PRÁTICAS EDUCATIVAS, MEMÓRIAS E ORALIDADES

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Mathematics and astronomy: a interdisciplinary proposal focused on scientific literacy

ARTICLE

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Abstract
This paper aims to propose an interdisciplinary pedagogical script between the disciplines of geography and mathematics, combining concepts of astronomy – Earth's shape and Earth's movements in relation to the Sun – and mathematics – ellipses, spheres and spherical surfaces. The theoretical framework used takes into account authors such as Silva (2006), Honorato (2017) e Boczko (1984) for astronomy concepts, and Fazenda (2003; 1991), José (2008) and Trindade (2008), for interdisciplinary studies. Just as Chassot (2003), Hazen and Trefil (2009) and Sasseron and Carvalho (2011) to guide on scientific literacy. The construction of the script proved to be positive, taking into account pedagogical, social and cultural aspects and the gradual evolution of students' learning.
Keywords: Astronomy. Mathematics Education. Interdisciplinary. Geography Teaching.

Matemática e astronomia: uma proposta interdisciplinar voltada para a alfabetização científica

Resumo
Este trabalho propôs um roteiro pedagógico interdisciplinar entre as disciplinas de geografia e matemática, juntando conceitos de astronomia – forma da Terra e movimentos da Terra em relação ao Sol – e de geometria – elipses e superfícies de revolução. O referencial teórico utilizado leva em consideração autores como Silva (2006), Honorato (2017) e Boczko (1984) para conceitos de astronomia, e Fazenda (2003; 1991), José (2008) e Trindade (2008), para estudos em interdisciplinaridade, assim como Chassot (2003), Hazen e Trefil (2009) e Sasseron e Carvalho (2011) para balizar sobre alfabetização científica. A construção do roteiro mostrou-se positiva, levando em consideração aspectos pedagógicos, base social e cultural e uma evolução gradual da aprendizagem dos alunos.

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Palavras-chave: Astronomia. Educação Matemática. Interdisciplinaridade. Ensino de Geografia.

1 Introduction

Based on our teaching experience in the monitoring and residency programs during undergraduate studies, we are often questioned by students about the application of mathematics content. The vast majority of students still see this subject as a heap of contents that do not correspond to each other, or even, more problematically, that do not make sense in real life.

It is from this place of confusion and doubt reported by the students that emerges the idea of a pedagogical proposal that relates base subjects seen in other moments of the students' trajectories. And also to allude mathematics content to other disciplines - in this case, especially geography - bringing them together in a walk through an astronomical application. For this, basic concepts such as interdisciplinarity are indispensable, as Fazenda (2008, p.34) states:

> [...] Interdisciplinarity is defined as the interaction between two or more disciplines, we find that such a definition can lead us from the simple communication of ideas to the mutual integration of the key concepts of epistemology, terminology, procedure, data, and the organization of research and teaching, relating them.

Based on the concept presented by Fazenda, one can observe the importance of interdisciplinarity, especially to act as a bridge between disciplines and also as "a daring and searching attitude towards knowledge" (FAZENDA, 2008, p.34).

Based on this, one can think of Geography as an excellent tool to walk through current concepts, because, according to José (2008, p.4), "Working with current issues allows the development of comparisons between different realities. It allows the student to question, question certain truths and, based on them, elaborate explanations".

Allied to this, interdisciplinarity also acts as a tool for classical disciplines, such as mathematics, which, still according to José (2008), has a different language that first needs to be understood and only then applied. Still in this sense, Fazenda adds:

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> [...] to teach mathematics is, above all, to teach to 'think mathematically', to make a mathematical reading of the world and of oneself. It is a way to expand the possibility of communication and expression, contributing to social interaction, if thought of interdisciplinarily" (FAZENDA, 2003, p. 62).

Despite being seen separately in the school curriculum, mathematics and geography are subjects that are highly intertwined by concepts that touch on both. Thus, an interesting and potential perspective is to study the two disciplines in a complementary way, aligning content and highlighting important points of both. Thus, mobilizing the perspective of interdisciplinarity to understand and modify the world (FAZENDA, 1991).

Based on the concepts of interdisciplinarity presented above, a base will be built for the dissemination of scientific literacy in students, which according to Chassot (2003, p.91) can be considered "[...] as one of the dimensions to enhance alternatives that favor a more committed education". Or even defined as knowing how to use science, understand scientific facts, understand everyday problems - considering the difference between knowing science and doing science (HAZEN; TREFIL, 2009).

Although the concepts of scientific literacy or scientific literacy are widely discussed for the correct denomination of the term, this work will refer to scientific literacy, also based on the writings of Sasseron and Carvalho (2011, p. 61), who use the term and understand that "Thus thinking, literacy should develop in any person the ability to organize their thinking in a logical manner, in addition to assisting in the construction of a more critical consciousness in relation to the world around them.

We have in mind the preparation of students for social life and also for making the right decisions in different aspects of life, in a way that is supported by scientific literacy. According to Bertold (2020), this literacy is an important mechanism for economic and social development and the school is considered one of the most important sources of this knowledge.

According to Santos (2007, p. 475) "The growing concern with science education has been advocated not only by science educators, but by different professionals; its objectives have had a wide scope". And it is solidified in the concern to awaken the scientific knowledge in the student body that this work seeks to relate astronomy and

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mathematics concepts, in a pedagogical proposal focused on reaching the understanding about the concepts of the planet we live on.

From all of the above, this work aims to elaborate an interdisciplinary pedagogical proposal focused on scientific literacy through the relationship between mathematics and geography using concepts such as ellipses, spheres, spherical surfaces, and astronomy. Seeking to answer ways to move two concepts of disciplines, originally studied separately, in a didactic proposal, guided by the concepts of interdisciplinarity and with the intention of disseminating scientific literacy.

It is also taken into consideration one of the competencies observed in the Common National Curricular Base (BRASIL, 2017, p.528) of developing an "[...] integrated view of mathematics, applied to reality, in different contexts". Foreseeing the formation of critical and reflective citizens and contributing to the general education of students (BRASIL, 2017).

The theoretical framework used takes into consideration authors Silva (2006), Honorato (2017) and Boczko (1984) for astronomy concepts, and Fazenda (2003 and 1991), José (2008) and Trindade (2008), for studies in interdisciplinarity. As well as Chassot (2003) and Hazen and Trefil (2009) and Sasseron and Carvalho (2011) for scientific literacy.

This work is divided into sections, which are respectively: (2) theoretical framework, (3) work methodology, (4) pedagogical guide relating the concepts of mathematics and geography and (5) final considerations.

2 Theoretical framework

This section is divided into two main topics for the elaboration of the pedagogical proposal: the concepts related to scientific literacy and interdisciplinarity.

2.1 Scientific literacy

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Acting as a tool to help in the construction of fundamental concepts for life in society and also as a means to administer and manage information that is acquired all the time, scientific literacy - with concepts already discussed above - would act together with the school in the perspective of "[...] claiming for the school a more active role in the dissemination of knowledge" (CHASSOT, 2003, p.90).

In the midst of a technological age and of many sources of information, it is of extreme importance that the students have discernment of what are reliable sources of news and mainly feel capable of researching, checking and judging facts and information.

Going even further, Chassot (2003) considers a scientific illiterate person to be "[...] incapable of reading the universe". This puts into question not the contents approached in school, but the way they are approached, with what purpose, and the students' ability to interpret what they have been taught.

It is in this sense that scientific literacy is present, also acting as a form of social transformation, and can be inserted from the most basic situations of everyday life to deeper discussions about science (SANTOS, 2007). Thus, this process is able to interfere in personal and public issues, being an agent of change and behavior in society, because, as Santos (2007, p.480) explains, "Literacy as a social practice implies the active participation of the individual in society, in a perspective of social equality [...]".

To be aware of how the planet we live on functions and relates to us and other celestial bodies is also to be aware of phenomena that occur every day in society. Thus, seeking to explain and exchange the concepts seen in the classroom subjects is a way to act in the construction of scientific literacy in students.

This is possible by creating perception of the why of events and their explanations, based on facts that are not unfamiliar to them, as well as relating them to the mathematical content already seen. This is also possible by using practices to build critical thinking, which not only absorbs information about the facts, but also analyzes and creates other knowledge from what has been seen.

2.2 Interdisciplinarity

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Acting in this script as a tool for lapidating concepts previously seen and also as the main actor for the goal of reaching scientific literacy in students, interdisciplinarity is the path that maps this study.

Fazenda (2016, p.63) calls attention to the importance of always starting from a place of inquiry, of questioning in front of a theme:

> [...] the interdisciplinary posture seeks to reopen the paradigmatic certainties, resulting from the theories that configure the current school science, and more, seeks to consider as fundamental to the construction of this science, the judicious research on the committed actions that occur in the classroom.

Whether in a movement of trying to question the ties that guide each discipline, trying to get rid of boundaries to address relevant issues, or even in school practice, by questioning with the students themselves the origins and bases of the concepts seen in the classroom and encouraging the research of new methods.

Fazenda (2016) also calls attention to the knowledge of the responsible teacher in a special attitude, making himself aware of his limitations, competencies, incompetencies, possibilities, and limits of his discipline. Thus, it is important to have trained professionals who feel at ease when working with interdisciplinary issues.

In addition, the author also points out that the interdisciplinary methodology "[...] is based on dialogue and collaboration, is founded on the desire to innovate, create, and go beyond, and is exercised in the art of research [...]" (FAZENDA, 2016, p.69). Thus, it makes clear the importance of creativity and willingness to dialogue between disciplines. And, especially, a review of concepts to "realize oneself interdisciplinary" and thus tread the paths to be traveled with care.

3 Methodology

This research has a qualitative approach, taking into account only aspects that are not represented numerically, being concerned with the understanding and learning of students (CÓRDOVA; SILVEIRA, 2009). It has an applied nature, as it is understood that the pedagogical proposal presented here can be used in regular basic education classes.

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This proposal is directed particularly to students in the third year of high school, because it is in this period of time that the studies about ellipses are made, considering that students have already had knowledge about the surfaces of revolution in the second year. However, it is necessary to point out that the script to be explored in the next section did not have application with students, due to incompatibilities between school calendar and the time of year in which the research was being established.

To analyze the themes presented above, we will take as a basis the concepts of Fazenda (2008, p. 37):

> The concept of interdisciplinarity [...] is directly linked to the concept of discipline, where interpenetration occurs without basic destruction to the sciences. One cannot in any way deny the evolution of knowledge by ignoring its history.

That is, we will not exclude the disciplines in this script, but rather use the concepts of both for in-depth studies, intertwining them. Although we must mention that the script tries to explain the concepts of astronomy using mathematical language - giving a solid base for the contents studied in this discipline, which often seem meaningless to students.

The approach used is school interdisciplinarity, pointing out that "In school interdisciplinarity, the notions, purposes, abilities and techniques aim to favor, above all, the learning process respecting the students' knowledge and its integration" (FAZENDA, 2008, pg. 37). Thus, using the student as an active researcher to search, look for concepts and develop connections between disciplines.

We also refer to the concepts of Sasseron and Carvalho (2011, p.66) where they clarify that:

> [...] the assumption that science teaching can and should start from problematizing activities, whose themes are able to relate and reconcile different areas and spheres of life of all of us, aiming to look at sciences and their products as elements present in our daily lives and that, therefore, present a close relationship with our lives.

That is, being pertinent the discussion about the study of mathematics with the concepts of astronomy, for the teaching of science and especially its connection with the reality of students, following the precepts of D'Ambrosio (2019, p.online) who highlights:

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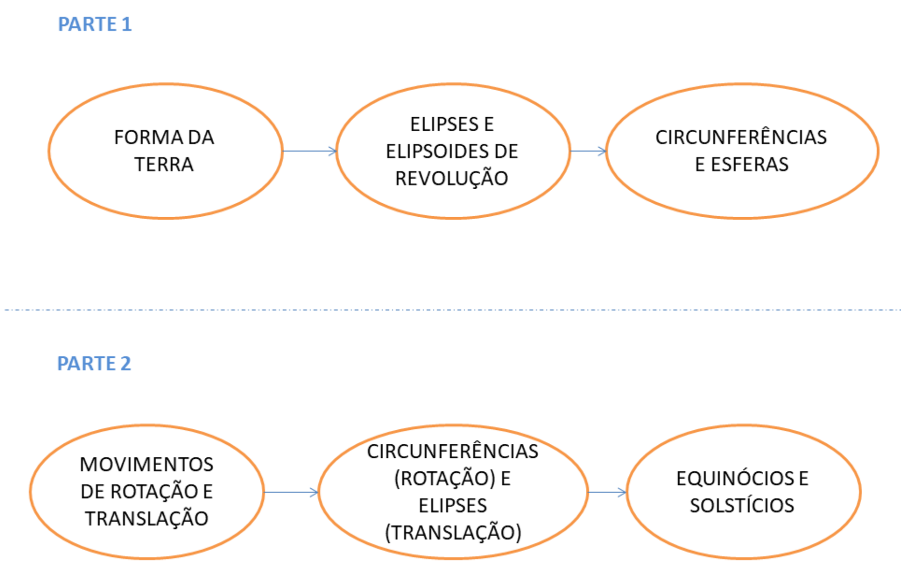
"We speak then of a mathematical knowledge/doing in the search for explanations and ways to deal with the immediate and remote environment. Obviously, this mathematical knowing/doing is contextualized and responds to natural and social factors." He also reports the concern with the particularities of the students, of their respective family learning nuclei, and of how the receptions to the approached content will be.

It also seeks to "[...] stimulate questioning, critical reflection on the question itself, what is intended with this or that question instead of passivity in the face of the teacher's discursive explanations [...]" (FREIRE, 1996, p.33). Thus, the intention is to launch well-founded questions, as previously mentioned when addressing concepts of interdisciplinarity, and, at the same time, stimulate critical thinking and reflection, the foundations of scientific literacy.

Based on these definitions, in order to relate the subject focus of ellipses, spheres and spherical surfaces, with the concepts of astronomy, the script of definitions shown in Figure 1 below will be followed:

Figure 1 - Steps addressed in the script description



Source: Own authorship, 2022

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As explained in Figure 1, the script will be divided into two parts:

- Part 1: relation of the Earth's shape to the ellipsoid of revolution, being obtained through the revolution of an ellipse over any straight line. It also includes the simplification of the Earth's shape through the spherical surface;
- Part 2: characterization of the rotational and translational movements of the earth with circles and ellipses and how geographical phenomena can be explained from this perspective, detailing the solstice and equinox.

The digital tools will be of great importance in this pedagogical proposal, using the Geogebra software in its classic mode, because it is easily accessible to any computer connected to the Internet. The use of this tool was mainly so that students can visualize the concepts discussed here, since they are mainly three-dimensional ideas.

Thus, according to Trindade (2008, pg. 82), "a deconstruction is sought, a break with the traditional and the daily school task", aiming for a border region between the regions of the two disciplines, where one coexists with the other without invading spaces, allowing dialogue and sharing of knowledge.

4 Results and Discussion

To analyze the astronomy themes and their relationship with mathematical concepts, the students should be aware of or introduced to the contents of ellipses, ellipsoids and spherical surfaces. Thus, the teacher can make the interchange between the disciplines of mathematics and geography, taking advantage of the concepts of interdisciplinarity presented above.

4.1 Shape of the earth

Always making use of the interdisciplinary proposal mentioned above, the teacher can, at first, ask the class about the shape of the planet we live on and also about its characteristic movements. Even ask to see pictures and illustrations, asking the students

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about their previous knowledge about the theme to be discussed. Thus, trying to investigate whether students are aware of the relationships (to any degree) between astronomical aspects and mathematics.

The shape of the Earth has a complicated aspect when we deal with an approach to mathematical knowledge, because it does not assume the characters of a known geometric solid. According to Silva (2006, p. 2):

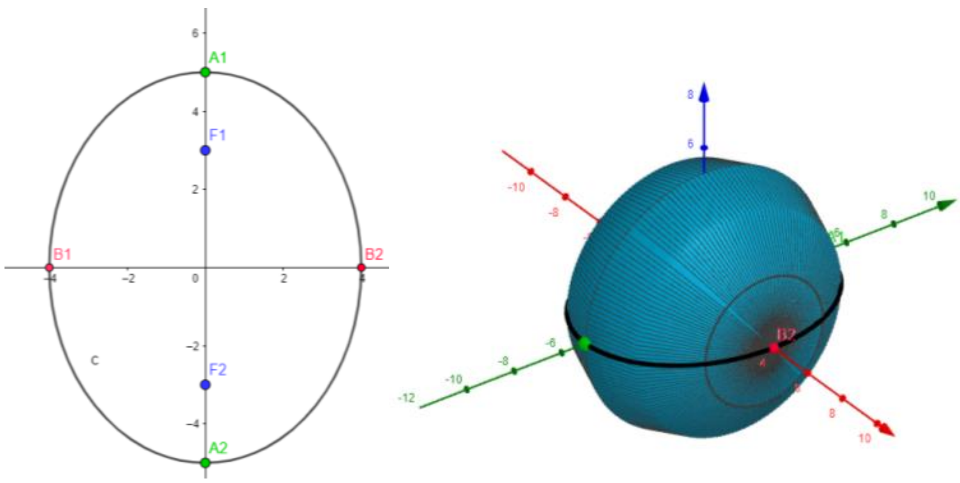
> Since it is not easy to express the real shape of the Earth mathematically, an attempt was made to interpolate a solid that best approximated it. In 1924, the International Union of Geodesy and Geophysics concluded that the Earth could be conveniently represented by a certain ellipsoid of revolution, which was then called the International Reference Ellipsoid (IEO).

The ellipsoid of revolution discussed in this work is the revolution of an ellipse (commented on earlier) around any line, characterized as a surface of revolution. In other words, the teacher will refer to concepts already known by the students (ellipses and surfaces of revolution) to work with the shape of the Earth.

In Figure 2.a, we have a representation of an ellipse of Equation 8 and in 2.b an ellipsoid of revolution, made by revolution of the ellipse about the abscissa axis (x-axis) in the Geogebra software. From this point on, we will consider that all the figures mentioned were plotted in this software.

Figure 2 - Ellipse and ellipsoid of Revolution

2.a Elipse 2.b Elipsoide de Revolução



Fonte: Autoria Própria, 2022

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$$\frac{x^2}{16}+\frac{y^2}{25}=1 \quad (8)$$

In this way, the teacher can point out that the shape of the Earth can be estimated through the revolution of an ellipse on any line, resulting in the ellipsoid of revolution (a surface of revolution, already mentioned above). In the case of the example presented, it can be noted that the ellipse in question has a major axis parallel to the ordinate axis (y-axis), center at the origin of the Cartesian plane and foci at points (0,3) and (0,-3), vertices of the major axis located at points (0,5) and (0,-5), and vertices of the minor axis located at points (4,0) and (-4,0).

The center was chosen as the origin of the plane to facilitate the equation of the ellipse formed. It is also important to point out that the ellipse is formed in the two-dimensional plane, while the ellipsoid surface is formed in three-dimensional space. The ellipsoid in question has its intersections with the x, y and z axes located at the points (4,0,0), (-4,0,0), (0,5,0), (0,-5,0), (0,0,5) and (0,0,-5), given precisely by the length of revolution having absolute value 5 (length of half of the major axis) and 4 (length of half of the minor axis). For more depth, the teacher can also mention the deduction of a general equation of revolution ellipsoid, using the original ellipse.

Also according to Silva (2006), it is possible to admit a simplification of the Earth's shape to minimize calculations, and thus adopt a spherical shape for representation. In Figure 3.a, we can see the ellipse of Equation 8 and a spherical surface of Equation 9, with the same center and radius 5 (length of half the longest axis of the ellipse). Figure 3.b illustrates the comparison of the ellipsoid 2.b and the spherical surface, supporting what has been said about the simplification of the Earth's shape to a spherical surface - with relatively small errors of approximation.

Figure 3 - Spherical Surface and Ellipsoid of Revolution and Spherical Surface

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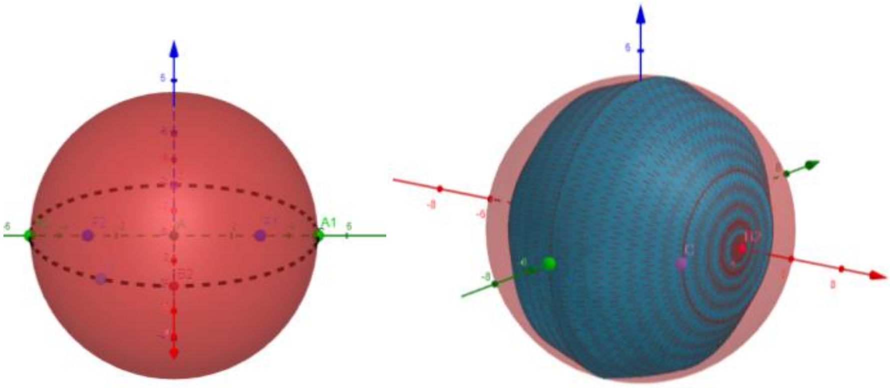
3.a Spherical Surface and Ellipse 3.b Ellipsoid of Revolution and Spherical Surface



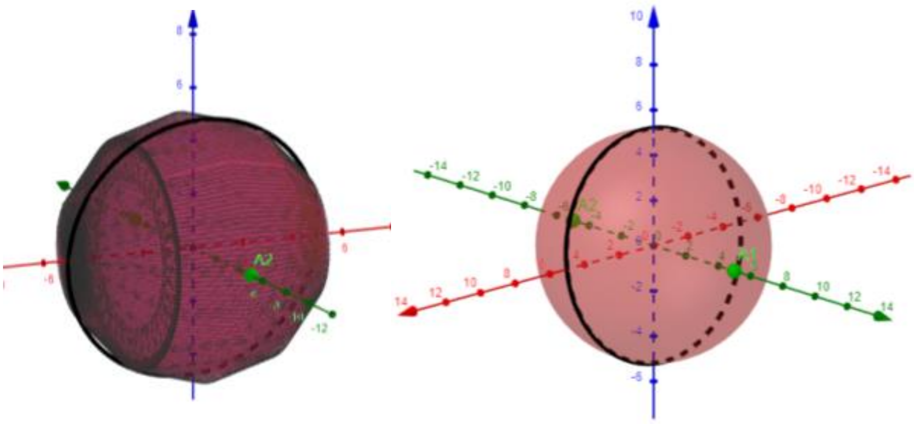
Fonte: Autoria Própria, 2022

$$x^2 + y^2 + z^2 = 25 \quad (9)$$

For further exploration, the teacher can also mention about deducing the general equation of a spherical surface, using the revolution of an original circle (or a semi-circle) of Equation 10. This circle has a radius equal to 5 (the same radius as the spherical surface) which gives rise to a spherical surface, as illustrated in Figure 4 below:

Figure 4 - Spherical Surface and Circumference

4.a Revolution of the circle 4.b Spherical surface and circle



Fonte: Autoria Própria, 2022

$$x^2 + y^2 = 25 \quad (10)$$

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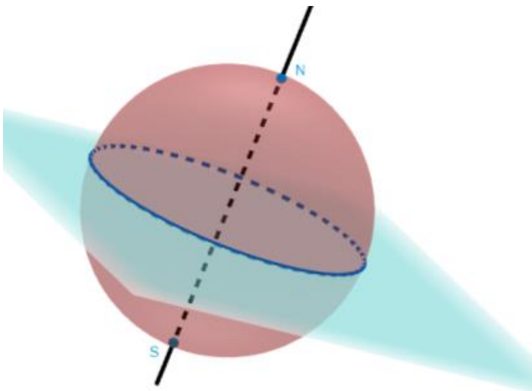
And it is because of this spherical shape of the Earth that it is not possible to faithfully reproduce the coordinates on a map. For, as mentioned before, the sphere is in three-dimensional space and maps are in the two-dimensional plane.

4.2 Earth movements

To begin studying the movements of the Earth and its relationship to the Sun, we must first pay attention to the reference planes and axes used.

In agreement with Silva (2016, p.2), "The Earth has an axis of rotation, whose extremities constitute the true or geographical poles, North (N) and South (S)." By sectioning the Earth's sphere in the middle with a plane perpendicular to the axis of rotation, we have the division of it into the Northern and Southern hemispheres. Also according to Silva (2016), this plane is called the Equatorial Plane and by making the intersection of this plane with the earth's sphere, we obtain a circumference that represents the equator, as observed in Figure 5 below:

Figure 5 - Earth with rotation axis and equatorial plane



Source: Own authorship, 2022

It is important to note that, as shown in Figure 6 and according to Honorato (2017), the Earth's axis of rotation (straight line) is tilted relative to the other line (straight line), with an angle of inclination of approximately 23°.

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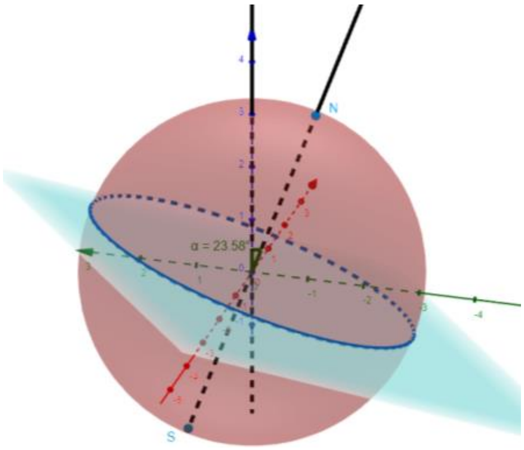
To make reference to something already known by the students, the teacher can compare the positioning of the Earth with those of the axes of three-dimensional space, as shown in Figure 6 below:

Figure 6 - Sphere with center at the origin of three-space



Fonte: Autoria Própria, 2022

In this figure, the sphere is represented by equation 11:

$$x^2 + y^2 + z^2 = 9 \qquad (11)$$

That is, the sphere that represents the Earth has a radius equal to 3. It is necessary to point out that the planes perpendicular to the lines are plotted in the software using the point tool and the line perpendicular to the plane. Being the point of the plane, the center of the sphere used as Earth (origin of three-dimensional space).

As explained, the plane formed is perpendicular to the Earth's axis of rotation and passes through the origin of three-dimensional space. The line that makes an angle of 23° with the axis of rotation is the straight line above the dimension axis (z-axis).

With this we can allude again to the equatorial plane mentioned above and mention the imaginary divisions of the Earth: "All planes, parallel to the Earth's Equator, which intersect the Earth's surface will define circumferences called Geographic Parallels" (BOCZKO, 1984, p.52), illustrated by Figure 7. Thus, as "The semi-

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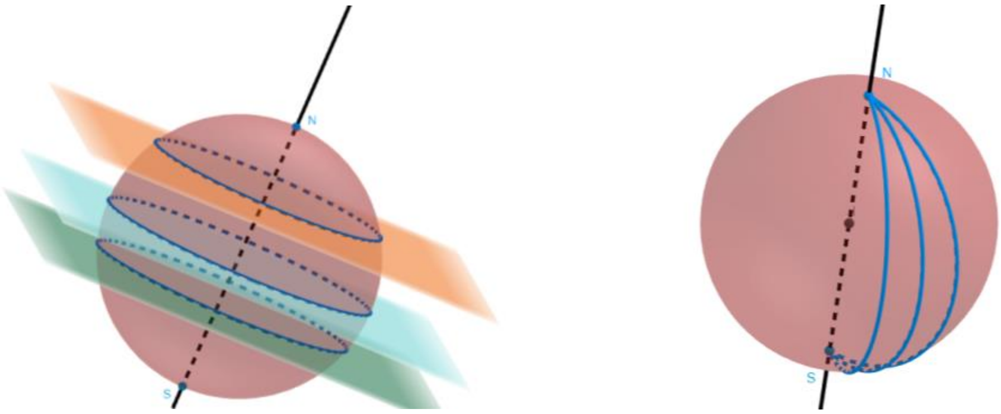
circumferences centered on the Earth's center and passing through the Earth's poles determine the Geographic Meridians" (BOCZKO, 1984, p.52).

Figure 7 - Earth with parallel and meridian divisions

7.a Sphere divided into parallels

7.b Sphere divided into meridians



Source: Own authorship, 2022

The planes parallel to the equatorial plane (in blue) are the orange and green planes. Thus, the teacher can draw attention to the fact that in every section of sphere by planes, the result of the intersection will be a circle (which form the poles of the planet) and that the spherical wedges (not covered here) form the meridians. In this paper we will focus on the rotational and translational movements of the Earth, explained in the sections below.

4.2.1 Rotation

According to Honorato (2017, p.17), the Earth's rotation can be described as "Movement of a body around its own axis. Therefore, the Earth's movement will occur around the axis of rotation explained above and will last for approximately twenty-four hours.

The teacher can draw students' attention to the fact that at the pole of the Equator, represented by the largest circle in Figure 7, a point would complete one full turn

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around the circle when the day is 24 hours long. This being so, traversing the entire length of the circumference, being calculated by Equation 12 (MODERNA, 2013):

$$C = 2 * \pi * R \tag{12}$$

Characteristic equation of the length of a circle, where R represents the approximation of the Earth's radius. It is also interesting to remember that the radius considered is the largest possible, i.e., the radius of the circle obtained when the ellipsoid that represents the Earth is cut by the plane of the Equator. This is due to the approximate shape of the Earth's spheroid, which will not have the same radius for each intersection made by the planes described in Figure 7.

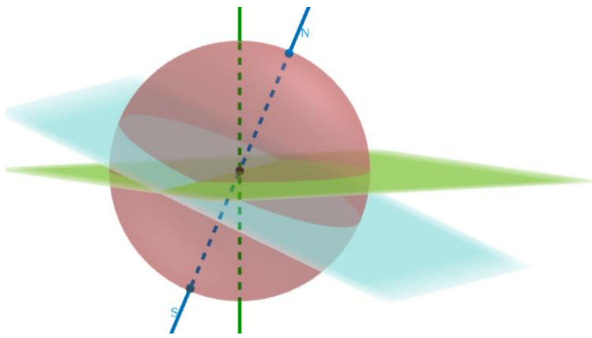
4.2.1 Translation

The translation motion of the Earth consists of its displacement around the Sun. According to Silva (2006, p. 10), we have:

> [...] the Sun is considered immobile in space, occupying one of the foci of the ellipse that becomes the Earth's orbit. Thus, the helical (three-dimensional) motion of the Earth around the Sun is now performed in a plane (two-dimensional), which is called the plane of the ecliptic [...] in which are located the centers of the two stars [...]

The plane of the ecliptic, mentioned earlier, is a plane perpendicular to the line that makes 23° with the axis of rotation, as seen below in Figure 8:

Figure 8 - Earth with equatorial plane and plane of the ecliptic



Source: Own authorship, 2022

In blue, the equatorial plane and in green the ecliptic plane. That is, a plane parallel to the plane formed by the ordinate and abscissa axes (x and y axes), with

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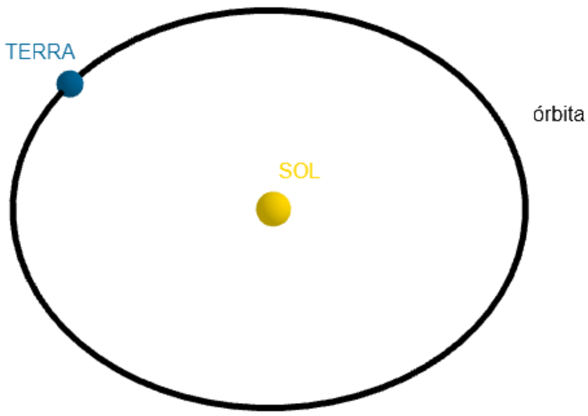
components only on the coordinate axis (z axis). It is up to the teacher to comment that since the direction vectors of the lines illustrated in Figure 8 are the same as the direction vectors of the aforementioned planes, the planes also form an angle of approximately 23° with each other.

Following this reasoning, we can infer that the Earth's orbital motion relative to the Sun acquires an ellipse shape (with the Sun located at one of its foci), as explained in Figure 9 below. It is necessary to emphasize that this orbit model is an approximation of the helical motion mentioned by Silva, and it is interesting to show students first the true motion and then the approximation made for an elliptical orbit, illustrated in Figure 9.

Figure 9 - Earth's orbit with elliptical shape



Source: Own authorship, 2022

According to information from Silva (2006), the length of the half of the major axis of the ellipse is approximately 149,680,000.00 km and the ellipse has eccentricity of about 0.0167 of measurement. With this information, the teacher may ask students to calculate the length of the minor axis of the ellipse as follows.

As seen earlier, the length of the half of the major axis is approximately $a = 0{,}15 * 10^{-9}\, Km$. Knowing that the eccentricity can be calculated by (13):

$$e = \frac{c}{a} = 0{,}0167 \;=>\; c \cong 0{,}002505 * 10^{-9}\, Km \tag{13}$$

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Therefore, the distance from the center to one of the foci will be c. On the other hand, we can also calculate the value of the half of the minor axis of the ellipse, knowing that:

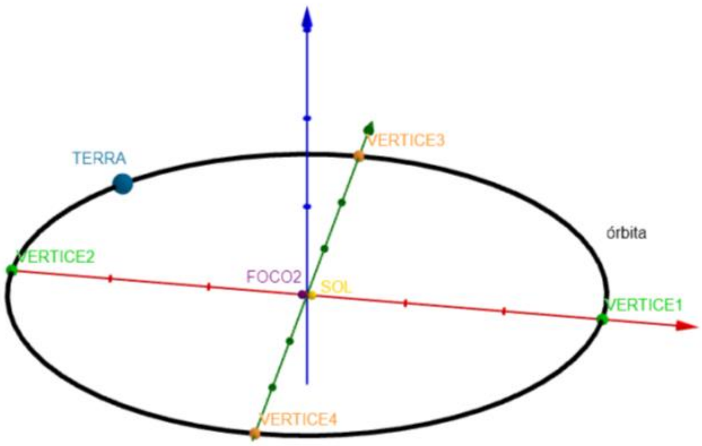
$$a^2 = b^2 + c^2 \; => \; b^2 = a^2 - c^2 \cong 0{,}02249 \, * 10^{-9} \; Km \quad (14)$$

In equation 14, we used the fundamental relation of the ellipse, mentioned in section 4.3 of this work. To facilitate the plotting of the ellipse, let's consider it with center at the origin of three-dimensional space and the axes with the sizes observed previously. The ellipse observed in Figure 10 below, has Equation 15 and due to the large numbers observed for the sizes of the axes, was plotted at scale 1:1000000000.

$$\frac{x^2}{0{,}0225} + \frac{y^2}{0{,}02249} = 1 \quad (15)$$

In the case of the example presented, it can be highlighted that the ellipse in question has a major axis almost equal to the length of the minor axis, characterizing almost a circumference. Foci at the points (0.002505,0,0) and (-0.002505,0,0), noting that in Figure 8 only one of the foci is shown, in which is located the Sun, for better viewing. It also has vertices of the major axis located at points (0.15.0.0) and (-0.15.0.0) and vertices of the minor axis located at points (0.0.149.0) and (0.-0.149.0), seen in Figure 10 below:

Figure 10 - Earth's orbit with elliptical shape in three-dimensional space



Fonte: Autoria Própria, 2022

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As for the distance between the Sun and the Earth, it is possible to infer from the equations above that we have the shortest possible distance (perihelion) and the greatest possible distance (aphelion) happening when the Earth, in its orbit, reaches the position of intersection with the axes (vertices of the ellipse), observed above.

- Equinoxes and Solstices

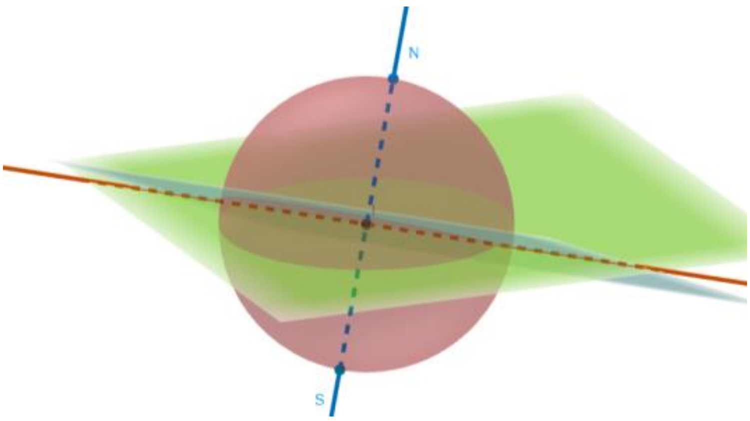
Some geographical phenomena are also of great importance for the seasons: the equinoxes and solstices, which mark the beginning of the seasons. An equinox is characterized as the phenomenon that divides the day into two equal parts (twelve hours of light and twelve hours of darkness). This happens because the sun's rays fall directly on the equator, dividing the Earth's poles equally with light and darkness (BOCZKO, 2012).

As for the solstices, we can infer that:

> [...] the distribution of light around the globe is not uniform, resulting in longer days than nights, or vice versa. When a summer solstice happens, we have the longest day for a given hemisphere and, analogously, when there is a Winter Solstice, we have the longest night (BOCZKO, 2012, p. 47).

It is also possible to comment on geographical phenomena, based on the Earth's position on the ellipsoid of the ecliptic plane. As mentioned above and illustrated in Figure 7, the planes of the elliptic and the equatorial plane touch and intersect with a straight line, shown in Figure 11.

Figure 11 - Intersection between the equatorial and ecliptic planes



Source: Own authorship, 2022

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If you think convenient, the teacher responsible can ask students to calculate this intersection, using the software, asking for the intersection of the two planes and taking the opportunity to comment that every intersection of two planes is characterized geometrically as a line.

That is, a line that passes through the origin of three-dimensional space and has great importance because it is considered, according to Silva (2006, p.14) "called the line of the equinoxes. For, when the line and the plane of the ecliptic are superimposed, the equinoxes occur precisely at their intersections (i.e., at the vertices of the major axis - vertices 1 and 2, as illustrated in Figure 11). Solstices, on the other hand, occur whenever the Earth's orbit reaches the vertices of the minor axis (vertices 3 and 4) of the orbital ellipse, as also shown in Figure 11.

The closure of the script can be given with the questions that may still arise with the students and also seeking to know their opinion about the content covered and the way it was applied. It is clear that the reception of the students to the subject is of great value and serves as a thermometer for moments like this.

It is also suggested the possibility of expanding this script to address geographic projections and distortions, making connections with two-dimensional plans and three-dimensional spaces. And also, when addressing the content of translation, comment on the influence of the elliptical orbit on the seasons.

4.3 Feasibility of the roadmap

As we can see throughout the script, astronomy-related questions are directly linked to mathematical concepts seen by students throughout their education, thus it is of great interest that they can be used beyond the classroom and traditional assessment tools. This can serve, as mentioned before, to explain everyday facts, acting as a way to organize thoughts and as a tool for critical awareness in relation to the world.

Analyzing all the provisions reported here, it is possible to adopt the detailed script as long as there can be, beforehand, also a review of the math and astronomy

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concepts with the class, so that the students remember and feel comfortable visiting the definitions to be addressed.

In addition, it is necessary to use the links not only between the two disciplines, but also the responsible teachers and the school as a whole to make tools and concepts feasible. It is also worth mentioning the execution time, as an extra class workload is required for the learning to be solidified and worked on in the necessary time.

The physical space available is also a point to be discussed, with the need for a computer lab to work on the use of image plotting software, crucial to the understanding of several abstract concepts presented here, such as planes and spheres and intersections. It is also necessary that the class mediator has a good command of the tool, who, besides doing the experiments previously, should help the students in their own plotting.

Despite not having been directly applied in the classroom, all the steps present in the proposal were designed for the best possible performance for a future application. As for the pedagogical viability, a slow pace was adopted, of dependent approaches in order of priority during the construction of the proposal. In other words, basic concepts were presented beforehand, so that other topics derived from these could be discussed later.

The illustrations and plotting of the elements were designed so that the students could base themselves and have the autonomy to make their own interactions. The software used is easily accessible, intuitive in approach, not requiring any installation of other programs and having its language completely in Portuguese.

5 Concluding remarks

This work aimed to develop an interdisciplinary educational proposal focused on scientific literacy, through the relationship between mathematics and geography using concepts such as ellipses, spheres, spherical surfaces and astronomy. Alluding to the contents of ellipses, spheres and also astronomy and also using the Geogebra software to help plotting graphs and visualizations.

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However, it is important to take into consideration the audience to be worked on in the script, bearing in mind that the student class is heterogeneous and arrives with different knowledge bases - not only with regard to school contents, but also their worldviews, personal conceptions and socio-political-economic background. It has to be taken into account that some students may be experiencing a first contact with some concepts and may be delicate in approaching the topics.

It is the teacher's role to make it clear that the content studied is common to all living on planet Earth, as it dialogues with everyday phenomena that are not perceptible to the eye, but directly influence people's lives. Contributing to a broader view of the students about the content studied in school and its relationship with everyday events.

This encourages the formation of citizens who are aware of their place in the world, of their attitude towards situations, and strengthens the construction of a social being who is aware of global events and the repercussion of their actions. It is also possible to generate impact for the community in which it is inserted, with the insertion of people more aware of safe sources of information, with opinions based on proven facts, that will not be easily influenced by any media vehicle.

It should also be noted that, for the adoption of a curriculum with interdisciplinary passages, a previous planning of great volume and detail is required. Thus, it is necessary that teachers have time for this planning and also for discussions with colleagues about an interdisciplinary tactic, as well as study the mastery of digital tools mentioned here to aid students' understanding.

Therefore, a form of curriculum reformulation is needed so that teachers are able to program and plan movements with this bias. Moreover, it is noteworthy that interdisciplinarity is a powerful and immense field for teaching, full of opportunities to work with subjects in many different ways. It is emphasized that this work only presents a suggested script, not being an irreducible plan, with total room for adaptation and restructuring. Leaving as an indelible mark only the search for new possibilities, attention and sensitivity in the process of teaching and learning.

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