Teaching and learning astronomy behind the camera: A case study of astronomical phenomena throughout earth's orbit and rotation

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Effective strategies for teaching and learning Astronomy are spreading worldwide. Astronomy is a subject of interest in both formal and informal education programs. This study aimed to map students' interest, prior knowledge, sources of information, and perceptions of astronomy's relevance. Additionally, we evaluated the impact of using a model in students' learning. A structured, anonymous questionnaire was administered to 77 high school students to assess the benefits and challenges of incorporating the model into the teaching-learning process. The results highlight astronomy's strong potential for student development, as its interdisciplinary nature fosters critical thinking and a deeper understanding of natural phenomena. Furthermore, integrating astronomy with other disciplines proved to be an effective practice, significantly enhancing students' learning experiences.

Keywords: Model; seasons; equinoxes; brainstorm; interdisciplinary learning; student engagement.

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1. Introduction

Effective strategies for educators and students in teaching and learning Astronomy are spreading worldwide. Astronomy is a subject of interest in both formal and informal education programs. The International Astronomical Union (IAU), a union of professional astronomers, offers a wide range of activities, covering topics from beginners to doctoral and postdoctoral students. Among the initiatives of the IAU, the following stand out: (i) The IAU Office for Astronomy Development (OAD), which promotes the use of astronomy for social development, encompassing education, culture, and health. It also provides financial support for astronomy education and outreach in developing countries. (ii) The IAU's Astronomy for Development (AfD), a program focused on integrated educational strategies and sustainability [1–3]. The National Aeronautics and Space Administration (NASA) Education Programs offer various programs and resources for educators and students. NASA's Astrobiology Institute (NAI) promotes education in astrobiology. NASA's Universe of Learning provides a variety of educational resources and tools, including interactive websites and applications, to teach astronomy and space sciences to students of all ages. NASA's Night Sky Network connects astronomy clubs and educators with resources and activities to promote astronomy education locally [4]. The European Space Agency (ESA) has programs focused on education and the promotion of astronomy, such as ESA's Space Science Education, which provides educational materials on astronomy, as well as workshops and competitions to engage students and educators. Cosmos for All is a set of ESA educational initiatives aimed at increasing access to resources on space sciences and astronomy [5]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has been involved in promoting astronomy education through programs such as the International Year of Light and Light-based Technologies and Astronomy and World Heritage. The latter is an initiative to preserve and promote sites of astronomical significance, which includes educational programs to raise awareness about the cultural and scientific importance of these sites [6]. The International Dark-Sky Association (IDA) is a global organization that runs education and awareness programs about astronomy and the importance of a dark night sky for astronomical observation [7]. The Global Astronomy Month (GAM), organized by Astronomers Without Borders, is an annual event that brings together sky observation activities, workshops, and scientific outreach events worldwide [8]. The International Space University (ISU) organizes courses and workshops in various parts of the world for students and professionals interested in space studies [9]. As presented above, astronomy is a science of global interest. It studies the universe and its celestial bodies, such as planets, stars, and galaxies. It involves a broad range of scientific disciplines, including physics, chemistry, biology, and geography [10–12]. It is also an essential subject in national curricula worldwide, both for early education and teacher training [13–20]. Teachers and researchers are developing various educational materials to bring astronomy into primary and secondary school classrooms [21]. These efforts aim to integrate astronomy content into the classroom using diverse didactic tools that combine theory and practice to facilitate the teaching of topics such as Earth's rotation [22], the Solar System [23], geodesy, geographic location, astronomical instruments, astronomical events, celestial coordinate systems, the Moon, and more [24]. Another important aspect of astronomy education is its multilingual approach in classrooms. Its use in teaching serves as a medium for students to learn a second language [25]. Inclusivity is another relevant term associated with astronomy. The lack of scientific vocabulary in sign languages is becoming increasingly evident as more deaf students are included in formal and informal education spaces. This presents a new opportunity for the development of an astronomy-related vocabulary in sign language that respects the visual culture of the deaf community [13]. Astronomy careers are of multicultural interest. Simultaneous research conducted in multiple countries on students' career aspirations suggests that many students consider astronomy as a potential scientific and professional path [16]. Astronomy and teacher training are also topics of debate in scientific and academic communities. Discussions advocate for its inclusion in initial and continuing teacher education programs, as part of teaching praxis, and tailored to the real needs of teacher training [14, 15, 26, 27]. This study was conducted with high school students from a public school located in Marabá, Pará, Brazil. The region, part of the Brazilian Eastern Amazon, faces social and infrastructural challenges that significantly impact science education, especially due to limited access to laboratory resources. This reality underscores the need for innovative, low-cost, and highly accessible didactic approaches. With this in mind, we constructed a physical model to simulate the Earth's rotation and revolution. Our method integrated artificial lighting mechanisms, physical representations of the Sun and Earth, and the exploration of relative distances and positions. This didactic strategy was employed to illustrate the dynamics of solar illumination, the Sun as a star, planet Earth, and their distance and positional relationships, facilitating the comprehension of phenomena such as seasons, solstices, and equinoxes. The study's objectives were achieved and structured as follows: (2) Research Problem, (3) Results, (4) Discussion, and (5) Conclusion.

2. Research problem

The objective of this research was to map students' interest, prior knowledge, sources of information, and the relevance of astronomy. Additionally, we aimed to observe the impact of using a model in students' learning. A structured, anonymous questionnaire was administered to a sample of 77 high school students to assess the potentially favorable and antagonistic factors of using the model in the teaching-learning process.

2.1. Research methodology

The methodological steps included problem definition, literature review, and data collection, primarily through interviews with the target audience [28]. The literature review encompassed relevant books, journals, scientific articles, and dissertations. Although the initial plan anticipated in-person interviews and direct practical demonstrations with the model, the emergence of the COVID-19 pandemic necessitated the full adaptation of activities to a virtual environment. Interviews were conducted via Google Forms, and online classes, specifically designed for remote teaching, were held using Google Meet. To optimize learning, the activities were structured into three progressive stages. The first phase involved the collaborative construction of the model representing the seasons, solstices, and equinoxes, utilizing brainstorming techniques [29]. The model was crafted from 20 mm thick styrofoam, set on a 500 mm wide by 100 mm high square base, and incorporated a dark background to optimize visualization. Figure 1 displays the final version of the Sun-Earth system model. Subsequently, students watched a demonstrative video illustrating the model's functionality, with a focus on the Earth's rotation and revolution movements [30]. The final phase involved a virtual discussion to clarify doubts and stimulate critical reflection, culminating in the application of a questionnaire to assess students' comprehension of the phenomena presented.

The model demonstrations, as shown in Fig. 1, were conducted under two experimental conditions: with and without artificial illumination. These conditions were employed to simulate the following astronomical events:

i. The summer solstice in the Southern Hemisphere and the winter solstice in the Northern Hemisphere, occurring approximately on December 22;

ii. The autumnal equinox in the Southern Hemisphere and the vernal equinox in the Northern Hemisphere, with an estimated date of March 23;

iii. The winter solstice in the Southern Hemisphere and the summer solstice in the Northern Hemisphere, around June 21;

iv. The vernal equinox in the Southern Hemisphere and the autumnal equinox in the Northern Hemisphere, occurring around September 23.

Demonstrations with the model (Fig. 1) were conducted under two conditions: without (left) and with (right) artificial lighting.

The model's top view (Fig. 2) shows the same Sun-Earth system model but from a different perspective. It displays the model as a whole, highlighting the positional relationship between the Sun and the Earth. In this view, the model is

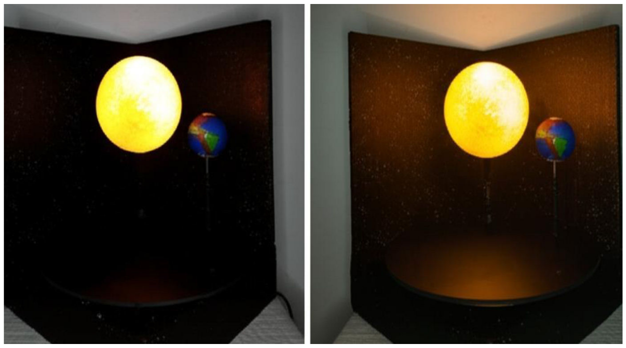

FIGURE 1. Model of the Sun-Earth system: without (left) and with (right) artificial lighting.

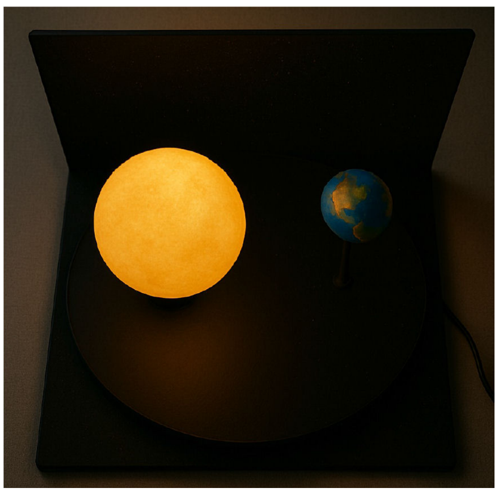

FIGURE 2. Model of the Sun-Earth system: Top view.

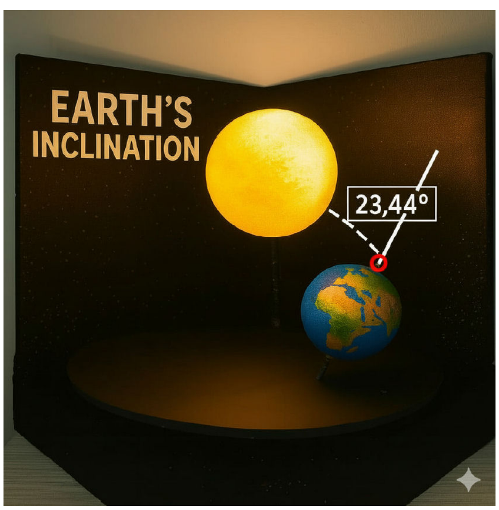

FIGURE 3. Illustration of the Earth's axial tilt of 23.44^0 degrees.

"unlit", which could represent a demonstration condition or a moment when the artificial lighting is not active, contrasting with the first image where the focus is on the light from the Sun.

The Fig. 3, illustrates the Earth's axial tilt of $23.44°$ degrees, which is the main cause of the seasons. The model shows the Sun (represented by a luminous sphere) and the Earth (a globe), with the tilt clearly visible. This inclination is crucial for understanding how the incidence of sunlight varies across different parts of the planet throughout its orbit.

3. Results

Following the didactic application, an anonymous questionnaire comprising 15 questions was administered to a sample of 77 high school students from the first, second, and third years in Marabá, Pará, northern Brazil. This questionnaire aimed to ascertain students' interest in astronomy, their prior knowledge, primary sources of information, perceived relevance of astronomy, and their evaluation of the model's impact on their learning. Analysis of student responses regarding their interest in astronomy, specifically the question: "Are you interested in learning about astronomy?" (Fig. 4), revealed that the majority of students (80.5%) expressed interest in studying the subject. A Chi-Square Test ($p < 0.001$)

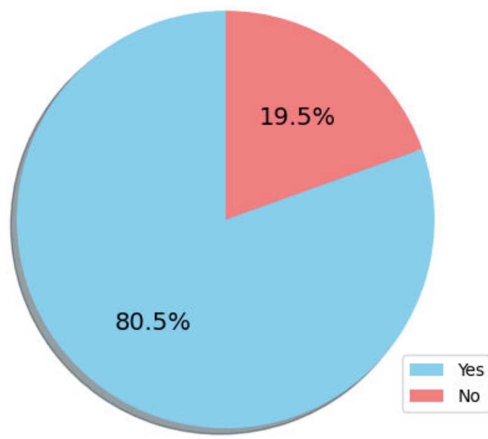

FIGURE 4. Students' interest in learning about astronomy. The majority of students (80.5%) expressed interest in studying the subject.

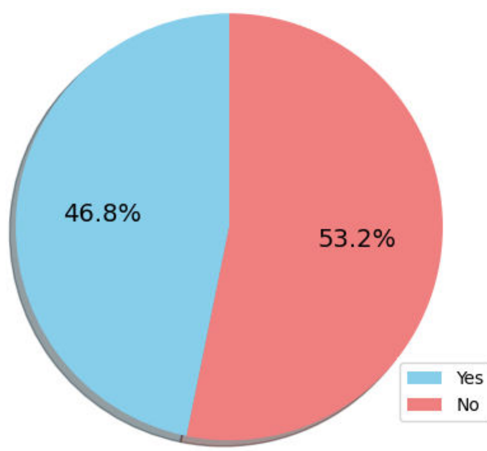

FIGURE 5. Students' prior access to astronomy materials. Most participants (53.2%) reported not having had access to astronomy-related materials before the study.

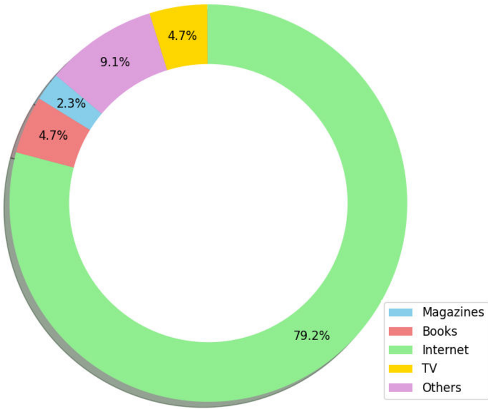

FIGURE 6. Means through which students accessed astronomy topics. The internet was the primary source (79.2%), followed by other sources such as magazines (2.3%), books (4.7%), television (4.7%), and other means (9.1%).

confirmed that a significant majority of students are indeed interested in learning astronomy.

Regarding prior exposure to astronomy-related materials, responses to the question: "Have you had access to any astronomy-related material?" (Fig. 5) indicated a balanced distribution, with 53.2% reporting no prior access. The near-equal distribution of "Yes" and "No" responses suggests this variable may be due to random reasons, as confirmed by a Chi-Square Test ($p = 0.57$) showing no significant difference between those with and without prior access.

Figure 6 illustrates the means through which students accessed astronomy topics. The internet emerged as the predominant source, utilized by 79.2% of students, followed by "Others" (9.1%), books (4.7%), television (4.7%), and magazines (2.3%). A Chi-Square Test ($p < 0.001$) indicated that this distribution is not random, confirming the internet as the primary medium for accessing astronomy content. Discussions with students further highlighted that lessons incorporating experiments or activities, such as those involving the model, significantly facilitate learning and understanding of topics like seasons.

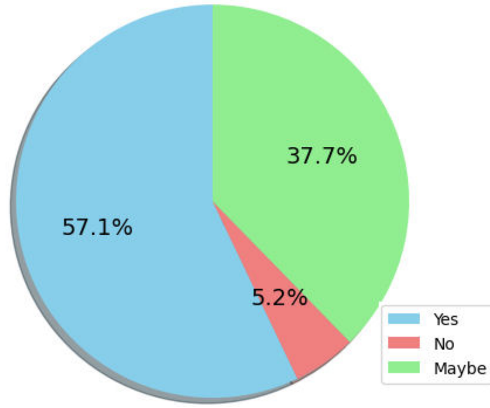

FIGURE 8. Students' opinions on integrating other disciplines with astronomy. More than half (57.1%) consider this practice beneficial, while 37.7% were undecided, and 5.2% disagreed.

Student perceptions of the didactic application's impact on learning performance are presented in Fig. 7. A substantial majority (64.9%) believed that the applied methodology improved their learning performance, while 31.2% were unsure and 3.9% did not perceive a contribution. A Chi-Square Test ($p < 0.001$) affirmed that the majority of students consider the didactic application beneficial to their performance.

Figure 8 shows student opinions on the integration of other disciplines with astronomy to enhance understanding. Over half of the students (57.1%) considered this practice beneficial, 37.7% were undecided, and 5.2% disagreed. A Chi-Square Test ($p < 0.001$) indicated that students generally recognize the benefits of integrating other disciplines with astronomy.

Regarding students' interest in understanding the importance of studying the seasons, Fig. 9 demonstrates that 92.2% expressed interest, while 7.8% showed no motivation. This strong interest was further confirmed by a Chi-Square Test ($p < 0.001$).

The results in Fig. 9 show that the majority of students are interested in understanding why they need to study the

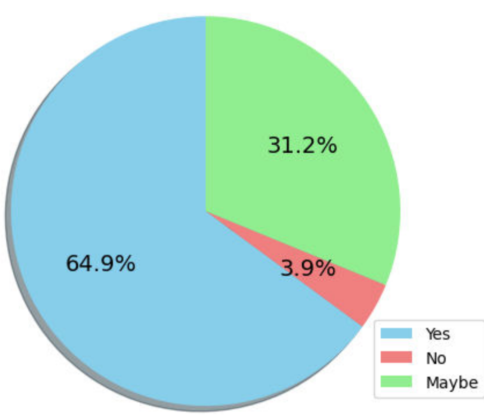

FIGURE 7. Students' perception of the applied didactic approach. Most students (64.9%) believe that the methodology adopted contributed to improved learning.

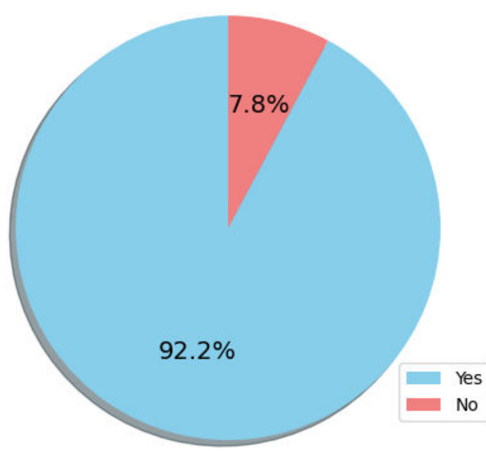

FIGURE 9. Students' interest in understanding the importance of studying the seasons. The majority (92.2%) expressed interest in learning more about the topic.

topic of seasons. A Chi-Square Test ($p < 0.001$) confirms this result.

The Earth's rotational axis has an obliquity of approximately 23.44° with respect to the plane of the ecliptic hat is, the plane in which the Earth orbits the Sun. This axial tilt gives rise to seasonal variations in insolation (solar energy per unit area) received by each hemisphere, as follows: At the June Solstice (circa 21 June).

With the Northern Hemisphere tilted towards the Sun, solar rays strike at an angle closer to perpendicular, increasing mean daily insolation Wm^2 and prolonging daylight hours. Conversely, the Southern Hemisphere, tilted away from the Sun, experiences reduced insolation and shorter days [31,32]. We have the December solstice (circa 21 December) The situation is reversed: the Southern Hemisphere is inclined towards the Sun, receiving greater insolation and longer days, while the Northern Hemisphere undergoes a corresponding reduction in energy input and daylight duration [33]. In March and September we experience the equinoxes ($\approx$ 20 March and $\approx$ 22 September). At these times, Earth's rotational axis lies approximately perpendicular to the Sun's rays, yielding almost identical insolation in both hemispheres and equal durations of day and night [34].

Figure 10 presents students' responses to the question: "What is the cause of the seasons?"

Figure 10 presents students' knowledge about the causes of the seasons. Only 40.3% correctly identified Earth's tilt as the primary cause, while 18.2% correctly mentioned both tilt and revolution. A notable 22.1% mistakenly attributed it to Earth's rotation, and 19.5% associated the phenomenon with climatic patterns.

Figure 11 presents students' responses to the question: "What are the four seasons?"

These findings indicate existing conceptual gaps regarding this astronomical phenomenon, as supported by a Chi-Square Test ($p = 0.0203$). In contrast, a high percentage of students (93.5%) were able to correctly identify the four seasons (Fig. 11). When asked about the Earth's movement around the Sun (Fig. 12), confusion between rotation and revolution was observed, with 40.3% of responses indicating rotation and 59.7% indicating revolution. A Chi-Square Test ($p < 0.0001$) confirmed that students often confuse these two concepts.

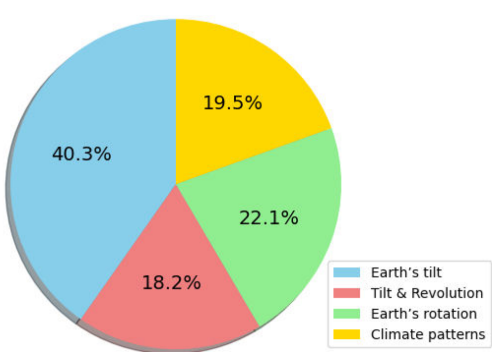

FIGURE 10. Students' knowledge about the cause of the seasons. Only 40.3% correctly identified Earth's tilt as the determining factor, while 18.2% correctly mentioned both tilt and revolution. Another 22.1% mistakenly attributed it to Earth's rotation, and 19.5% associated the phenomenon with climatic patterns.

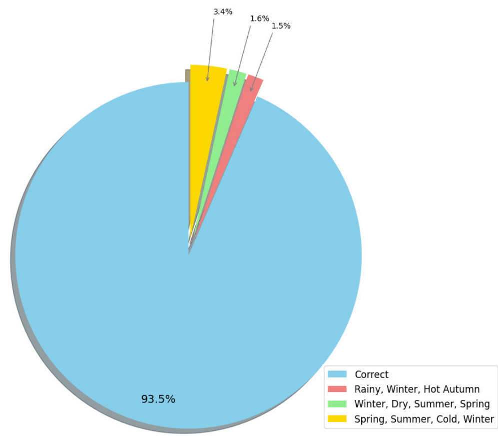

FIGURE 11. Students' knowledge of the four seasons of the year. The majority (93.5%) provided correct answers, while 6.5% presented incorrect responses.

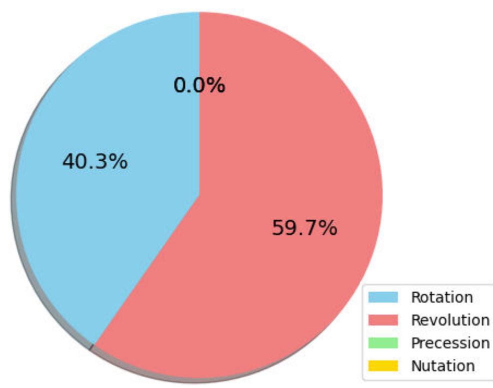

FIGURE 12. Identification of Earth's movement around the Sun. While 59.7% correctly identified revolution, 40.3% confused it with rotation.

The integration of astronomy and geography knowledge was assessed in Fig. 13. While 42.9% of students found the experience constructive for their learning, 50.6% were undecided, and 6.5% did not consider it beneficial. A Chi-Square Test ($p < 0.0001$) indicated that students generally perceive this integration as positive.

Regarding the perceived relevance of the model for classroom application (Fig. 14), the majority of students (75.3%) considered the activity relevant, with 23.4% responding "maybe" and only 1.3% stating "no". A Chi-Square Test ($p < 0.0001$) corroborated that most students consider activities with the model relevant for the classroom.

Figure 15 illustrates the perceived impact of integrating theory and practice on teacher-student communication. A strong consensus emerged, with 96.1% of students believing this approach enhanced interaction and learning, while 3.9% did not consider it advantageous. A Chi-Square Test ($p < 0.0001$) indicated that students view the integration of

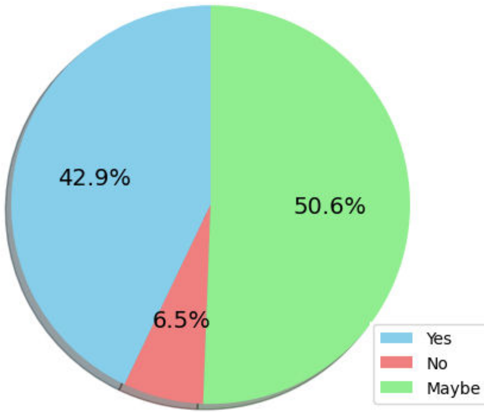

FIGURE 13. Students' assessment of the integration between astronomy and geography. For 42.9%, the experience was constructive, while 50.6% were undecided, and 6.5% did not consider it beneficial.

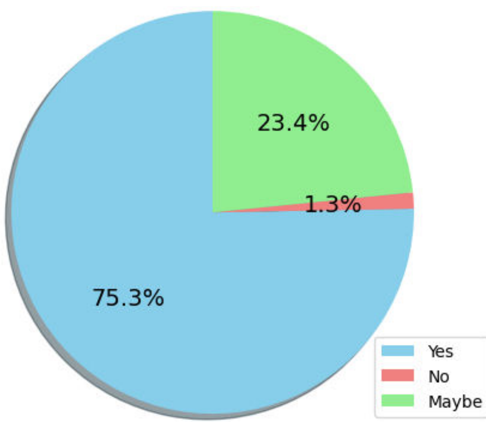

FIGURE 14. Students' perception of the relevance of the model for teaching astronomy. Most students (75.3%) consider the activity relevant for classroom application.

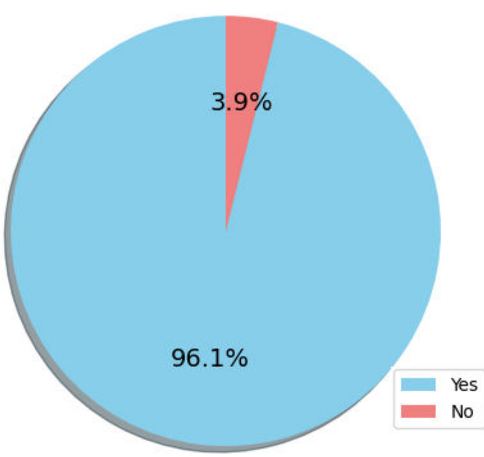

FIGURE 15. Impact of integrating theory and practice on teacher-student communication. For 96.1% of students, this approach enhanced interaction and learning.

theory and practice positively for improving teacher-student communication.

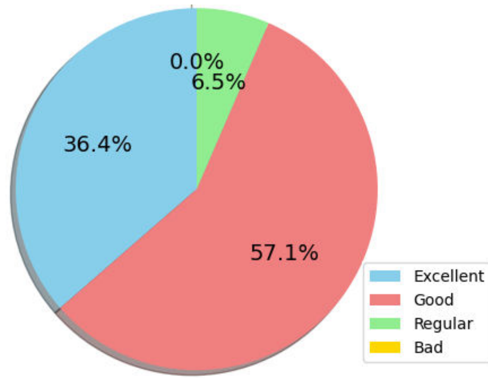

FIGURE 16. Students' evaluation of the model presentation. Most classified the presentation as "good" (57.1%) or "excellent" (36.4%), while 6.5% rated it as "regular". No students considered the presentation "poor".

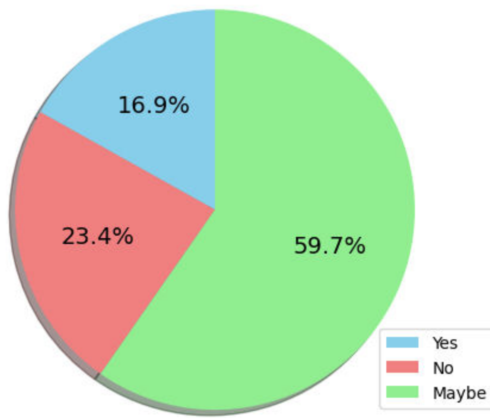

FIGURE 17. Students' perception of their ability to construct a similar model. Most students (59.7%) responded "maybe", while 16.9% stated they would be capable, and 23.4% considered themselves unable to do so.

The evaluation of the model presentation (Fig. 16) yielded predominantly positive responses. Most students classified the presentation as "good" (57.1%) or "excellent" (36.4%), with only 6.5% rating it as "regular" and no students considering it "poor". A Chi-Square Test ($p < 0.0001$) confirmed that the majority of responses rated the model presentation positively.

Finally, regarding students' perceived ability to construct a similar model (Fig. 17), hesitation was evident. While 59.7% responded "maybe", 23.4% stated they would be unable, and only 16.9% believed they would be capable. A Chi-Square Test ($p < 0.0001$) indicated that despite believing it is possible, students showed hesitation in their ability to replicate the model.

4. Discussions

The students who participated in the study do not have astronomy as part of their high school curriculum. Additionally, they have no prior education or experience in astronomy, either in formal or informal settings. This teaching approach, which combined the use of cameras in formal online classes, models, and digital technologies, represented the students' first formal educational experience in astronomy. The following aspects related to astronomy and the use of the model were explored: interest in astronomy, access to materials, means of access, didactic application for improving learning, interest in the subject, causes of observed phenomena, the Earth's translational movement, as well as the construction and application of the model and its relevance for learning. The results show that, regarding interest, most students expressed an interest in astronomy (80.5% vs. 19.5% of students who are not interested in learning astronomy) (see Fig. 14). Regarding prior access to materials related to the subject, the proportion of students who had access (53.2%) and those who did not (46.8%) is statistically balanced, suggesting that this variable may be due to purely random reasons (see Fig. 5). Concerning the means of access to astronomical knowledge, the internet is predominant at 79.2%, followed by "Others" (9.1%), books (4.7%), TV (4.7%), and magazines (2.3%) (see Fig. 6). In terms of the didactic application of the model, 64.9% of students believe that this approach improves learning, while 31.2% are unsure and 3.9% think it does not contribute (see Fig. 7). The integration of astronomy with other disciplines, such as geography, is seen as positive by 57.1% of students, 37.7% are unsure, and 5.2% do not consider this practice beneficial (see Fig. 8). Regarding the interest in understanding the reasons for studying astronomy, 92.2% of students expressed interest, while 7.8% showed no motivation (see Fig. 9). Regarding the students' knowledge about the causes of the seasons, 40.3% correctly identified the Earth's tilt, 22.1% believed it was caused by the Earth's rotation, 19.5% pointed to climatic factors, and 18.2% mentioned a combination of tilt and Earth's translation. These results indicate conceptual gaps about this astronomical phenomenon (see Fig. 10). On the other hand, 93.5% of students were able to correctly identify the seasons (see Fig. 11). When asked about the movement of the Earth around the Sun, confusion was observed between the concepts of rotation and translation, with 40.3% and 59.7% of responses, respectively (see Fig. 12). The integration of geography and astronomy knowledge was perceived as positive for learning by 42.9% of students, while 50.6% were undecided, and 6.5% did not consider the practice beneficial (see Fig. 13). Regarding the use of the model as a relevant activity in the classroom, 75.3% of students said yes, 23.4% answered "maybe", and 1.3% said no (see Fig. 14). The integration of theory and practice was perceived as positive for learning by 96.1% of students, while 3.9% did not consider this approach advantageous. When asked to evaluate the model, the responses were predominantly positive: 57.1% rated it as "Good", 36.4% as "Excellent", 6.5% as "Fair", and 0% as "Poor" (see Fig. 16). Finally, regarding the ability to construct the model, students showed hesitation: 59.7% answered "Maybe", 23.4% said "No", and only 16.9% stated they would be able to construct the model. The aim of this study was to map the students' interest in astronomy, their prior knowledge of the subject, the sources of information used, and the perceived relevance of astronomy in their education. Additionally, the study sought to analyze the impact of using the model on learning. The results indicate that students show interest in astronomy. However, their prior knowledge of the subject does not stem from strategic actions by governmental, private institutions, NGOs, or schools, but rather from casual everyday situations. In this context, the internet stands out as the primary source of astronomical knowledge. Students perceive astronomy as a relevant subject for their education, assigning it an interdisciplinary character by considering its integration with other areas such as geography to be positive. Moreover, they view it as a practical science, capable of incorporating technology and models into teaching, and critical, as it encourages reflection through questions such as those related to the seasons and Earth's movements.

5. Conclusions

The goal of this study was to map the students' interest in astronomy, their prior knowledge of the subject, the sources of information used, and the perceived relevance of astronomy in their education. Furthermore, it sought to analyze the impact of using models on learning. To achieve this goal, we conducted an exploratory survey in a virtual environment, followed by a bibliographic review of the seasons. Subsequently, we interviewed students from the 1st, 2nd, and 3rd years of high school at a public school in Marabá, Brazil, using an anonymous questionnaire. The results confirm the great potential of astronomy in student development. The interdisciplinary approach broadens critical thinking, promoting a deeper understanding of nature and the knowledge necessary for our survival. The study, both qualitative and quantitative, highlighted the effectiveness of the tools used in the classroom, as pointed out by the literature. Activities of this type, when adapted to the reality of Brazilian education, offer a simple, accessible, and enriching methodology. The data show that students have significant interest in astronomy. Despite the lack of access to formal and informal programs that promote knowledge of the subject, most were able to access content primarily through the internet, which may indicate a scarcity of physical materials, such as books and magazines, and a lack of encouragement for reading. When exposed to astronomy through didactic practices, students considered the approach effective for learning. The integration of astronomy with other disciplines was considered a successful practice, but students showed uncertainty about the impact of this integration on their learning process. We also observed that, although students can identify the seasons, there is confusion regarding the causes of their formation, as well as the Earth's rotational and translational movements. In summary, students perceive astronomy as a relevant subject for their education. The integration with other areas of knowledge, the use of technology and models in teaching, and the stimulation of critical and reflective thinking are aspects that enrich their learning. However, the implementation of these practices requires adjustments, especially concerning the construction and use of models, to ensure that students feel secure and confident in their ability to replicate them.

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