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Argentinean students' and teachers' conceptions of day and night: an analysis in relation to astronomical reference systems

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ABSTRACT: This work analysed the evolution of day/night cycle conceptions held by students of different ages and teachers in the Patagonian region of Argentina. The research was based on drawings, written explanations and semi-structured individual interviews. The results showed that both teachers and students had significant comprehension problems. These difficulties were related to the astronomical frame of reference used to explain this phenomenon at every educational level. The results obtained showed the need to adjust the teaching of Astronomy in order to attain adequate understanding of the most common celestial phenomena through the educational use of the topocentric reference system.

KEY WORDS: day and night, conceptions, reference systems, astronomy

INTRODUCTION

The ideas held by children concerning everyday astronomical phenomena have been studied at different times during the 20th century. However, these investigations peaked at the end of the 80s with the generalized research of students' so-called alternative ideas, which had to be eliminated or modified in order to facilitate significant learning of the most effective and applicable scientific explanations (Posner et al., 1982).

At the same time with alternative conceptions research, another perspective on the construction of knowledge was born from the idea of mental models (Johnson-Laird, 1983), conceived as working models in the subject's mind, which process propositions and images and make possible the description, explanation and prediction of events. These mental models evolve with time in order to organize information, beliefs and suppositions in a coherent way, thus contributing to the understanding of the world with which we interact every day. The relevance of this approach is that mental models allow the subject to reason as to how systems function, giving meaning to the images and evaluating the

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propositions as true or false. In this way, the subjects make inferences and predictions, answer questions, decide upon actions and control their implementation. These internal representations therefore fulfill functions similar to scientific models, as they allow description, explanation, prediction and efficient action in relation to a system (Harrison & Treagust, 2000).

Diverse studies have been carried out to explore the mental models children use when thinking and acting in relation to celestial phenomena that can be observed in the sky (Baxter, 1989; Vosniadou & Brewer, 1992, 1994; Schoon, 1995; Chiras & Valanides, 2008). In a similar vein, Vega Navarro (2007) carried out a revision of existing works on children's ideas regarding different astronomical topics, such as the shape of the Earth, day and night, the seasons of the year and the lunar phases.

This research analyzes mental models used by students of different ages for explaining the phenomenon of day and night and how these ideas evolve throughout the different educational levels. The teachers' conceptions are also examined in order to find a possible source of the inadequate representations given by the students.

This study is distinctive in that it analyzes the relationship between teachers' and students' mental models and the astronomical reference system they use, implicitly, to formulate their explanations for the day/night cycle. It is interesting to evaluate whether these explanations constitute "synthetic models" (Vosniadou & Brewer, 1992), in which explanations learned in a school context are combined with ideas formed through experience of everyday life. This line of investigation, involving analysis of the reference systems, has been little studied.

REVIEW OF RELEVANT LITERATURE

Students' Conception of Day and Night

In the past, research has been carried out with students of different ages on the explanations they give for the day and night phenomenon. For example, Sadler (1987) performed an investigation with 9th grade students and found that they had various ways of explaining the phenomenon, some of which were notable due to the fact that the students were 14 years old. Some of these were: "the clouds block the Sun" or "the Moon blocks the Sun". Similar results were found by Baxter (1989) with students whose ages ranged from 9 to 16.

Jones, Lynch and Reesinck (1987) carried out a study with students from Tasmania (between 9 and 12 years old) and found that the day and night phenomenon was explained in the following ways:

a) The Sun and the Moon come closer and then move away ("miraculous movement").
b) The Earth rotates, and the Sun and the Moon are stationary in space, in opposite positions.
c) The Sun and Moon revolve around the Earth.
d) The Earth and Moon revolve around the Sun (with the Earth rotating on its own axis).
e) The Earth rotates, and at the same time revolves around the Sun (with the Moon revolving around the Earth).

Vosniadou and Brewer (1994) carried out exhaustive research with students between 6 and 11 years old in order to identify the children's mental models with respect to day and night. The authors maintained that the belief that the Moon appears at night and disappears during the day is a consequence of children's personal experiences, both real (the Sun appears during the day and not at night), and those perceived to be so (the Moon can be seen during the entire night). In other words, they concluded that these models originate from the particular way each subject understands and justifies the appearance and disappearance of the celestial bodies (if they do so on their own, if something blocks them, if they disappear because they move, etc.).

Chiras and Valanides (2008) analyzed 4th and 6th grade elementary students' mental models concerning day and night. They found that the large majority had incorporated models that could be classified as "geocentric" in spite of the fact that at school they had received instruction based on the heliocentric model (the Earth rotating on its axis revolving around the Sun). As a result, the authors presumed that the students require certain prior knowledge or prerequisites in order to understand the day and night phenomenon in terms of the Earth's rotation:

a) The Earth has a spherical shape.
b) The day/night cycle relates only to the Earth's rotation around its own axis.
c) It is impossible to have only day or night on Earth.
d) The Earth's axis is tilted.
e) The Moon does not emit its own light and has nothing to do with day or night.
f) Light rays travel in a straight line.

When we analyze the inadequate explanations offered by the students we can see that several of them are based on the erroneous assumption held by children, and by many adults, that the Moon is present in the sky every night. In consequence, the explicative models tend to be "adapted" without questioning this "knowledge", and the Moon is included in practically all the explanations, even those that indicate adequate comprehension of day and night based on the Earth's rotation.

Over many years different research papers have been published which suggest there is a need to promote changes in science classes: from traditional methodology, based on reading texts and listening to "lectures" from the teacher, to proposals that focus on the student's own process of knowledge-building. As a consequence of these changes, students of different ages have attained better understanding of the day and night phenomenon and of the Earth's and Moon's movements as seen from space. This has been made possible by the development of didactic sequences that focus on certain aspects in particular: for example, promoting the conceptual change using collaborative learning (Çelikten et al., 2012), carrying out scientific activities with pre-school children (Kallery, 2011; Dogru & Seker, 2012), using the computer as a useful support to visualize movement of the celestial bodies in three dimensions (Isik-Ercan et al., 2014), for graphical representations (Schwarz et al., 2011), to model and build simulations (Joolingen et al., 2014), and to use the planetarium as an educational resource (Türk & Kalkan, 2015) which can offer explanations from two different reference systems (from a point on the Earth's surface or from a point external to the Earth) (Plummer, Wasko & Slagle, 2011).

However, other researchers question some of the results by objecting to the interview and drawing methodology in the studies with children (Hannust & Kikas, 2010). They showed that scientific knowledge about day and night and the seasons of the year are declined during the years after they were taught, and that the students from higher grades (7th and 9th) give more "common sense" answers than the younger students (5th grade). It is possible that this is connected to learning about the astronomical phenomena purely by rote, quite separate from what can be observed in the sky every day (Kikas, 1997). Alternatively, this can be connected to the predominant use of the heliocentric reference system, which is very complex for children, to the detriment of the topocentric reference system, which is more associated with the everyday observations and experiences of every terrestrial observer (Galperin & Raviolo, 2014).

In this work we focus on the latter point: Which reference system do students and teachers use implicitly when trying to explain the day/night cycle?

Conceptions held by pre-service and in-service teachers about day and night

Different studies showed that some of the ideas held by in-service or pre-service teachers are similar to those of elementary school students (Camino, 1995; Schoon, 1995; Vega Navarro, 2001; Govender, 2011). For example, Schoon (1995) carried out a study with pre-service teachers and compared their answers to those given by a group of 5th grade elementary students, obtaining similar answers and percentages. With regard to day and night, 18% of the pre-service teachers and 19.6% of the 5th grade students held that this phenomenon happened due to the Earth's movement around the Sun. The scientific explanation that the day/night cycle was due to the Earth´s rotation was given by 77% of the pre-service teachers and 67% of the 5th grade students.

Camino (1995) detected that 27% of a group of pre-service and in-service teachers did not know the cause of the day and night phenomenon. He classified the results obtained into five categories, four of which correspond to models which were not scientific:

a) Scientific model: the Earth rotates on its own axis and also orbits the Sun.
b) Revolving Earth model: the Earth orbits the Sun in 24 hours without rotating on its own axis.
c) Rotation model: the Earth, located between the Sun and the Moon, rotates on its own axis and does not orbit any other body. The Sun and the Moon are situated opposite each other and don't orbit or rotate.
d) Revolving model: the Sun and Moon are diametrically opposite and orbit the Earth, which doesn't move, every 24 hours.
e) Vague explanations that the Sun, and eventually the Moon, are blocked by something.

The "rotation" and "revolving" models mentioned above can be considered "synthetic models" as defined by Vosniadou and Brewer (1994), given that they combine aspects of an initial, intuitive model based on everyday experience (the Moon can be seen at night) with aspects that have been learned through the socio-cultural context (the Earth is spherical and rotates on its own axis).

On the basis of these results, several proposals have been carried out with pre-service and in-service teachers which have achieved an improvement in their understanding of certain astronomical concepts (Ogan-Bekiroglu, 2007; Aydeniz & Brown, 2010; Shen & Confrey, 2010; Sackes, Trundle & Krissek, 2011; Jiménez Liso, López-Gay & Martínez Chico, 2012) and have made possible the identification of characteristics of the modelling process that teachers use when they try to explain the common astronomical phenomena (Shen & Confrey, 2007; Heywood, Parker & Rowlands, 2013). Nevertheless, other studies have shown that it is not easy to generate a conceptual change in matters of Astronomy, even in adults. This may be due to teaching methodologies that place excessive emphasis on declarative over procedural knowledge, and to epistemological beliefs as to what constitutes scientific knowledge and learning on the part of the teachers themselves (Stears, James & Good, 2011).

Based on the above, it is possible to conclude that the day and night phenomenon is not adequately understood by a large number of teachers and by a very significant percentage of elementary school students, in spite of it being taught in the classroom, and being considered one of the simplest topics to teach. The phenomenon also appears in text books at different educational levels, which means that the students are usually taught about this subject more than once during their years of schooling.

ASTRONOMICAL REFERENCE SYSTEMS: TWO EXPLANATIONS FOR DAY AND NIGHT

There is evidence of a significant "conceptual distance" between the students' and teachers' representations of the day/night cycle and the scientific model that explains this phenomenon by "observing" the Earth's rotation from a point outside our planet (using the "heliocentric frame of reference") (Jones, Lynch & Reesinck, 1987; Baxter, 1989; Vosniadou & Brewer, 1992, 1994; Camino, 1995; Schoon, 1995; Vega Navarro, 2001; Chiras & Valanides, 2008; Govender, 2011). However, none of these studies mentions the possibility of explaining the same phenomenon scientifically in a different way: using an astronomical frame of reference positioned on the Earth's surface (the "topocentric frame of reference"), which enables us to explain day and night using the daily movement of the Sun in the sky.

To define the positions of celestial objects, a frame of reference is necessary. There are multiple reference systems used in the study of astronomy, but each particular system is defined by only three geometric objects: an origin, a reference direction and a fundamental plane. Some of the most common options for origins are:

a) Heliocentric: the center of the sun lies at the origin.
b) Geocentric: the origin lying at the center of the Earth.
c) Topocentric: an observer on the surface of the Earth is at the origin.

Using the topocentric frame of reference, the day/night cycle can be adequately explained by understanding 'day' as the period of time during which the Sun is above our local horizon, and 'night' is defined by the visual absence of this body. As the Sun moves across the sky, at some point it will be below the horizon, causing the alternation day/night.

The explanation of day and night in a topocentric way is scientifically correct, although it can be questioned if associated with the old geocentric model of the universe; a "historical model" that attained a status of consensus within a certain historical context (Justi, 2000). This work does not suggest that teaching should be based on this historical model, but proposes the description of astronomical phenomena from the position of an earth-based observer, which is achieved by placing the origin of the system in this position (Lanciano, 1989; Camino, 1999; Galperin, 2011).

To sum up, both frames of reference mentioned are equally able to explain the day and night phenomenon (Dunin-Borkowski & Mank, 1992; Shen & Confrey, 2010; Plummer, Wasko & Slagle, 2011). Nevertheless, apart from the day/night cycle and some other celestial phenomena visible from the Earth, the heliocentric reference system is used more by scientists because of its capacity to describe the astronomic phenomena that occur in our Solar System in a simple and precise way. Consequently, the use of one or the other will depend on the simplicity of its description, explanation and predictive capacity in relation to the context of its use. This article therefore focuses on analyzing the frame of reference (heliocentric or topocentric) used implicitly by students and teachers when attempting to explain the day/night cycle. Our objective is to analyze whether certain difficulties in understanding detected in students and teachers can be associated with the reference system they have chosen to describe and explain the phenomenon.

METHODOLOGY

This study was carried out with 279 students of different ages enrolled in educational institutions in the Patagonian region of Argentina: five urban elementary schools, a high school located in a rural area and a College of Education. This research also included 40 in-service teachers (32 elementary level and 8 high school level), who were starting a training course related to the teaching of Astronomy (see Table 1).

Table 1 Details of the students and teachers included in the study

Level	Grade or Year	Number
Elementary	4^{th} to 7^{th}	183
High School	8^{th} to 12^{th}	76
College	1^{st} and 2^{nd}	20
Teachers	All represented	40
Total	All represented	319

Blank sheets of paper with the title “Expressing our ideas about celestial phenomena” were handed out. Participants were then asked the following question: “How would you explain the phenomenon of day and night with a drawing? If it helps, you can write an explanation”. Subsequently, semi-structured interviews were held with 10 students from

6th and 7th grade in elementary school, 10 students from 8th to 12th year of high school and 4 teachers (2 of elementary level and 2 of high school level). These interviews made it possible to draw up analysis categories for participants' drawings, and at the same time, highlight the relation between the external representations and the mental models used by the students and teachers to explain day and night. Complete transcripts were made of the interviews, thus allowing the phrases representing the different models used to be extracted.

In order to increase the reliability of our analysis of the interviews, each researcher independently carried out a continuous reading of the answers obtained and suggested categories for their classification. The categories were then compared and agreement was sought as to their definition. Finally, the generalizations agreed upon were validated by returning to the data to verify the degree to which they could be confirmed as categories for analysis (Erickson, 1986).

The answers obtained in response to the question about the day/night cycle were first classified, taking into account the reference system used by the participant to describe or explain the phenomenon: topocentric (from a point on the Earth's surface) or heliocentric (from a point external to the Earth). Secondly, the analysis carried out took into account whether the answer was appropriate or not from a scientific point of view. Consequently, the analysis categories used in this work were:

1. Scientifically appropriate heliocentric representation (SAHR): the day/night cycle is explained from the perspective of the Earth's rotation on its axis. The Moon is not involved in this phenomenon.
2. Scientifically appropriate topocentric representation (SATR): the day/night cycle is explained from the perspective of the daily movement of the Sun in the sky. The Moon is not involved in this phenomenon.
3. Scientifically unacceptable heliocentric representation (SUHR): the day/night cycle is explained by observing the Earth from outer space. The Moon is involved in the explanation or the phenomenon is associated with the translation movement of the Earth. Night is generally associated with the presence of the Moon.
4. Scientifically unacceptable topocentric representation (SUTR): the day/night cycle is explained by observing the sky from a point on the Earth's surface. The Moon is involved in the explanation. Night is generally associated with the presence of the Moon.

RESULTS

The numbers of students and teachers that used each model to explain day and night are presented below. Some of the drawings made for the study are also shown, which help identify the mental representation used by each individual when they attempted to explain the day/night cycle. Finally, quotes taken from the interviews with students and teachers are shown, which validate the categorization of the models.

Representations to explain the day/night cycle

Based on the appearance of the explanations for day and night, the proportion of students (divided into educational levels) and teachers that used the different representations mentioned above to explain day and night was calculated (Table 2).

Table 2 The proportion of students and teachers that explained the day and night phenomenon according to the reference system used and whether the representation is scientifically appropriate or not.

Representations to explain day and night	Elementary level	High School level	College level	Teachers
Number of participants	183	76	20	40
Heliocentric, scientifically appropriate (SAHR)	2.7 %	9.2 %	40.0 %	72.5 %
Topocentric, scientifically appropriate (SATR)	6.0 %	1.3 %	10.0 %	0 %
Heliocentric, scientifically unacceptable (SUHR)	7.7 %	18.4 %	30.0 %	15.0 %
Topocentric, scientifically unacceptable (SUTR)	69.4 %	48.7 %	0 %	5.0 %
Other representations	8.2 %	18.4 %	20.0 %	7.5 %
No response	6.0 %	4.0 %	0 %	0 %
Total	100 %	100 %	100 %	100 %

As shown in Table 2, few students at elementary or high school levels managed to explain the day and night phenomenon appropriately using either of the two reference frames. In contrast, almost ¾ of the teachers were able to explain the phenomenon adequately, although they all did so using the heliocentric frame of reference.

A significant increase in the percentage of participants offering an adequate heliocentric explanation can be seen as the educational level progresses (from 2.7% of elementary students to 72.5% of the teachers). In contrast, the proportion of participants using the appropriate topocentric explanation increased very little with educational level and was even zero in the teachers' case.

By analyzing Table 2, it can be seen that the heliocentric explanations, in both the appropriate and unacceptable versions, are in the minority at the elementary level, representing only 10.4% of student responses. At high school level, this percentage increases, with heliocentric representations accounting for 27.6% of student responses. Finally, these become a significant portion of the college students (70%) and teachers (87.5%). This result shows a great conceptual distance between students' representations, most of which are topocentric, and the teachers', most of which are heliocentric.

A large proportion of elementary and high school students offered topocentric explanations, most of which are scientifically unacceptable. In contrast, the college students and teachers offer almost no representations based on this reference system.

At all levels, representations are offered which are confused or do not explain the day/night phenomenon, and which can therefore not be classified into the proposed analysis categories. In addition, despite the everyday nature of the day/night phenomenon, some elementary and high school students were not able to outline a response to explain it.

Some examples are shown below of drawings and explanations corresponding to each of the analysis categories. In some cases subcategories have been identified, which correspond to those identified previously by other authors mentioned in the bibliographical review carried out.

Scientifically appropriate heliocentric explanations

Presented below are explanations and drawings corresponding to students and teachers, who adequately explained day and night using the Earth's rotation on its own axis. As can be seen in Figure 1, the explanatory diagrams corresponding to the different educational levels are similar in spite of there being very few appropriate heliocentric explanations at the elementary and high school levels:

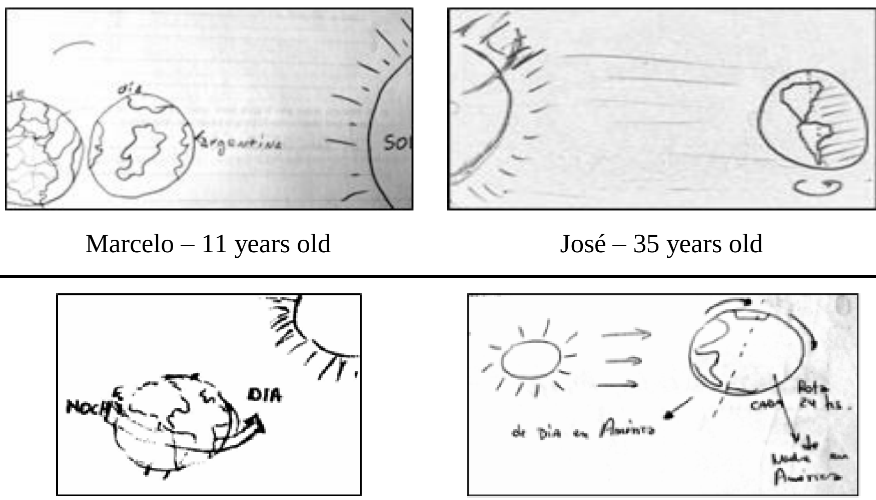
> *"Since the Earth rotates on itself, when the Sun is pointing towards the continent, in that part it is daytime. When it does not, it is nighttime." (Mariana, 12 years old)*

> *"The day and night phenomenon is caused by the rotational movement of the Earth on its own axis. This movement occurs during a 24 hour period." (Claudia, high school teacher)*

Scientifically acceptable heliocentric answers regarding day and night were very rare at elementary (2.7%) and middle school (9.2%) levels, even though this subject constitutes part of the curriculum and is present in the textbooks from the first years of schooling. At college level the proportion of students giving this kind of answer was much higher

(40%), despite it not being an explicitly taught topic at this level. However, 50% of the college students continued to offer answers that are inaccurate from a scientific point of view about an unquestionably common phenomenon. On the other hand, 72.5% of the teachers adequately explain the day/night cycle. This is not so surprising since they teach this subject to their students in school. In spite of this, however, 27.5% were still unable to appropriately explain this phenomenon.

It is worth clarifying that the categorization of an answer does not necessarily indicate the mental model of the person drawing a certain diagram or giving a certain explanation, especially if they are children (Hannust & Kikas, 2010). As a consequence, the answers catalogued as "adequate from a scientific point of view" do not necessarily imply that we can be certain the person has been able to build an adequate mental representation of the day/night cycle. On occasions, subjects express ideas or draw diagrams out of simple repetition, or by other mechanisms, without complete understanding of what they are saying. In this case, we have considered as "adequate" any representation that gives the Earth's rotation as the cause of day and night, and that does not include the presence of the Moon, without considering whether other phenomena, such as the inclination of the Earth's axis, are accurately represented.



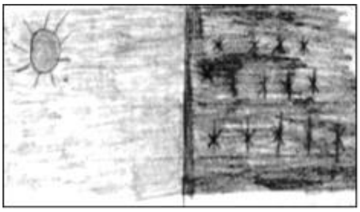
Marcelo – 11 years old | José – 35 years old

Elena – Teacher | Carmen - Teacher

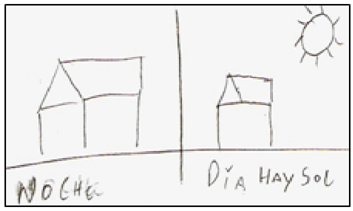
Figure 1 Scientifically appropriate heliocentric representations (SAHR) of the day and night phenomenon given by a 6th grade elementary student, a college student and two teachers.

Scientifically appropriate topocentric explanations

Two drawings made by students that adequately explain day and night with the topocentric reference frame are shown in Figure 2. In this explanation, the Sun's presence defines day and its absence, night (which implies the possibility of seeing the night stars). The change day/night can thus also be explained as a consequence of the Sun's daily movement.



Diana – 11 years old

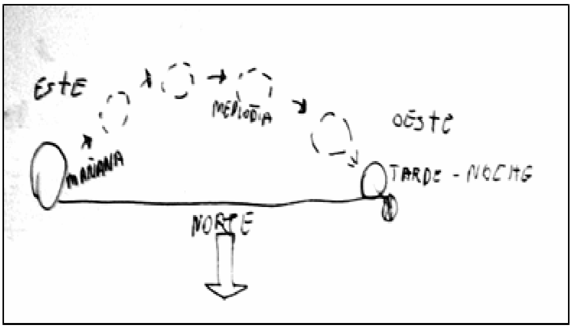


Morena – 20 years old

Figure 2 Scientifically appropriate topocentric representations (SATR) of the day and night phenomenon made by two students, one in elementary school and the other at college.

In spite of the simplicity of this explanation, it was used adequately by only 14 of the 319 subjects tested (4.4%), none of which were teachers. Because of this, there were very few phrases and drawings that identify scientifically appropriate topocentric explanations like the following, which indicate an understanding of the way the Sun moves across the sky during the day, even though this movement is not observed to be southward in our latitude (see Figure 3):

> *"From the Earth it seems as if the Sun is moving and goes turning around. Say that here is [Mount] Currumahuida and here is [Mount] Motoco, when the Sun hides behind the Motoco it becomes night and when it appears over the Currumahuida it becomes morning." (Martín, 11 years old)*



Martín – 11 years old

Figure 3. Drawing of the daily movement of the Sun by an elementary school student, to explain day and night in a topocentric way.

The above topocentric explanation becomes significant because of its relation to the everyday observation of the sky carried out by this student, who uses two mountains close to his home as clear references for the occidental and oriental horizons. The drawing that goes with his explanation illustrates the mental representation he has managed to construct with regard to the daily motion of the Sun and its absolute relation to the day and night phenomenon.

Scientifically unacceptable heliocentric explanations

Table 2 shows the proportion of people who use the heliocentric reference frame to develop their explanation but do not give satisfactory answers to the day and night question. According to the representations mentioned previously in the bibliographical revision, the representations given by the participants may be classified into the following subcategories:

a) The “rotation model”: the Earth rotates on its axis while the Sun and the Moon lie in opposite positions.
b) The “revolving model”: the Moon and the Sun are in opposite positions and move around the Earth.
c) The “revolving Earth model”: the movement of the Earth around the Sun causes the day/night cycle.

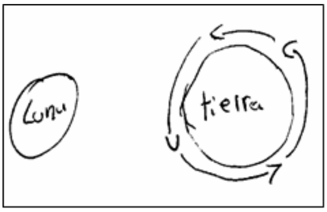
Given that the last two models "b" and "c" involve celestial bodies moving in space, they are placed together in one subcategory named “movement models”.

Below, phrases and drawings are presented (see Figure 4) which were produced by students of all ages and teachers. They are representative of the scientifically unacceptable heliocentric models identified to explain day and night: rotation or movement. These inadequate models persist even in college students and teachers.

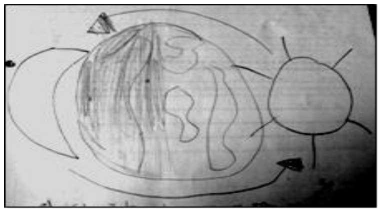
> *"The Sun revolves around the Earth… and illuminates parts." (Lautaro, 12 years old)*

> *"The side of the Earth illuminated by the Sun is daytime, the dark side is night. As the Earth revolves in its orbit the sun rises and sets in different parts of the world." (Adrián, 17 years old)*

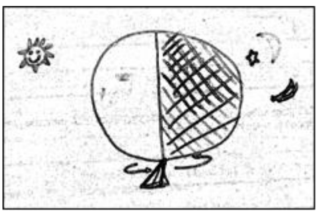
> *"The Earth revolves around the Sun. With this movement part of it is in darkness, and this causes the night. When "it moves", the part that was in night is illuminated by the Sun, then it is day." (Fátima, Teacher)*



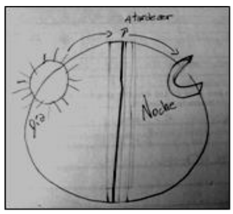
Agustín – 15 years old



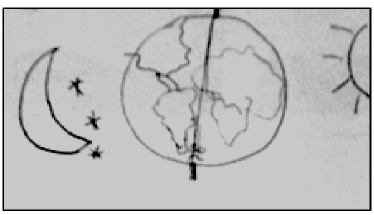
Marcela - 10 years old



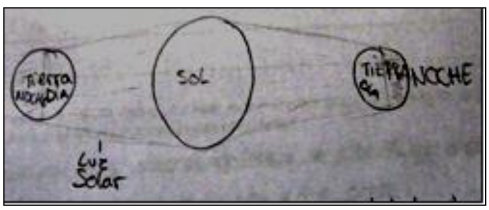
Natalia – 29 years old



Elena - 11 years old



Sara – Teacher



Ernesto - 15 years old

Figure 4 Scientifically unacceptable heliocentric representations (SUHR) of the day and night phenomenon present at all educational levels: rotation model (to the left) and movement models (to the right).

As previously mentioned, heliocentric explanations are predominant in college students and teachers, where the appropriate explanations are proportionally more frequent than the inadequate ones. The opposite happens at elementary and high school levels, where most participants do not use heliocentric representations. However, when they do, they do so with a greater proportion of unacceptable responses.

A significant improvement is evident in the use of the heliocentric explanation of the day and night phenomenon at college level, and even more so in the group of teachers. In the teachers' case, it is possible to associate this with the need to teach this subject explicitly to the students. However, very few elementary students are able to explain this everyday phenomenon satisfactorily, which shows a great distance between students' and teachers' representations.

Scientifically unacceptable topocentric explanations

The percentage of participants who use the topocentric frame of reference to explain the day and night phenomenon, but do so inadequately, is shown in Table 2. The "alternation model" is the name given to explanations that suggest the presence of the Sun during the day and the Moon at night through different mechanisms that cause the appearance and disappearance of one or both of these bodies. All the scientifically unacceptable topocentric representations given by participants are based on this model. To simplify the analysis, attention has been paid only to the permanent presence of the Moon in the night sky, whether or not it is drawn as it is really seen, with its right or left side illuminated, as applicable.

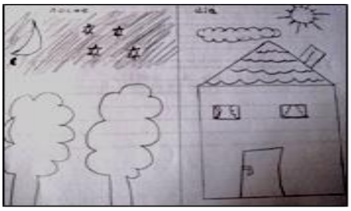
As can be observed in Table 2, the alternation model thoroughly predominates at high school and elementary levels, where the topocentric frame of reference is the most used. In contrast, this model is almost absent in college students and teachers, where the heliocentric reference frame is prevalent. It is important to note that although the college students do not use the alternation model, this does not necessarily imply that they understand the scientific model, since, as has been pointed out, an important percentage explained the phenomenon from a heliocentric reference frame, but used inadequate models.

Phrases and drawings (see Figure 5) that can be associated with the use of the alternation model, in which the day/night cycle is explained inadequately by associating the Moon with nighttime, can be seen below:

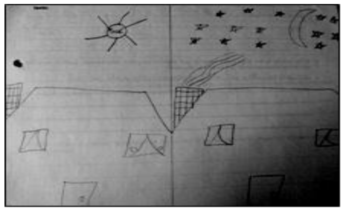
> *"The Sun moves little by little across the sky, until it is night and the Moon comes out." (Rosa, 11 years old)*
>
> *"The sun gradually hides and the Moon appears, and it shines on the Moon and makes it shine." (Alfredo, 13 years old)*

"The Sun rises on this side, during the day it gets all the sunlight, then it hides and the Moon comes and gives light…" (Vanesa, 15 years old)

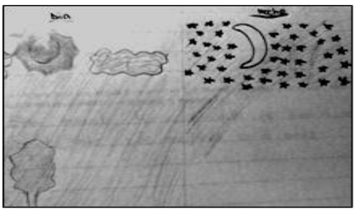
"The day is the moment when the Sun illuminates the Earth. During the night, the Sun illuminates the other part of the planet; where there is no Sun the Moon can generally be seen…" (Lidia, Teacher)



Karina - 11 years old

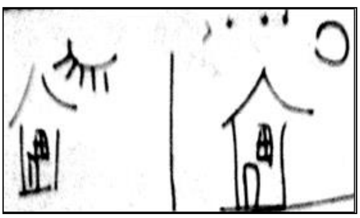


Maira - 11 years old

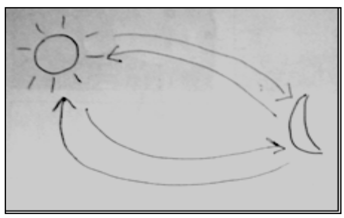


Dorys – 16 years old

Solange – 13 years old



Marcela - Teacher



Lidia - Teacher

Figure 5 Scientifically unacceptable topocentric representations (SUTR) of the day and night phenomenon: alternation model. The first row corresponds to the drawings of elementary students, the second to high school students and the third to teachers. The side of the moon that is illuminated is not analyzed, since only its presence or absence during the night is of interest to note.

DISCUSSION

Most of the elementary and high school students' representations in this study use the topocentric frame of reference to describe the succession of day and night. In this way, the students try to explain the phenomenon from their position as terrestrial observers, indicating the changes that they perceive (or believe they perceive) when they gaze at the sky. In contrast, the teachers and college students prefer to use the heliocentric reference frame, where they explain day and night by describing the movements of the astronomic bodies from a point external to our planet.

This substantial difference in the use of the heliocentric frame of reference, beginning from a certain educational level (and most notably in teachers) could be the result of a formal teaching process at the higher level. However, 47.5% of the teachers reported having learnt about the subject only in elementary school. Only 12.5% said they had participated in a systematic teaching process on the astronomical phenomena at college, even though these subjects appear in most elementary level curricula. Therefore, the marked increase in comprehension level with regard to the day/night cycle observed in the teachers is noteworthy. This was also accompanied by a change in the reference frame (heliocentric) used to explain it, in contrast to the elementary students, who primarily used the topocentric frame of reference.

It is therefore possible that the difficulties presented by elementary students regarding comprehension of day and night could be related to the heliocentric reference frame used at this level, a period during which the students present a profoundly topocentric description of the astronomical phenomena. It would seem that these difficulties are not overcome by the different teaching strategies often used in the classroom. The objective of most of these strategies is for the students to understand the heliocentric scientific explanation (García Barros, Mondelo & Martínez Losada, 1995, 1996; Stahly, Krockover & Shepardson, 1999; Yang, Soprano & McAllister, 2012; Çelikten et al., 2012). It is therefore important to clarify that the use of heliocentric explanations with the students do not necessarily imply that they were able to construct a heliocentric scientific representation for day and night. On the contrary, many students and teachers proposed inadequate heliocentric models, the "rotation" or "movement" models, where they "observed" the movements of the Sun — Earth — Moon system from an imaginary position external to Earth, but they placed the Earth at the center of the system.

Similarly, the use of topocentric explanations does not necessarily imply that the student or teacher has constructed a geocentric mental model, where the Earth is stationary in the universe and everything moves around it. On the contrary, this frame of reference works very well for describing and explaining what can normally be seen in the sky

(Lanciano, 1989; Gellon et al., 1995), and does not mean that the Earth's movement from a heliocentric point of view is being negated.

CONCLUSIONS/IMPLICATIONS

The day-night cycle can be satisfactorily explained using two distinct reference frames: topocentric (with the Sun moving in the sky and being either above or below the local horizon) or heliocentric (with the planet rotating on its own axis, alternating the sectors that receive direct sunlight).

In spite of these two possible ways of explaining the phenomenon satisfactorily, this study showed that most of the Argentinean elementary and high school students interviewed did not display adequate comprehension of the day and night phenomenon. A similar result was found in a notable percentage of college students. This could be related to the erroneous idea held by many elementary and high school students that the Moon is present in the sky every night.

A high percentage of elementary and high school students proposed explanations for the day/night cycle based on their own topocentric position, which shows a certain intellectual convenience for describing the phenomenon from where they are positioned. In contrast, school texts and curricular materials are generally presented at an early age using explanations or drawings based on the heliocentric frame of reference, which implies a certain level of complexity (Martínez Peña & Gil Quílez, 2001; Chiras & Valanides, 2008).

In spite of day/night cycle teaching based on the rotational movement of the Earth, it is clear that everyday perceptions, whether based on direct observations or not, are often stronger than school teachings. This lead to synthetic models, which try to combine the scientific explanations taught with the students' preexisting conceptual structures (Vosniadou & Brewer, 1992). Because of this, it is important that day and night be taught repeatedly at the different educational levels. This subject is generally considered by teachers to be extremely simple and obvious and, therefore, not in need of an in-depth approach.

The analysis conducted showed that the representations used most frequently by the elementary and high school students to explain the day and night phenomenon were centered on their condition as terrestrial observers. In consequence, this should be considered the appropriate frame of reference for the teaching of astronomical phenomena, principally at elementary level. A suitable approach would begin with a description of the astronomical events using a topocentric reference frame, gradually shifting towards the heliocentric reference frame which involves greater conceptual complexity. With this approach it would be possible to overcome the difficulties detected in this study, which result from attempts to incorporate the heliocentric model, with its associated prerequisites and complexities (Chiras & Valanides, 2008), from a very early age.

The heliocentric frame of reference is overvalued in textbooks used by elementary students, and also in most of the audiovisual materials that are presented to the children through the media. This causes a conceptual overload to the detriment of aspects related to direct observation of the sky. Some of these educational materials even contain mistakes whose origins can be traced to the difficulty of integrating two reference frames, heliocentric and topocentric, where the movements and appearance of the celestial bodies have different characteristics. This requires the students to have developed certain spatial abilities and imaginative skills.

In conclusion, it is recommended that the teaching of Astronomy begin with the use of topocentric descriptions and explanations, particularly at elementary level. In this way, students can be placed at the center of their own observations and learning with regard to the most common celestial phenomena. The development of curricular materials that place emphasis on describing and explaining the daily astronomical phenomena using the topocentric frame of reference is therefore indispensable, as is the use of simple images, representations and models described from our position as terrestrial observers.

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