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## **Teaching Seasons with a Hands-on Activity**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors MCB and VCM designed the study, performed the analysis. Author ORDS wrote the first draft of the manuscript. Author TFV managed the analyses of the study. All authors read and approved the final manuscript.*

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### **ABSTRACT**

A simple experiment built by the students can be used to investigate the seasons at different latitudes. With the help of the experimental apparatus, phenomena such as the midnight sun, the apparent motion of the sun, and the influence of the tilt of the earth's axis can be easily explained. In addition, the equatorial region has a warmer climate, while temperatures near the poles are more severe. In order to contribute to the teaching of astronomy in elementary education, this work aimed at developing an auxiliary material for science and physics teachers, using simple but correct language and easy to consult, and at evaluating its pedagogical potential. The first has a quantitative approach, for which an experiment was conducted comparing the performance of elementary school students on an assessment instrument consisting of 29 questions about physics and astronomy, before and after the introduction of the interdisciplinary notebook for practical activities in astronomy. The second phase has a qualitative approach of descriptive type, for which we used the field diary prepared by the researching teacher during the implementation of the activities, as well as the documents prepared by the students as a data collection tool. The results of the first phase were organized using the paired parametric t-test. The choice of this test accounts for the intra-individual dependence of the observations. In general, our results show a build-up of practical and dynamic thinking that motivates students to be interested in astronomy and, most

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importantly, a change in the attitude of the teacher-researcher in front of the classroom. We believe that the implemented material has a great pedagogical potential, with a motivational and reflective character.

*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].

Gaspar [3] defends the idea of teaching in which experimental practices can promote greater interaction between students and teachers, thus expanding their educational knowledge, that is, when experimental activities are proposed in an investigative way, they contribute to student motivation and improve understanding of contents.

Experimentation drives students, the question of the teacher questioning them and letting them trace paths to find a solution to a problem is challenging as they should not have all the answers available, sometimes the teacher who is a support to the student should not give ready answers, with a manual for use and proof of theories, but let them follow their own paths and questions, in order to have a concise success with their thoughts [3].

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 [1-11].

## 2. 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 [12].

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 [13, 14].

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 [14]. 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 [15-18].

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 [19], 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 [20-23]. 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, Fig. 1.

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° north is shown in Fig. 2.

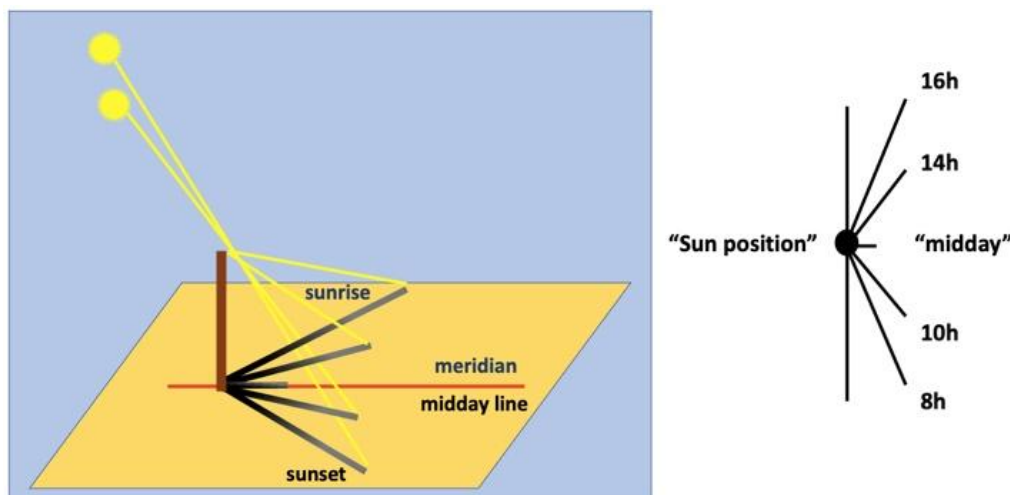
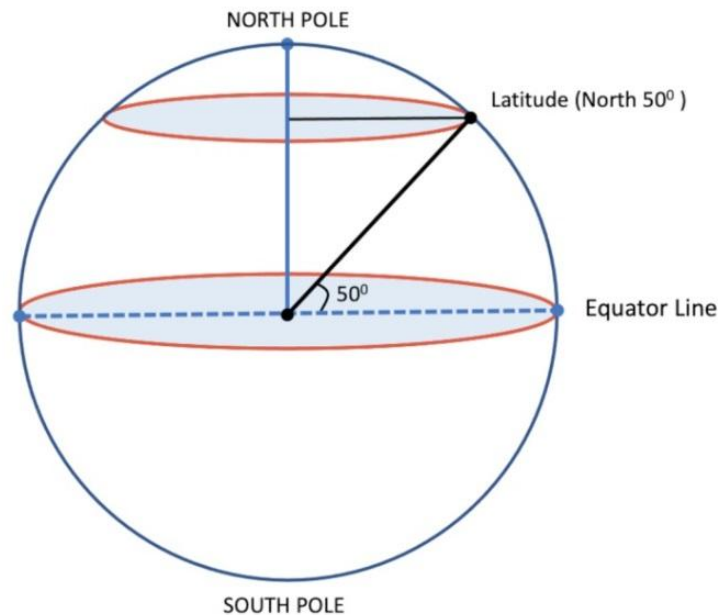


Fig. 1. Shadow of the gnomon at different times during the day



**Fig. 2. Representation of the 50<sup>th</sup> parallel North**

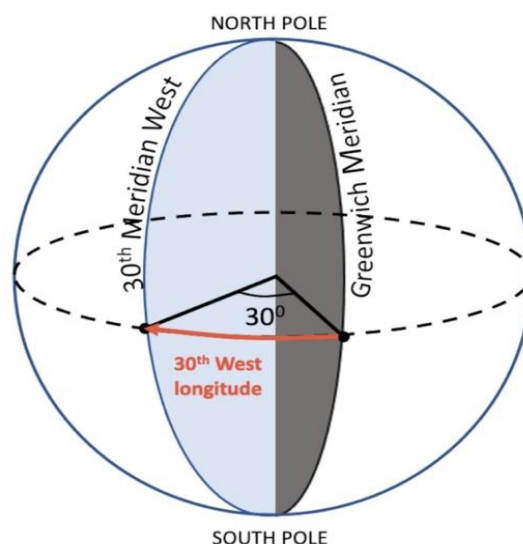
Longitude expresses, in degrees, the distance of a point from the Greenwich Meridian, chosen as a reference. A meridian is an imaginary line that passes through points that have the same longitude, as shown in Fig. 3.

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

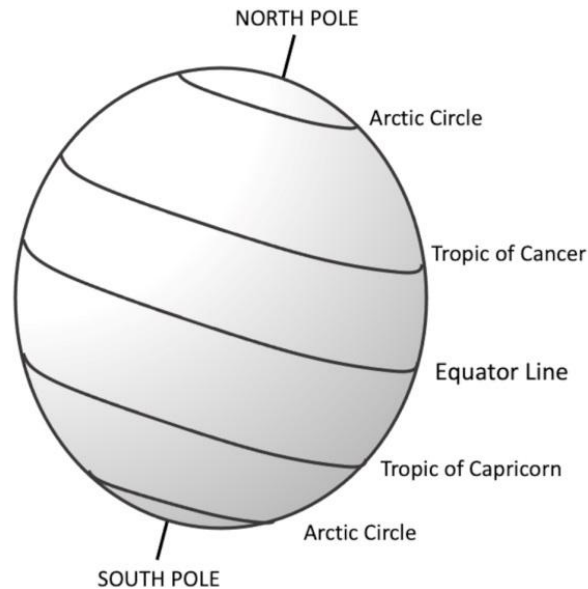
In addition, two other lines, called the Tropic of Cancer and Tropic of Capricorn, are represented.

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.

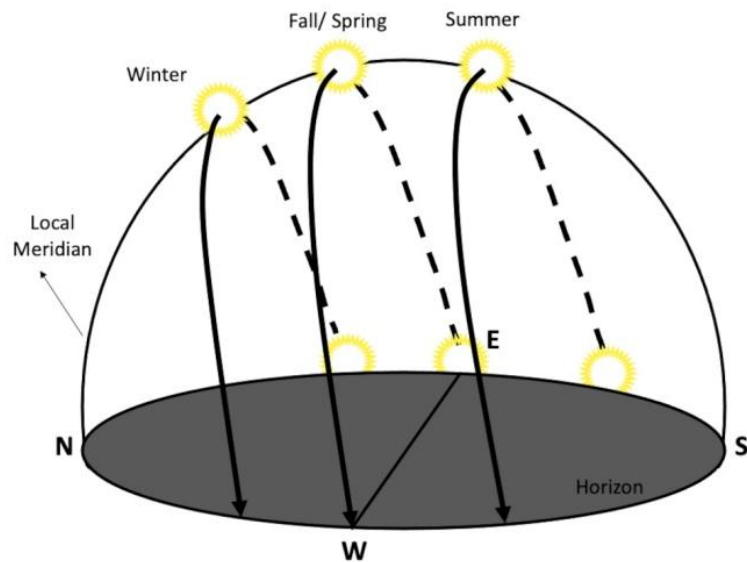
On the summer solstice, outside the intertropical region, the Sun will be reaching its maximum height at noon. As shown in Fig. 5, the height will be minimal at the culmination of the winter solstice.



**Fig. 3. Representation of the 30<sup>th</sup> west meridian**



**Fig. 4. Representation of parallels**



**Fig. 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 [21].

According to Fig. 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  $23.5^\circ$  South) and ending at the Tropic of Cancer in the northern hemisphere (latitude  $23.5^\circ$  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.

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 (Fig. 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.

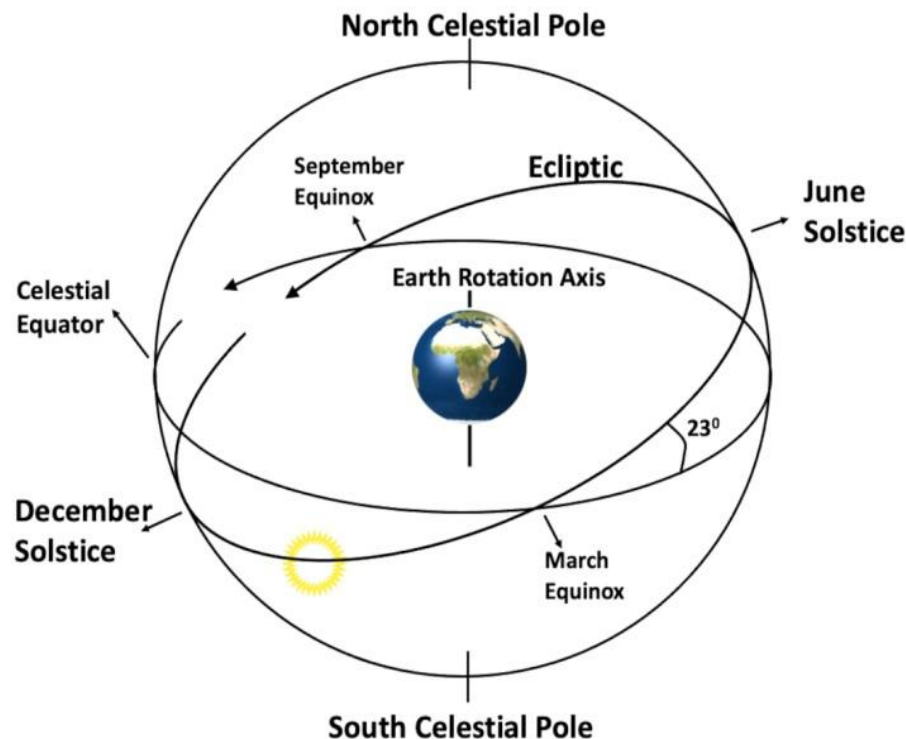


Fig. 6<sup>1</sup>. Representation of the inclination of the ecliptic in relation to the Earth's axis of rotation

<sup>1</sup> The dimensions of the Sun and Earth are not to scale, they are merely illustrative.

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.

#### 4. 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 [24]. 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 [16, 25].

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 [25, 26].

Wilton S. Dias and Luis Paulo Piassi published an article in 2007 [27] 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.

#### 4.1 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° 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 Fig. 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.

##### 4.1.1 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.

#### 4.2 From March to June

On March 22<sup>nd</sup>, the Sun's rays will be perpendicularly incident on the Equator, latitude 0, as shown in Fig. 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.

##### 4.2.1 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.

#### 4.3 From June to September

As shown in Fig. 9, during the June solstice, the Sun reaches its maximum height at the Tropic of Cancer ( $23.5^{\circ}$  N), raising temperatures. The Southern Hemisphere now has low temperatures

and short days, while Europeans are in the midst of summer.

##### 4.3.1 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 [27].
4. Shortest day of the year in the Southern Hemisphere and the longest one in the Northern Hemisphere.

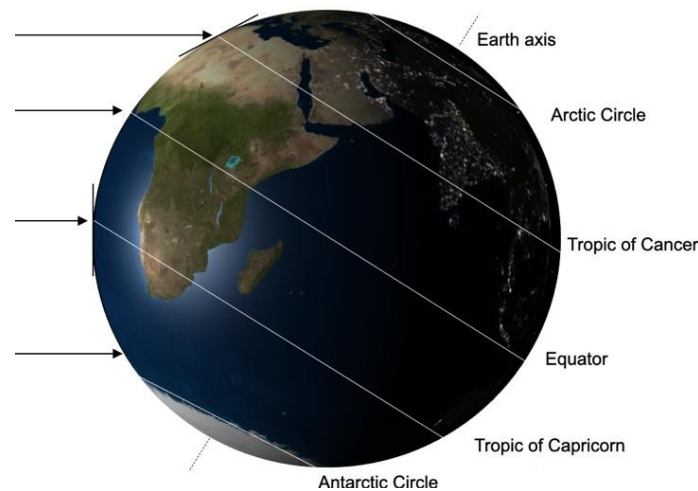


Fig. 7. Representation of the sun's rays at the December solstice (adapted<sup>2</sup>).

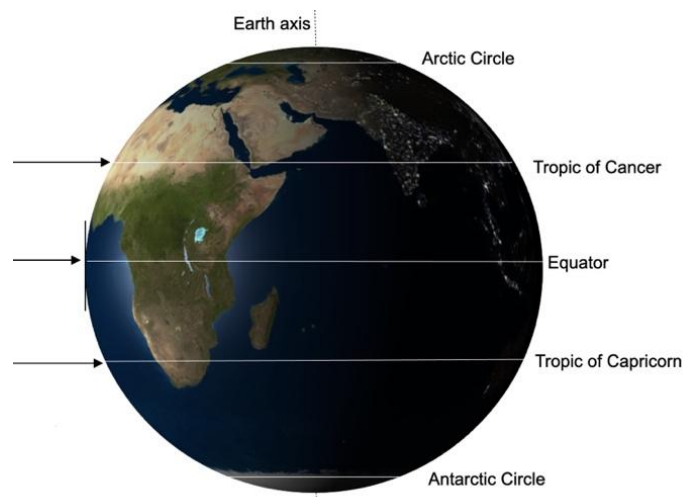


Fig. 8. Representation of the sun's rays at the equinox (adapted<sup>3</sup>)

<sup>2</sup> Available: <https://en.wikipedia.org/wiki/Season>

<sup>3</sup> Available: <https://en.wikipedia.org/wiki/Season>

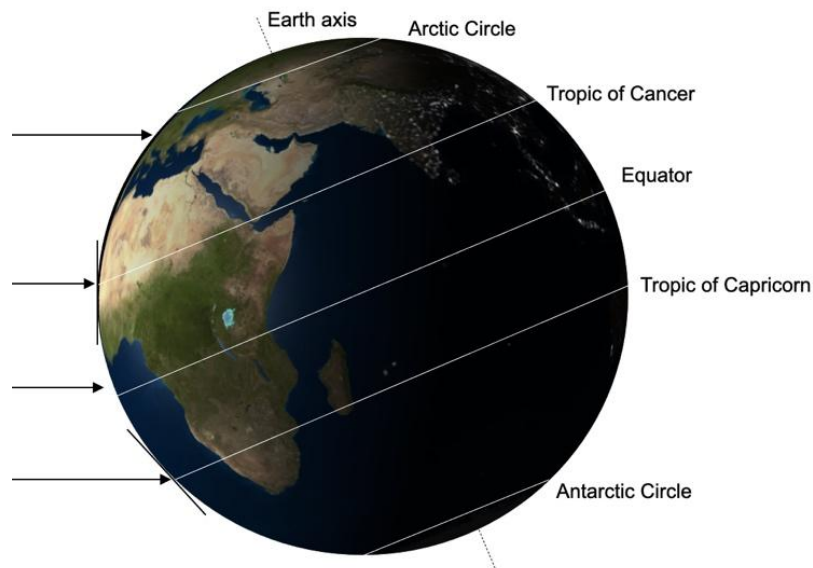


Fig. 9. Representation of the sun's rays at the June solstice (adapted<sup>3</sup>)

#### 4.4 From September to December

On September 23, the equator again receives solar energy perpendicularly, as already shown in Fig. 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.

##### 4.4.1 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.

## 5. 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 [28, 29]. 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.

### 5.1 Activities and construction of the Planetarium

#### 5.1.1 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.

#### 5.1.2 Problematising 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?

### 5.1.3 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.

### 5.1.4 Materials

- 1 4cm diameter Styrofoam ball (for each student);
- 1 printed copy (colored or not) of the Earth template (Fig. 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.

### 5.1.5 Procedures

1. Cut out the Earth template (Fig. 10)
2. Paste the cutout on the Styrofoam ball (Fig. 11)

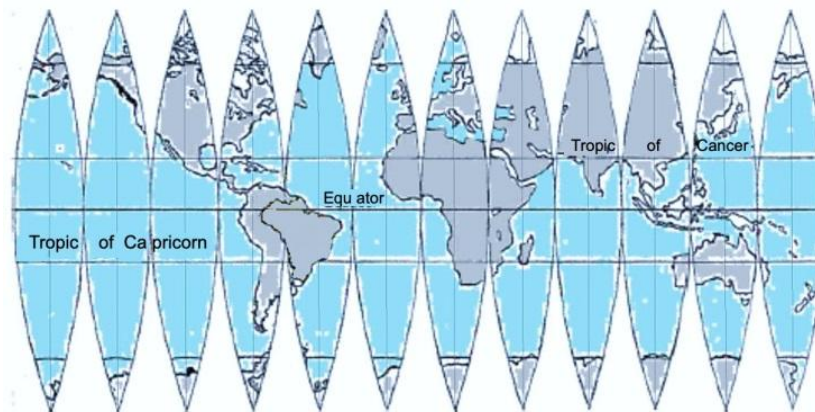


Fig. 10. Earth template for cutout



(a)



(b)

Fig. 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 (Fig. 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 support their 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?"



**Fig. 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.

#### **5.1.6 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.

#### **5.1.7 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.

### **6. METHODOLOGY**

This work is based on the assumptions of mixed research, descriptive type. A questionnaire and a field diary were created by the researching professor during the implementation of the produced support material in a classroom of a Brazilian private school. This was used to record the observations and comments made during the practical implementation of the proposal. Since students increase their knowledge through interaction with each other, it is important to document how they interact, argue, ask questions, and participate in a group.

The study of the collected material was conducted according to the assumptions of qualitative research in order to understand the interactions of the research subjects. To evaluate the difference between the two time points studied, we analyzed the questionnaires answered by the students under quantitative assumptions. In this analysis, we used a paired parametric t-test that accounted for intra-individual dependence of the observations.

The research data were collected in the second half of 2019, for which a physics teacher (the researcher himself) and two seventh grade classes of the elementary school of a private institution in the southern region of Brazil were available. The number of students in class A was 24, while that in class B was 22. There were practically the same number of boys and girls in both classes. However, only 17 students from Class A and 19 from Class B responded to the original questionnaire; the other students were not present that day for some reason.

## 7. RESULTS AND DISCUSSION

With the aim of investigating and verifying the effectiveness of the new teaching methods for physics and astronomy for learning in general, an experiment was conducted comparing the performance of elementary school students using an assessment instrument consisting of 29 questions about physics and astronomy before and after the application of the teaching. The questionnaire was designed to allow us to understand how much the students already knew about the topic being studied. The questions were related to the position and movements of the Earth, its distance from the Sun, day and night, the apparent movement of the Sun, the concepts of latitude and longitude, and the seasons.

The groups were composed of people of both sexes, with one group consisting of 19 people and the other of 17 people. To determine the difference in performance between the two time points studied, the paired parametric test (t-test) was chosen, since this test takes into account the intraindividual dependence of the observations. Defining  $D$  as the difference between the post- and pre-intervention variables, the  $T$  statistic of the paired t-test is as follows:

$$T = \frac{\bar{D}}{s_D / \sqrt{n}},$$

where  $\bar{D}$  and  $s_D$  are the mean and standard deviation of the differences  $D$  and  $n$  is the sample size. The  $T$  statistic has an asymptotic students  $t$  distribution with  $n - 1$  degrees of freedom [30].

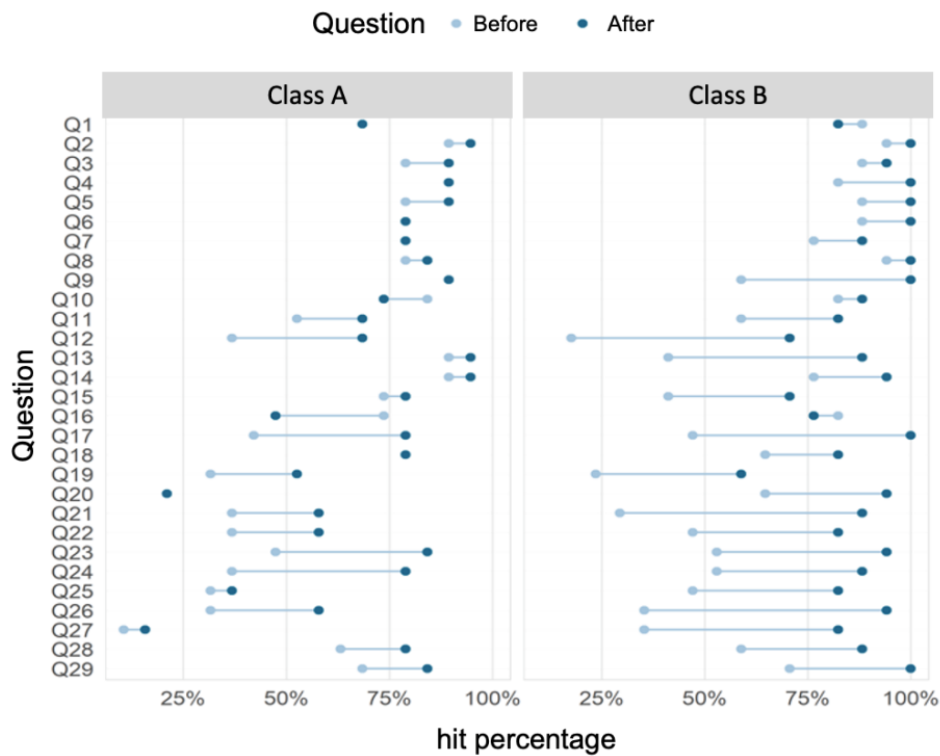
For the graphical representation in this case, profile plots of the measurements of the variables of interest before and after the intervention were used, where each line represents the progression of each student and the points are the values of the scores obtained at the two time points. The main purpose of creating the profile plots was to examine the behavior of the response variables in relation to the assessment period and to visually compare the results of the intervention.

For all tests, the significance level was set at 5%. All analyzes were performed using the statistical environment R (R Development Core Team), version 3.3.1.

Fig. 13 presents the information about the students correct answers for each question, considering the two assessment periods. It can be observed that for Class A, questions Q24, Q23, Q17, and Q12 produced the best results after instruction, while questions Q21, Q26, Q17, Q12, and Q27 were the highlights for Class B, which produced visibly better results.

The questions with the largest increases that converge between classes are Q12, Q17, and Q27; two of these deal with interdisciplinary concepts of astronomy with geography, dealing with topics such as meridians and parallels. This is an important finding because when the geography teacher teaches such concepts, they will already make sense to the students. They already know where they are used. The third question with the highest rate of correct answers among the classes, at the end of the paper, is the question that relates the seasons to the distance between the Earth and the Sun. This is a result that we consider very important for the evaluation of our didactic proposal, since such conceptual errors are also very common among children's teachers.

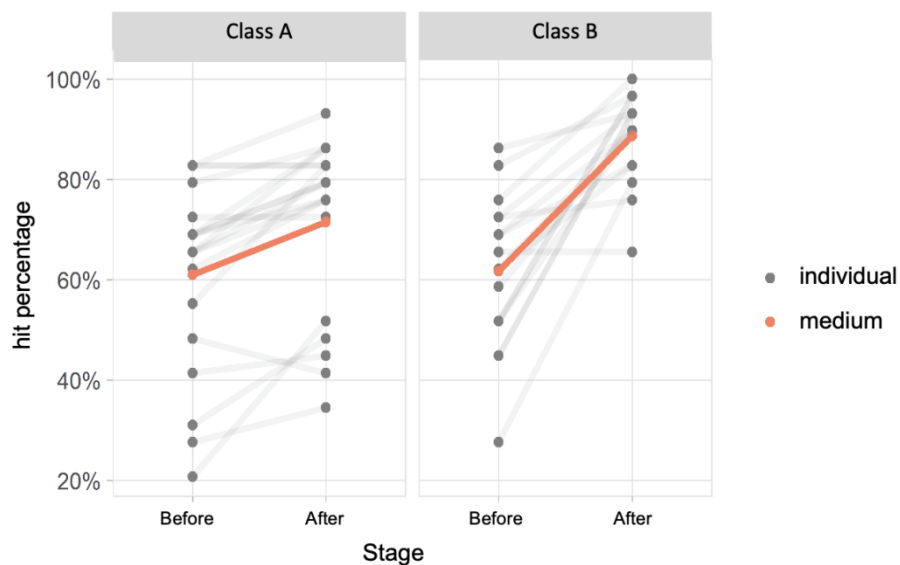
It can also be highlighted that for question Q16, the percentage of correct answers was lower in both groups after applying the teaching methods. In addition, the percentage of correct answers for questions Q1, Q9, Q18, and Q20 remained the same after the intervention in Class A, while in Class B the percentage of correct answers for question Q1 decreased.



**Fig. 13. Distribution of students correct answers by question and class in the two evaluation moments**

Fig. 14 shows the individual profiles in terms of correct answers (percentage of questions answered correctly in the assessment instrument) in the two assessment phases, organized by class. It can be seen that in most

individual cases there is a significant improvement in performance, which is reflected in the evolution of the average correct answers, which increase from 61% to 71.5% in class A and from 61.7% to 88.6% in class B.



**Fig. 14. Graph of individual profiles and average of the correct answers of the study participants before and after the intervention**

**Table 1. Descriptive measures of performance gain of study participants and paired t-test results**

| Class | Gain (Before-after) |        |         |        | T-statistic | P-value  |
|-------|---------------------|--------|---------|--------|-------------|----------|
|       | Minimum             | Mediam | Maximum | SD     |             |          |
| A     | −6,90%              | 10,53% | 31,03%  | 9,58%  | −4,7892     | < 0,001* |
| B     | 0,00%               | 26,98% | 51,72%  | 16,68% | −6,6677     | < 0,001* |

\*:  $p - value < 0,05$ ; SD: Standard deviation.

Supplementing the previous figures, Table 1 shows the descriptive measures of individual performance gains (difference between post- and pre-intervention) by group, as well as the results of the paired t-test comparing the two assessment time points.

It is noteworthy that there is a significant increase in performance in both groups ( $p$ -values < 0.001), with Group B standing out the most with an average individual performance increase of 26.98% and no decrease in this measure in all cases (no student regressed their performance).

In the last application of the final questionnaire, two more essay questions were asked to learn what they could perceive in the applied process. The students unanimously answered that they enjoyed participating in the practices and theories and recognized the importance of interdisciplinary and experimentation along with theory.

### 7.1 Carrying out the Practical Activity

At the beginning of the lesson, the teacher gave the students small Styrofoam balls, a drawing to cut out the ground plan of the earth (already with the imaginary lines and colored), a toothpick and some modeling clay. He asked them to cut out the apartment pattern and glue it to the sphere, place the toothpick on the sphere to represent its axis of rotation, and place the modeling clay on the bottom of the stick to support the sphere.

As for the collage, they noted that they could use as a base a line that divided the Styrofoam sphere in half to glue the equator line exactly on it to make it more correct. Then we asked them to observe where they were on the globe, and some began to question the time difference.

The teacher just watched while they finished the collage, the teacher attached a wooden base with a nozzle and a lamp on the floor, which at first already led to comments about what it would be used for, but the teacher did not answer.

We then asked the students to place their planets around the lamp, which was still off, to simulate a complete orbit around planet Earth; at that moment, the students realized that the lamp represented the sun. Nevertheless, each student placed their "Earth" somewhere, without asking and spontaneously, until one of the students pointed out that the Earth should not be placed so that it has a 90 degree angle to the ground because it has a tilt; another pointed out that they should all form an egg-shaped motion, that the Earth should be either closer or farther from the Sun.

The students arranged the planets in a disorderly fashion, and the inclination of most of them was always toward the sun, throughout the orbit. Then one student began asking his peers if the pole would thaw if it got too close to the sun. The students exchanged ideas among themselves and changed the inclination, but it was still far from what we consider correct. In a dynamic way, however, everyone participated in the process.

With the lamp off, the teacher asked the students to write the seasons on a piece of paper and place them where they thought they were. The students cheered as if they were at an amusement park and were clearly pleased with this exercise.

At this stage, a large number of students stressed that the piece of paper with summer should be placed on the Earth that is closer to the Sun, and the piece of paper with winter should be placed on the Earth that is farther from the Sun; this result corresponds to what we had already noted in the first questionnaire: *"If the summer paper is placed on the Earth that is closest to the Sun, then it should be summer all over the Earth, so it should be hot in Brazil and in the United States in December. Is that really so?"*.

One student quickly sought this answer by recalling movies he had already seen in which it

snowed in the United States at Christmas. At that moment, there was silence in the class. We understand that this silence is very important because they are thinking about the questions asked. Such questioning created a cognitive imbalance in the students because it "checkmate" the way they thought.

Students then had time to talk and come up with a new idea about the positions on the stations. After this step, students stressed the importance of spending the summer where the slope was more "illuminated."

After the students formulated the new hypothesis, the teacher turned on the lights and the students realized that they had to change the position of the earth and its slope because they did not understand that the lighting was necessary for the positioning.

This interaction allowed the teacher to seize the moment and ask some theoretical questions to get the students interested in the topic being discussed; they could research such questions at home if they wanted, but it was not mandatory.

At the beginning of the next lesson, students wanted to show that they had researched the questions noted in the notebook. In this lesson and the following one, the teacher introduced the theoretical aspects of this second module: the movements of the Earth and its relationships with the Sun. Again, we use texts and short videos to help us discuss the conceptual content.

The students asked several questions, mainly related to the solstices and equinoxes. Once the doubts were cleared, it was possible to see the students understanding in the reconstruction of the didactic planetarium, as they paid attention to the Earth's orbit and made it practically circular, as well as to the inclination of the Earth's rotation axis, which in this new construction always pointed to the same side, making possible the four seasons in the model.

The students wanted to explain the seasons using the didactic planetarium model by talking about the sun's rays being perpendicular to the earth's surface and inclined in relation to it. They emphasized the concentration of the sun's rays on a smaller area in summer and on a larger area in winter.

At the end of this lesson, the final questionnaire was used, which consisted of the same

questions as the initial questionnaire plus two discursive questions, to evaluate the activities carried out and whether they noticed any changes in their answers and whether there was any praise or criticism of the activities carried out.

In the final evaluation responses, there was unanimity that they had changed their answers a lot because they had already forgotten the content before starting the exercises, and that by doing the same exercises they were able to expand and remember many of the questions about astronomy.

This construction of practical and dynamic thinking helps to break down barriers between them, and collaboration can lead them to seek different ways to try to expand their horizons.

## 8. 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 students 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.

## CONSENT AND 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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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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