first is responsible for the alternation of day and night, for the apparent movements of the stars at night and for the apparent movement of the Sun during the day.

At this point, it is very pertinent to point out that the word “day” has two different meanings, and this may cause some confusion at this point. As well as expressing a period of approximately 24 hours (one complete rotation of the Earth, 23:56), day also refers to the bright part of the day when the Sun is above the horizon. As a distinction from clear days, the Greeks called this period nyctermer. Another movement is the orbit of the Earth around the Sun in 365.2422 days (because of this fraction, every four years there is a year with 366 days), more specifically 365 days, 5 hours, 48 minutes and 46 seconds. Usually, this period is called a year, you can find more details here [11].

It was well known that these time intervals corresponded to four predictable climatic phases, which followed one another even before these numbers were known. In this time period, there are two solstices and two equinoxes that mark the start of the seasons [12, 13].

Planets travel in elliptical orbits around the Sun, with the Sun at one focus. There is a misconception about ellipses, which are described as very flat figures. However, planetary orbits have small eccentricities compared to their circumferences [13]. In a cycle that lasts between 90,000 and 100,000 years, the eccentricity of the Earth's orbit varies between 0 and 0.070. Currently the eccentricity is about 0.017 [15-17].

Thus, there are times when the planet is closer to the Sun (perihelion) and other times when it is farther from the Sun (aphelion). Considering that we are dealing with astronomical distances, this difference is minimal. At perihelion (the point in the orbit where the distance from the Sun is minimum) the Earth is 5 million kilometers closer to the Sun than at aphelion (the maximum distance). While many still attribute the seasons to this difference in the planet's orbit [18], this explanation is incorrect.

3. APPARENT MOVEMENT OF THE SUN

At dawn, the Sun appears on the horizon and we have the impression that, as the day goes by, it moves, reaching a maximum point in the sky, then descending towards an opposite point on the horizon, until disappears at dusk.

When we use some specific points, such as the horizon line, it is possible to perceive the apparent motion of the celestial bodies. In principle, horizon can be understood as an imaginary line, the limit of an immense circular plane.

For orientation, we also use the system of cardinal points: North, South, East, and West, which can be determined through simple astronomical observations. An instrument called gnomon can be used to extract a variety of important information from the point of view of Astronomy. One of them is the meridian of the place where you are. This line runs through the geographic north-south position of the place where you are.

Essentially, the gnomon is just a vertical stake firmly inserted into the ground. This continuous variation of the shadow of this stake, as the Sun moves across the celestial sphere throughout the day, informs the fraction of the day at that moment, Figure 1 [19-22].

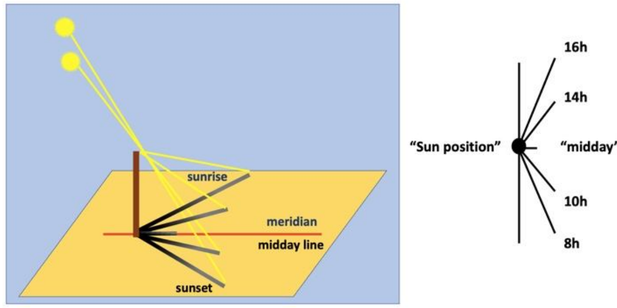


Figure 1. Shadow of the gnomon at different times during the day.

Local midday line can be determined by the smallest shadow cast by the gnomon, which is then local meridian line, which in turn indicates the north and the south cardinal points. By drawing a line perpendicular to the meridian, we find the east and west cardinal points.

The word meridian is directly related to a certain geographic coordinate. The geographic coordinates of a certain place on the Planet are called Latitude and Longitude. Both are represented by imaginary lines drawn on the terrestrial globe, and are used to help us locate certain points on Earth.

The equator can be understood as an imaginary line around the middle of the planet. It is halfway between the North and the South Pole, at *0* degrees latitude. An equator divides the planet into northern and southern hemispheres.

Thus, latitude expresses, in degrees, how far a point moves away from the equator. A parallel is an imaginary line that passes through all points with the same latitude, the parallel of 50^0 north is shown in Figure 2.

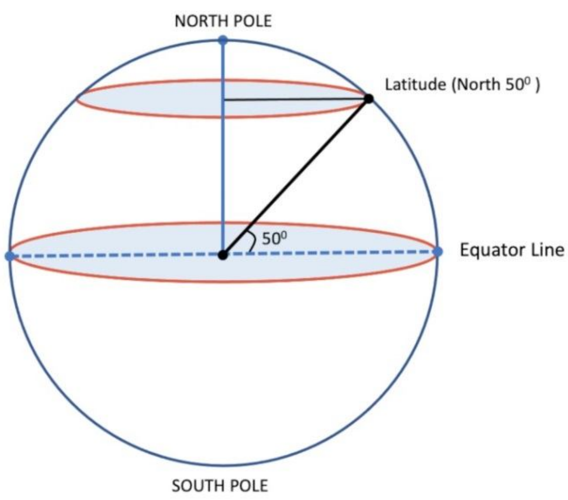


Figure 2. Representation of the 50^{th} parallel North.

Longitude expresses, in degrees, the distance of a point from the Greenwich Meridian, chosen as a reference. A meridian is an imaginary line that passes through points that have the same longitude, as shown in Figure 3.

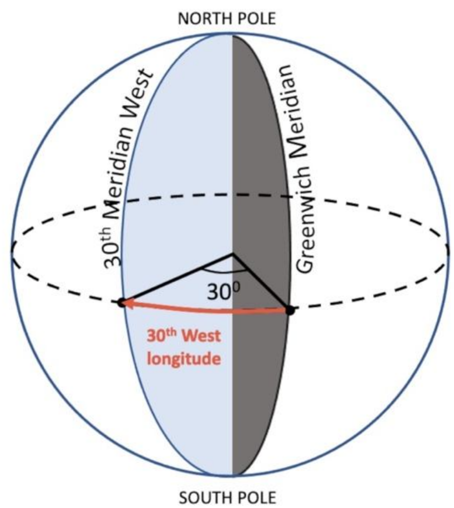


Figure 3. Representation of the 30th west meridian.

If we take the equator as a reference, we have some important parallels that have their own nomenclature, as shown in Figure 4.

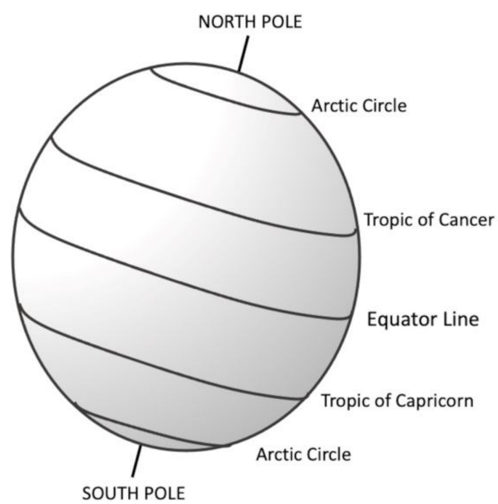


Figure 4. Representation of parallels.

In addition, two other lines, called the Tropic of Cancer and Tropic of Capricorn, are represented. These lines delimit the strip on the Earth's surface in which the so-called "sun is upright" occurs. At the equator, it occurs on the day of the equinoxes; for cities that are on the Tropic of Capricorn, the sun is high only once a year, December 21st.

On the summer solstice, outside the intertropical region, the Sun will be reaching its maximum height at noon. As shown in Figure 5, the height will be minimal at the culmination of the winter solstice.

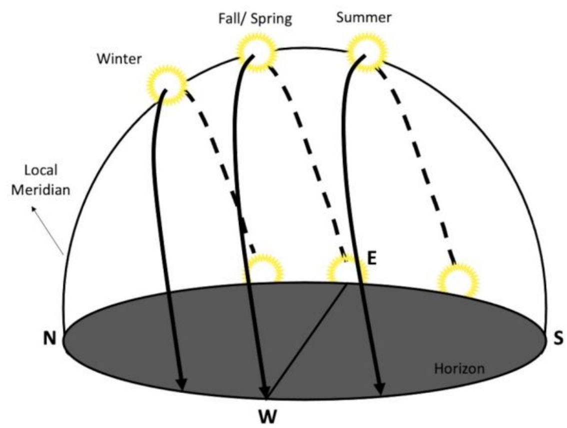


Figure 5. Maximum height of the Sun according to the time of year.

It is interesting to note that, despite the Sun rising in the same direction every day, the exact place the star appears on the horizon varies within a range of points on the horizon, around the true east cardinal point, which is the central point [20].

According to Figure 8, a person on the (east-west) line would observe the Sun more to the north, which follows a lower path relative to the horizon throughout the day. At this time, the days for this person would be shorter, while the days would become longer as the Sun rose further south.

Therefore, the Sun appears on the eastern horizon at different times during the year, starting at the tropic of Capricorn in the southern hemisphere (latitude 23.5° South) and ending at the Tropic of Cancer in the northern hemisphere (latitude 23.5° North). Thus, in December, for the observer on the east-west axis in the Southern Hemisphere, the Sun rises in the Eastern horizon over the Tropic of Capricorn, while in June, it rises over the Tropic of Cancer.

Seasons have distinct characteristics in the polar and equatorial regions. Near the poles, the year is divided simply into periods of darkness and light. Near the equator, it is divided into periods of rain and drought. In this sense, we cannot directly connect weather to a season because the well-known description of the seasons - spring (flower period), and autumn (fruit period), for example, applies only to temperate climates.

4. TILT OF THE EARTH'S AXIS OF ROTATION

In describing the Earth's orbit around the Sun, we have already seen that it is an ellipse with a very low eccentricity. Eccentricity is a measure of how much a circle has been 'smashed' to become an ellipse (if it is zero, we have a circle). Therefore, the variation in distance between Earth and the Sun does not affect the seasons.

There is an angle of about 23.5 degrees between the celestial equator and the ecliptic (Figure 6). When projected on the celestial sphere, the terrestrial rotation axis indicates the north and south celestial poles; this axis 'always' points to the same position on the celestial sphere. Consequently, through the course of a year, our planet goes through four particular positions: two solstices that mark the beginnings of summer and winter, and two equinoxes that mark the beginning of spring and autumn.

A Solstice (Summer or Winter) occurs when the Sun reaches its maximum angle from the celestial equator. A summer solstice will be marked by the longest day (insolation period) in one hemisphere, while a winter solstice means longer nights in the opposite hemisphere. The further we are from the equator, the greater the difference between the length of days and nights throughout the year. On the equator, days and nights never differ.

An Equinox (Spring or Autumn) occurs when the Sun crosses the celestial equator. In these periods, days and nights are of equal length (12 hours). When the autumnal equinox occurs in one hemisphere, the spring equinox occurs in the other. Hence, different areas of Earth will be perpendicular to the flow of solar energy during its orbit.

Because of the tilt of the axis of rotation, the same area on Earth receives different intensities of solar energy throughout the year. These variations change the amount of energy received by the area and consequently change temperatures and the length of the day, resulting in climatic variations.

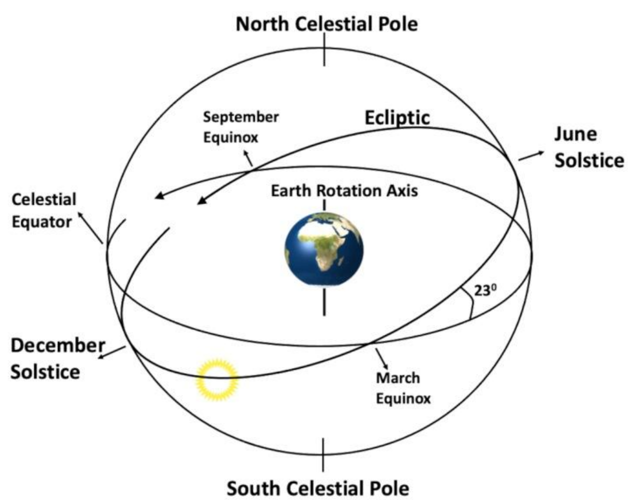


Figure 6[1]. Representation of the inclination of the ecliptic in relation to the Earth's axis of rotation.

Twice a year, the Sun is at its zenith between the Tropics of Capricorn and Cancer. On these lines, situated on the 23.5 parallel, the Sun is overhead only once a year (June 21 in the Tropic of Cancer and December 21 in the Tropic of Capricorn). The lines of the Arctic and Antarctic Circles define the region of Earth where in the winter period there will be at least one day in which the sun will not appear.

5. THE SEASONS OF THE YEAR

The study of the seasons has been one of the astronomy topics discussed in basic education, the final years of elementary school. Nevertheless, even today we find among teachers and even in some textbooks an excessive superficiality in the treatment of the subject, if not conceptual errors [23]. There's the widely publicized fact that the Earth's orbit is not a circumference, but an ellipse, which implies that the distance between our planet and the Sun can vary, which is often exaggerated in textbooks, resulting in misinterpretations [15, 24].

[1] The dimensions of the Sun and Earth are not to scale, they are merely illustrative.

There is a wrong explanation for the seasons related to the distance from the Earth to the Sun, that is, when the Earth is closer to the Sun it is summer and when it is farther from the Sun it is winter. This explanation can be found in several didactic texts [24, 25].

Wilton S. Dias and Luis Paulo Piassi published an article in 2007 [26] to demystify this concept that is often misrepresented by science teachers. The authors determined how the Earth's temperature is affected by its distance from the Sun. The mathematical expression they arrived at enabled us to visualize the magnitudes that determine Earth's temperature, as well as showing their dependence on Earth's distance from the Sun.

According to the calculations, the temperature variation caused by the difference in distance from the Sun is much smaller than the variation in insolation caused by the inclination of the Earth's imaginary axis.

We can now describe the main characteristics of the seasons in each hemisphere after understanding that the phenomenon of seasons does not depend on the distance between the Earth and the Sun at different times of the year, but on the inclination of the Earth's imaginary axis.

5.1 From December to March

In the southern hemisphere, at the December solstice, the Sun's rays hit the Earth practically perpendicularly at the Tropic of Capricorn (23.5^o South). A tangent line was drawn between the lines of the tropics to illustrate how the solar energy reaching the Earth's surface is concentrated along these lines, resulting in higher temperatures, as shown in Figure 7.

In other regions, such as in the high latitudes of the Northern Hemisphere, as in the Tropic of Cancer, the sun's rays reach the surface with a greater inclination in relation to the zenith, meaning the same energy intensity is spread over a larger area, resulting in cooler temperatures. During other summer days, with the Earth moving in its orbit, the sun's rays will hit other latitudes lower in the southern hemisphere, and the Tropic of Capricorn will have a lower maximum height.

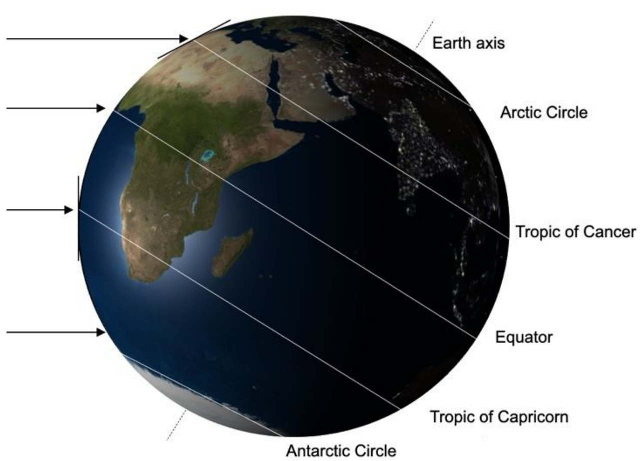


Figure 7. Representation of the sun's rays at the December solstice (adapted[2]).

[2] https://en.wikipedia.org/wiki/Season

5.1.1 Characteristics of the December Solstice

1. The Sun is at its maximum displacement south of the equator (it is over the Tropic of Capricorn, 23.5° south), so it is highest in the southern skies.

2. The Sun rises and sets with the greatest distance to the south, in relation to the east and west cardinal points.

3. The South Pole is always illuminated and the North Pole is always dark.

4. Longest illuminated day of the year in the Southern Hemisphere and the shortest in the Northern Hemisphere.

5.2 From March to June

On March 22nd, the Sun's rays will be perpendicularly incident on the Equator, latitude 0, as shown in Figure 8. At this time, the March equinox occurs. The sun's energy is evenly distributed in both hemispheres, indicating that spring has arrived in the northern hemisphere and autumn has arrived in the southern hemisphere. By this date, the Sun will rise into the Northern Hemisphere perpendicular to the horizon, meaning the days will get longer in the Northern Hemisphere and shorter in the Southern Hemisphere.

5.2.1 Characteristics of the March Equinox

1. The Sun is crossing the celestial equator from south to north, exactly over the Vernal point.

2. It is one of the two days of the year when the Sun "rises" exactly at the east cardinal point and sets exactly at the west cardinal point.

3. All regions of Earth are equally illuminated.

4. The time of day illuminated is equal to the time of night.

5. Sun is perpendicular to the Earth's equator.

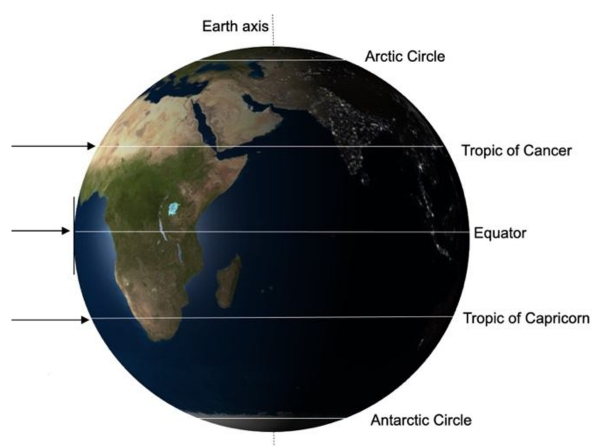


Figure 8. Representation of the sun's rays at the equinox (adapted[3]).

[3] https://en.wikipedia.org/wiki/Season

5.3 From June to September

As shown in Figure 9, during the June solstice, the Sun reaches its maximum height at the Tropic of Cancer (23.5^o N), raising temperatures. The Southern Hemisphere now has low temperatures and short days, while Europeans are in the midst of summer.

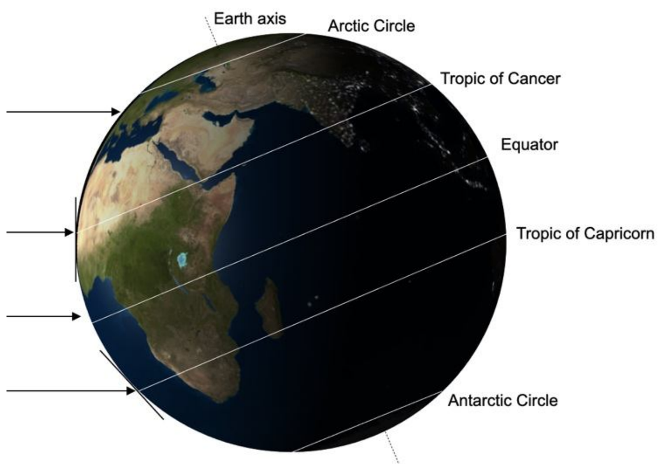


Figure 9. Representation of the sun's rays at the June solstice(adapted[3]).

5.3.1 Characteristics of the June Solstice

1. The Sun is at its maximum northward displacement.

2. The Sun rises and sets with the greatest distance to the north, in relation to the east and west cardinal points.

3. The South Pole lives with a long night of practically 6 months (Sun always below the horizon), while the North Pole enjoys the spectacle of the Midnight Sun [26].

4. Shortest day of the year in the Southern Hemisphere and the longest one in the Northern Hemisphere.

5.4 From September to December

On September 23, the equator again receives solar energy perpendicularly, as already shown in Figure 8, as the sun's rays perpendicular to the surface migrate upwards. The north and south once again receive equal amounts of energy. On this date, it's the September equinox, which marks the beginning of spring in the southern hemisphere and autumn in the northern hemisphere. The temperature is mild and there are equal stretches of day and night everywhere.

5.4.1 Characteristics of the September Equinox

1. The Sun is crossing the celestial equator from north to south.

2. It is the second day of the year when the Sun rises exactly in the East and sets exactly in the West.

3. All regions of the Earth are equally illuminated.

4. Again, the Sun falls vertically on the Earth's equator.

The sun's rays perpendicular to the surface migrate from the equator (September 23) back to the Tropic of Capricorn as Earth moves in its orbit, bringing another summer for Southerners and a winter for Nordics.

6. THE DIDACTIC PLANETARIUM

It is possible to conclude from the discussion in the text that it is not so easy to visualize the issues related to the seasons, in addition to other movements of the Sun, the Moon or the stars observed from Earth [27, 28]. Students listen to the news about seasons in different places on Earth, however few actually understand the process. Thus, a didactic planetarium will be presented, which facilitates the demonstration of the physical phenomena involved, with interdisciplinary connections between Physics, Geography, and Mathematics.

6.1 Activities and construction of the Planetarium

6.1.1 Content explored

- Earth Movements (Rotation and Translation);
- Rotation axis;
- Tilt of the Earth's rotation axis;
- Parallel lines;
- Light intensity;
- Latitude and longitude;
- Seasons;
- Solstice and Equinox.

6.1.2 Problematizing issues

a) What are the reasons for the seasons? And the days and nights?

b) Why at a certain time of the year, when we wake up at 6:30 in the morning, to go to school, it seems that it is still night and, six months later, when we wake up at the same time, it is already a clear day with a beautiful sun outside?

6.1.3 Objectives

- Assembly of a didactic planetarium;
- Enable students to deepen their understanding of basic astronomy concepts;
- Relate that it is not the distance that interferes with the seasons.

6.1.4 Materials

- 1 4cm diameter Styrofoam ball (for each student);
- 1 printed copy (colored or not) of the Earth template (Figure 10) (for each student);
- 1 toothpick (for each student);
- 1 modeling clay of any color;
- 1 school ruler;
- 1 pair of school scissors;

- 1 tube of school glue;
- 1 pen or pencil;
- 1 wooden base (to attach a socket with extension to plug into the lamp socket);
- 1 incandescent lamp (60w or similar);
- 1 roll of adhesive tape.

6.1.5 Procedures

1. Cut out the Earth template (Figure 10);

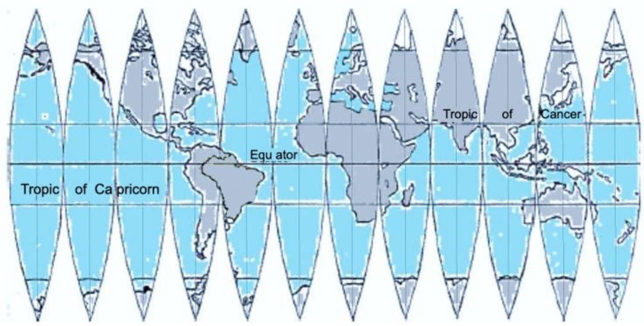
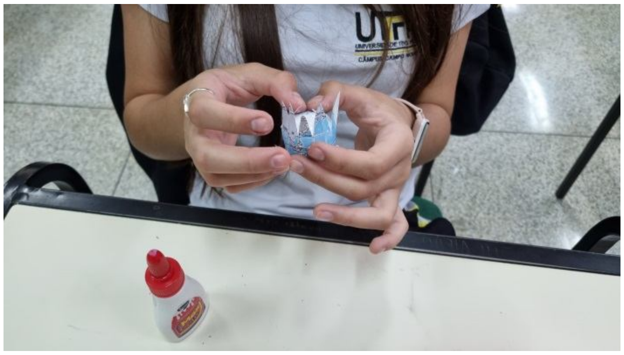


Figure 10. Earth template for cutout.

2. Paste the cutout on the Styrofoam ball (Figure 11);



(a)

(b)

Figure 11. Student making the collage. (a) Detail of the beginning of the bonding and (b) almost finished procedure.

3. Place a toothpick at the bottom of the ball, so that it crosses the entire styrofoam ball, representing the axis of terrestrial rotation;

4. At the end of the toothpick in the southern hemisphere, place a little modeling clay to fix the “Earth” built on the ground;

5. Take the double wire, at one end connect the male pin, at the other end connect a receptacle (socket/nozzle). Fix it on a wooden board (Figure 12).

6. Using adhesive tape fit/attach the wires that come out of the nozzle, to the wooden base and connect it to the socket;

7. Place the lamp in the socket;

8. Each student should place their "Earth" on the floor, to simulate the Earth's trajectory (orbit) around the Sun for a year (at this point, the teacher should not discuss the distance from the planet to the Sun, leaving it up to the students to decide how they will engage in the activity);

9. When all the spheres are in position, and the lamp is still off, ask the students to point which of those “Earths” each season of the year would be on, and then ask them to support their choice;

10. To create an imbalance in what the student already knows, the teacher can ask the following question if they suport they choice using the distance between Earth and the Sun, “If it's summer when the Earth is closest to the Sun and winter when it's farthest from the Sun, then in December, for example, it should be summer on the entire planet Earth. Is that what happens?”

Figure 12. Using the model.

11. Here, it is essential for the teacher to pay attention to the tilt of the Earth's axis. All Earths placed on the ground by the students must have the axis of rotation pointing to the same side. If the students have placed it differently, lead the discussion to get it right.

12. Afterwards, it is asked how day and night happen in this orbit.

13. It is requested here that the students discuss among themselves and elaborate an explanation for the occurrence of the seasons of the year and for the occurrence of the days and nights.

14. Then, the lamp is turned on so that the students perceive the difference in luminosity in the spheres - they will be able to perceive that the inclination is the reason for the seasons.

From this point onwards, the teacher continues questioning them about the seasons, solstice and equinox, luminosity at the poles, the reason for the planet's inclination, giving students the opportunity to be part of the process.

6.1.6 Debate

The approach to this activity is based on four key points:

1 - Explore the movements performed by Earth;
2 - Interpret how the seasons occur;
3- Communicate the results obtained and the knowledge acquired;
4 - Reflect and present the conclusions;

The expansion of knowledge in the process is due to the interaction of students throughout the process, they must reflect together and be active in the process. Students must submit reports on the activity performed.

6.1.7 Caution

Only the teacher should handle the socket in order to avoid shocks and students should be warned of the possibility of burns if they put their hand on the heated lamp.

7. CONCLUSION

A practical proposal has been developed to teach the seasons at different latitudes, as well as phenomena such as the midnight sun and the apparent movement of the Sun.

A teacher who practices constructivist teaching and creates an environment where students can interact and participate in the teaching-learning process can make astronomy an extremely productive and participatory tool for interdisciplinary work.

Physics, Geographers, and Mathematics are very interconnected disciplines, and a practice-based approach to learning Astronomy can improve their understanding. The subject's participation and the student's resuming of their role as an active person can improve their oral and written skills, socialization, and the possibility of appreciating Astronomy in their daily lives.

The activity, when presented to students, generates satisfaction from all. The student for being surprised to understand the fact the inclination of the earth's axis causes incidence in different ways in different parts of the surface, causing different phenomena, and the teacher for being able to facilitate learning. We hope that this material can be used by other teachers, with minor adaptations, to provide quality astronomy instruction.

ETHICAL APPROVAL

With this document we are attesting that consent has been obtained and that any identifiable individuals are aware of intended publication.
We attest that consent was obtained for all identifiable individuals in the manuscript.
The research project that generated the paper was submitted for approval by the CEP-UTFPR (ETHICS COMMITTEE IN RESEARCH INVOLVING HUMAN BEINGS) of the Federal Technological University of Paraná - Brazil, in accordance with the attributions defined in compliance with the CNS Resolution (National Council of Health) No. 466 of 2012, CNS Resolution No. 510 of 2016 and CNS Operational Standard No. 001 of 2013, and was approved. With case number in CAAE (Certificate of Presentation for Ethical Appreciation) 50459021.1.0000.5547. And with opinion approval number 4.993.567.

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