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A STUDY ON LOWER SECONDARY SCHOOL PUPILS' PERCEPTIONS OF CERTAIN ASTRONOMICAL PHENOMENA AND CELESTIAL BODIES

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ABSTRACT

The main purpose of this paper is to reveal certain misconceptions of astronomical phenomena and of celestial bodies that lower secondary school pupils have and which might represent an obstacle in the process of acquiring knowledge of astronomy, geography, and physics. We applied a questionnaire to a group of 26 pupils in the 6th grade at Colegiul Naţional Pedagogic „Gh. Lazăr" ("Gh. Lazăr" National Pedagogical College) in Cluj-Napoca, in the school year 2010 – 2011. The questionnaire consisted of six independent topics: the alternation of day and night, the seasons, the Moon, the solar system, the constellations and the speed of light. Pupils' answers to these questions emphasize the importance of the study of astronomy as a school subject in order to facilitate building up appropriate mind constructs of the highest degree of objectivity about the world, about the environment we live in.

Keywords: *mind construct, planet, seasons, the movements of the Earth, tipping of the axis*

INTRODUCTION

In the paper entitled „*Déclaration sur l'Enseignement de l'Astronomie en Europe*", published on the site of the European Association for Astronomy Education (EAAE), it is mentioned that, in numerous European countries, astronomy is not studied in schools at all or, if it is, the study is basically empirical. In other countries, astronomy is studied in a holistic approach, although several themes in astronomy are easy to grasp and they illustrate the interaction of science, culture, technology in its modern and historical aspects.

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We should also make a note of the fact that, through the medium of mass-media, pupils are exposed to a large range of ideas about the outer space and celestial bodies, which may lead to their building up incorrect or unclear mental representations of the concepts they come to learn about. We have also noticed that several people, in general, mistake astrologers for astronomers, although the two occupations are totally different. An astronomer is a scientist, a researcher who has studied for several years mathematics and optics in order to focus on the lifecycle of stars, the evolution of planets and galaxies. An astrologer "predicts" the future claiming that our lives and actions are affected by the movements of stars and planets.

We chose to approach this topic of pupils' conceptions thanks to our teaching practice observations: lower secondary school pupils have misconceptions about astronomical phenomena and celestial bodies and they believe that if scientific information is made public via various mass-media, it is obviously accurate.

Starting from these observations in our teaching experience, we wanted to verify, by applying a questionnaire, the following hypothesis: *pupils have erroneous conceptions of astronomical phenomena and celestial bodies, these wrongly-built ideas being an obstacle in pupils' forming a correct mental representation of Sun-Earth-Moon system*.

The objectives of our research were as follows:

- to identify lower secondary school pupils' concepts of astronomy;

- to analyse certain misconceptions of astronomy which pupils have;

- to establish a set of methods to help lower secondary school pupils avoid having or to correct their conceptions of astronomical phenomena.

THEORETICAL BASIS FOR RESEARCH

In the specialist literature, several studies have been published on the topic of pupils'/students' beliefs or perceptions. Crocnan (2006) made a classification of pupils' false beliefs. He considered that false beliefs are incorrect conceptions or wrong ideas and he labelled them as "*misconceptions*". The researcher pointed out that there are:

- *preconceptions,* these are concepts or ideas generally held and transmitted through oral tradition, and they have become popular beliefs, due to daily life experience. These concepts influence the proper understanding by pupils of certain other concepts of astronomy such as the apparent movement of the sun, the meteorite falls ("shooting stars").

- *non-scientific beliefs,* which include unscientific explanations from various non-scientific sources (religion, mythology, astrology). For example, various theories of the genesis of the universe are presented by religious

books, myths, legends, etc.

- *improper conceptual knowledge* has its origin in the inaccurate presentation of scientific information to pupils. For example, the cause of the existence of various lunar phases is mistaken for the occurrence of lunar eclipses, when Earth is positioned between the sun and the moon, and the moon is in the Earth's shadow (*umbra*).

- *misconceptions generated by language misuse* are caused by the use of certain lexical items which have different meanings in scientific language and everyday speech. For example, the meaning of the word *day* – a. length of time when the sunlight is visible; b. period of 24 hours; c. a time unit in a week; d. (in astronomy) a period of time lasting between two subsequent culminations of the Sun, or the period of time when the Sun is above the horizon. Another example is the ambiguous perception of the concept of height, which, in everyday speech, is related to vertical position whereas in astronomy refers to the angle made by the direction of observation of the sun and the horizontal plane. The Sun is "up" or "down" does not describe lengths or heights but angles. The Earth's movement of rotation "from the west towards the east" gives the impression that the cardinal points allow us to locate positions and movements in space when, in fact, they are exclusively meant for locating positions and movements on Earth.

- *incorrect factual conceptions* are wrongly construed ideas in early life which are assumed to be valid still in adulthood due to the fact that they were never challenged by counter-arguments or contexts to question their validity. For example, seasons occur due to Earth's distance from the Sun, all planets have a solid surface (as that of the Earth), all stars are of the same size.

Pupils have several misconceptions in their collection of knowledge acquisitions about certain celestial bodies. For example, they think that all constellations are visible and they are always located in the same place in the sky, wherever on earth an observer might be, even if they learnt about the dimensions of planet Earth and its hemispheres from geography lessons. Pupils often believe that "the stars shine in the same place in the sky every night"; therefore, if they are shown stellar maps which present the sky at different times of the year, or if they are encouraged to make direct observations of the constellations, they may change their false beliefs. Another misconception pupils have is that all stars are of the same size and their brightness depends on their distance from Earth.

Ciascai (2001, p.39) underlines the fact that "the sources of these misconceptions are empirical knowledge and academic knowledge" when a pupil is confronted with facts or information which he has not understood properly or which has not been explained to him appropriately". At that moment, the pupil accepted a line of reasoning or an explanation apparently correct, he then made generalizations for other situations by way of transfer, without checking its accuracy and internalized it to his own system of beliefs. From this, we deduce that it is necessary for us to identify pupils'

misconceptions of each subject matter they learn about in class in order to help them form accurate representations of various concepts.

METHOD

The study was carried out at Colegiul Naţional Pedagogic „*Gh. Lazăr*" in Cluj-Napoca, in the 2010-2011 school year.

The research sample was made up of a group of 26 pupils in the 6th grade. The limited number of participants to the test (26) in our research does not allow us to make generalizations for larger groups based on the results recorded.

In order to collect data a survey based on the application of a questionnaire was used. To identify the existence and persistence of misconceptions of astronomical concepts among pupils, we applied the same questionnaire at the beginning of the school year and at the end of it, after pupils did an optional course of astronomy, called "An Initiation into the Secrets of Astronomy", 1 class per week.

The questionnaire consisted of six independent topics: the alternation of day and night, the seasons, the Moon, the solar system, the constellations and the speed of light. Open-ended questions were used (e.g. How can you explain this phenomenon?), guided questions and picture-based questions (e.g. lunar phases). Statistical analysis (mathematical calculations) has been used to process data collected and we presented results using graphs.

RESULTS AND DISCUSSION

Topic: The alternation of day and night. The objective of applying a set of questions on this topic was to determine whether pupils are able to offer correct explanations of the apparent movement of the Sun caused by the rotation of the Earth about its axis and of what equinoxes and solstices are.

In the initial test (at the beginning of the school year), 20 pupils could correctly identify equinoxes and solstices (80% of the answers). Pupils acquired these concepts both from school and through various mass-media channels. In the final test (at the end of the school year), 24 pupils provided correct answers for equinoxes and solstices (92%). The progress shown could be explained by the change of belief students made as a result of academic schoolwork done throughout the course.

In the initial questionnaire, in the case of the question referring to the cause of alternation of daytime and night time, four types of answers

were recorded as shown in Figure 1: the rotation of the Earth about its axis – which is the correct answer – 12 pupils (46%), the rotation of the Earth around the sun – 9 pupils (35%); the rotation of Earth (without mentioning the type of rotation) – 3 pupils (11%); other answers (the Sun rises at daybreak and sets at dusk; by day we face the sun and by night we turn our backs on it) – 2 pupils (8%). A possible explanation of the 35% representing the pupils who answered that the rotation of the Earth around the Sun causes the alternation of day and night is the persistence of an abusive geocentric and anthropomorphic vision about the Sun that "wakes up" in the morning and "goes to sleep" in the evening, repeatedly promoted during kindergarten and primary school years. In the final questionnaire (as shown in Figure 1), pupils answered that the alternation of day and night is caused by the rotation of the Earth about its axis – 20 pupils (77%); the rotation of Earth (without specifying the type of rotation) – 5 pupils (19%); no answer – 1 pupil (4%).

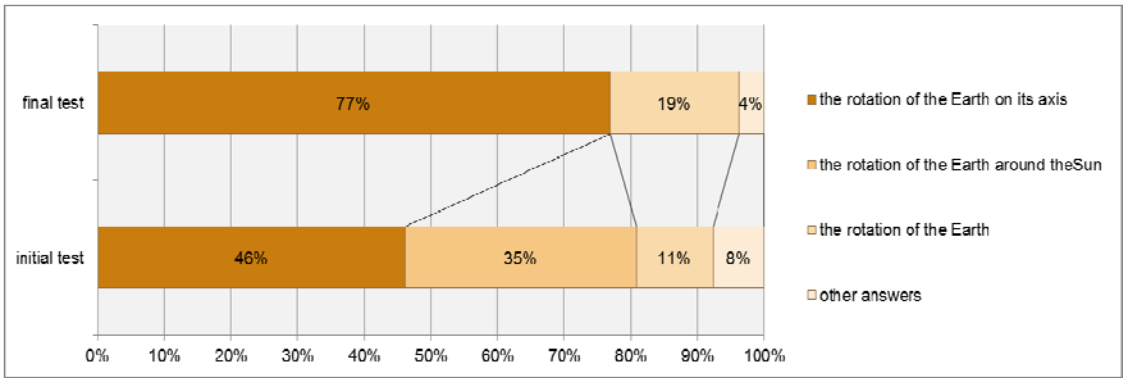

Fig. 1. Pupils' answers in the initial and final tests to the question on the alternation of day and night

To the questions referring to the duration of days and nights, in the initial questionniare, 20 pupils (77%) answered that days are longer in the summer time because the Sun is closer to the Earth, and 6 pupils (23%) did not offer any answer. In the final questionnaire, the same question on the length of days and nights, pupils offered the following answers (fig. 2): the tilting of the Earth's rotation axis – which is the correct answer - 14 pupils (54%); the fact that the Earth's orbit is circular – 6 pupils (23%); Earth is closer to the Sun in summer – 5 pupils (19%); no answer – 1 pupil (4%).

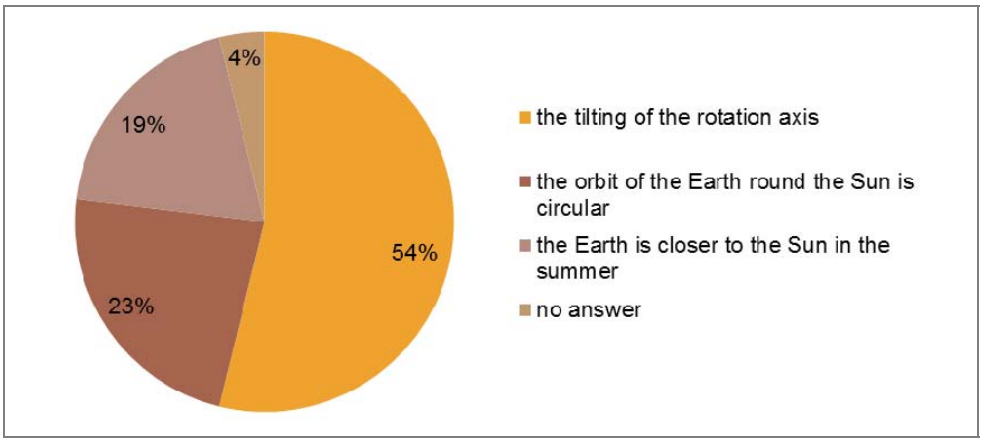

Fig. 2. Pupils' answers to the question on the length of days and nights (in the final questionnaire)

Topic: The occurrence of seasons on Earth. As the existence of *seasons* is a well-known fact by pupils, we formulated a question with two categories of answers: the first category refers to the influence of the Earth's features (distance from the sun, tilt of the Earth's rotation axis with respect to its orbital plane around the sun); the second refers to geographical conditions (*the presence of warm ocean currents in the summer and of cold currents in winter*).

In the initial questionnaire 20 out of 26 pupils (77%) answered that seasons occur because of the different distances from the Sun as the Earth is at certain points in its movement of revolution around the sun and 6 pupils did not answer this question.

In the final questionnaire (fig. 3), the occurrence of seasons was motivated by students as being caused by the tilt of the Earth's rotation axis with respect to its orbital plane around the sun (correct answer) – 19 pupils (73%); the Earth is closer to the Sun in summer than in winter – 4 pupils (15,3%); the strong warm ocean currents are more active in summer than in winter – 2 pupils (7,7%); or, gave no answer – 1 pupil (4%).

The distance between the Earth and the Sun which influences the warming up of the Earth in the same way in which a person's closeness to a heating stove influences the warming up of that person is the analogy on which pupils' incorrect answers are based.

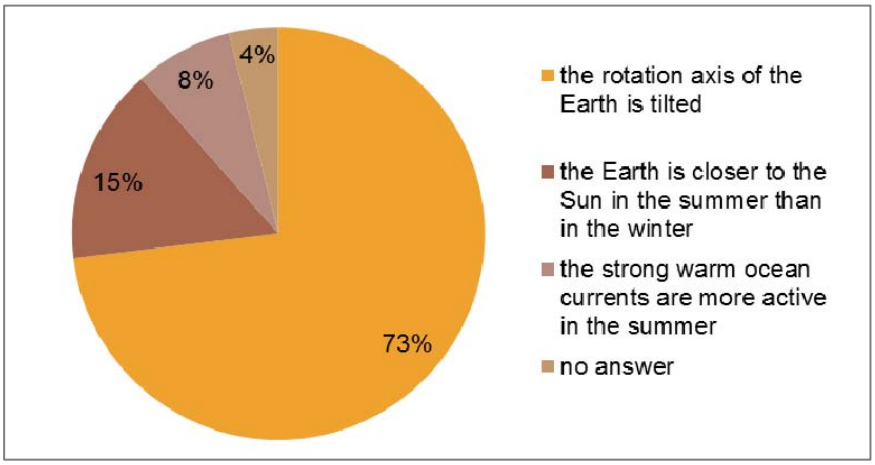

Fig. 3. Pupils' answers to the question on the cause of the occurrence of seasons (final questionnaire)

Topic: The Moon. We were interested to find out how pupils explain to themselves lunar eclipses, why the moon is bright – in order to check if they can make a difference between an illuminated body and a luminous one, what the phases of the moon are – we asked pupils to even draw the phases so they could reflect on the things observed, why we always see the same side of the moon.

In the initial questionnaire, 24 pupils out of 26 (92%) provided correct answers to the question on the moon eclipse and 18 (69%) provided correct answers to the question referring to the brightness of the moon.

In the final questionnaire, the question about the position of the celestial bodies during a moon eclipse was offered the following answers (illustrated in fig. 4): the Earth is positioned between the Moon and the Sun – the correct answer – 19 pupils (73%); The Moon is positioned between the Sun and the Earth – 5 pupils (19%) – this is a mechanical answer, pupils did not realize that if the Moon is between the Sun and the Earth we can see it directly, there can be no moon eclipse, but a solar eclipse; other answers – 2 pupils (8%) stated: "*when the moon passes in front of the Sun*".

To accurately understand the relationships between the Sun, the Earth and the Moon, a possible solution would be to provide students a spatial model of the solar system before they learn about eclipses so that they can fix knowledge of the position of the three celestial bodies with respect to one another at various moments in time and during the eclipses.

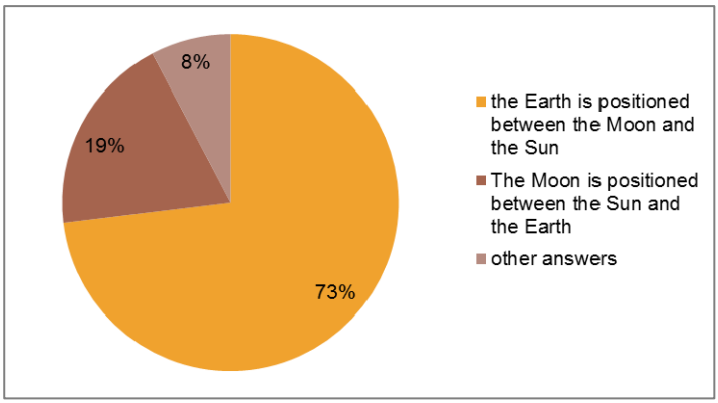

Fig. 4. Pupils' answers referring to the position of the three celestial bodies during a moon eclipse (final questionnaire)

To the question on why the moon is bright, in the initial test, pupils offered the following answers: because the moon is illuminated by the sun – correct answer – 23 pupils (88%); because the sun moves behind the moon – 1 pupil (4%); no answer – 2 pupils (8%) (fig. 5).

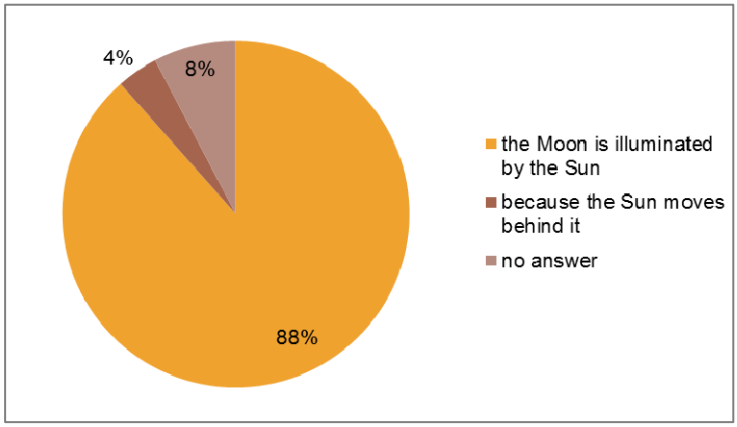

Fig. 5. Pupils' answers to the question on the brightness of the Moon (initial questionnaire)

As regards the lunar phases, in the initial test all pupils managed to make correct drawings of the phases, but the explanations accompanying these drawings varied and, in most cases, were incorrect, only 5 pupils succedeed in giving correct answers. The most frequent wrong explanation offered by students to this question was that the shadow of the Earth causes the change in the shape of the moon disk. Three pupils did not attempt an answer to this question.

With reference to the fact that we always see the same side of the

moon, pupils could not offer a correct explanation in the initial test; the most frequent explanation provided at this stage was that the Moon does not spin around its axis that is why it always shows the same side to an observer on the Earth. This misconception is related to a reference system. In a geocentric frame of reference, the Moon does not rotate, but in a heliocentric frame of reference, the rotation of the Moon is synchronous with its revolutionary movement around the Earth, therefore, the moon faces the Earth with the same side.

Topic: The solar system. The first question under this topic asked pupils to explain the difference between a star and a planet. The second question requested pupils to mention the number of planets in our solar system, this question being intended to check whether the pupils remembered the new concept that there are eight planets (not nine, as it was formerly thought), since they learnt in their Sciences and Geography classes the former structure of our solar system, a potentially persistent piece of information in pupils' minds.

To the question asking them to explain the difference between a planet and a star, in the final test, pupils' answers were as follows (see fig. 6): a star has its own light, whereas a planet does not – 18 pupils (69%); a star gives off heat, but a planet does not – 6 pupils (23%) – pupils associate light with heat; other answers – 2 pupils (8%) – a planet revolves around the sun, but a star does not; a star is gaseous, but a planet is not.

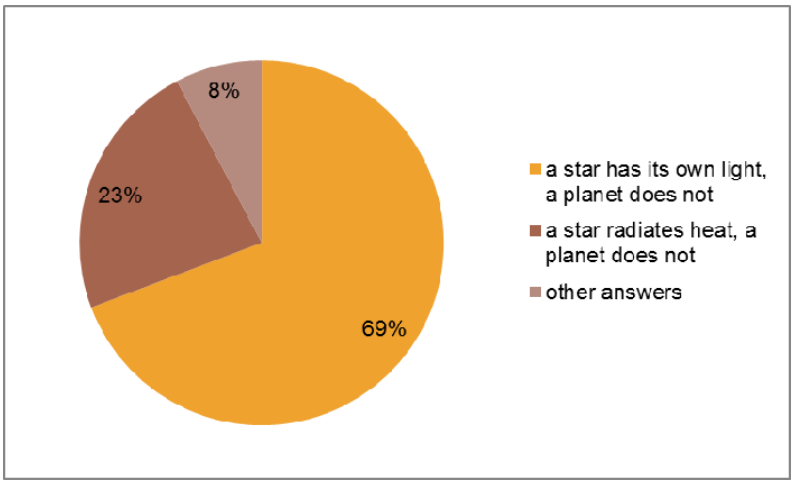

Fig. 6. Pupils' answers on the difference between a star and a planet (final test)

To the question asking them to mention the number of planets existing in our solar system all students gave correct answers, although, at the beginning of the school year, 16 pupils out 26 (61%) did not know that it was discovered that we have a planet less in our solar system, as popularized in the media since 2009, the International Year of Astronomy.

Topic: The constellations. To the question *"What is a constellation?"*, in the final test pupils answered (see fig. 7): a group of stars – 15 pupils (58%); other answers (several stars; some stars; stars; many stars) - 7 pupils (27%); *"I do not know"* or *"I do not want to answer"* – 4 pupils (15%).

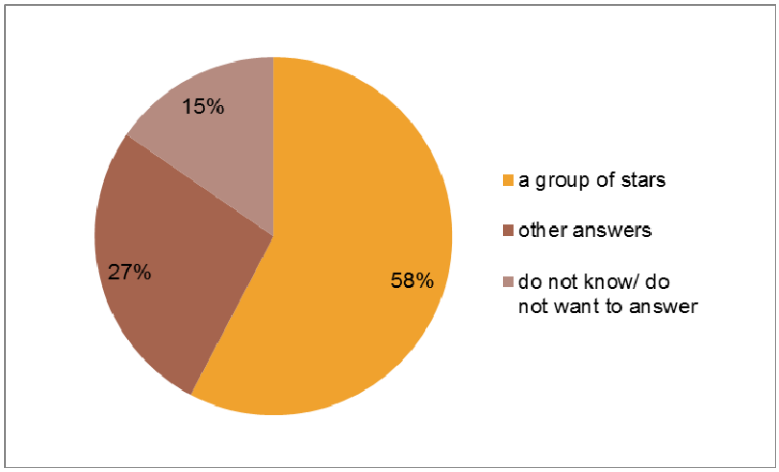

Fig. 7. Pupils' answers to the question on constellations (final test)

To the question asking them to explain whether the same constellations are visible anywhere to an observer located on Earth, if at the beginning of the school year wrong answers were given or the pupils did not know the correct answer, in the final test, 11 pupils gave correct answers (42%), that is, different constellations can be seen in the sky, depending on the location of an observer on Earth, whether he sees them from a place in the southern or northern hemisphere. 10 pupils (38%) did not offer any answer and 5 (19%) said that the same constellations can be seen wherever an observer on Earth might be positioned at a given moment.

Topic: The speed of light

The questions referred to the concept of distance in the outer space, pupils had to calculate the time for light to travel to the Moon from the Earth, using the formula for speed. This question was added as a new item in the final test, since pupils learn about the concept of speed of a body and the mathematical formula to calculate it only in the Physics lessons for the 6th grade. 18 out of 26 pupils (69%) computed correctly, 5 pupils (19%) wrongly derived the expression for time from the formula for speed ($s = d/\Delta t$), and 3 pupils (12%) got a wrong answer from their arithmetic calculations (see fig. 8).

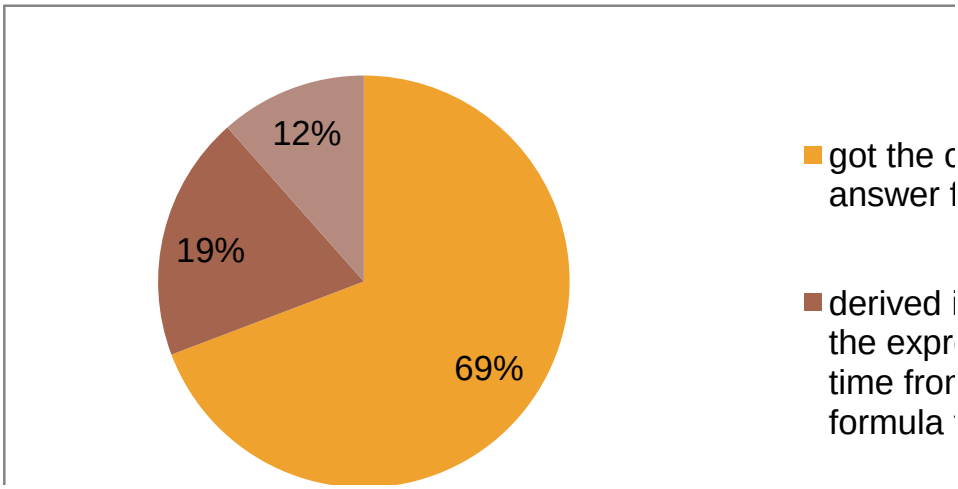

Fig. 8. The results of solving the problem on the time it takes the light to travel to the Moon from the Earth

CONCLUSIONS, LIMITS, NEW DIRECTIONS FOR FUTURE RESEARCH, SUGGESTIONS FOR CURRICULUM DEVELOPMENT

The answers given to the questionnaire referring to pupils misconceptions or false beliefs allowed us to identify what concepts of certain astronomical phenomena and celestial bodies pupils have. On the topic of stars and planets, we found out that many students did not mention that planet Earth produces heat, too, that there are huge distances in the universe and nor did they sense the differences in size between the celestial bodies – the apparent diameter of the sun is approximately equal to that of the moon. In as far as constellations are concerned, the pupils did not notice the fact that there are huge distances between the stars and, often, they did not either notice that the stars belonging to a constellation are not in the same plane. The way pupils explained the occurrence of seasons on Earth revealed one of the most common misconceptions pupils have – the cause of the existence of seasons is that the Earth is at various distances from the Sun during a year.

Our research points out that there are difficulties in the process of teaching-learning Sciences and Geography, and ignoring them can lead to a potential learning block in the cognitive development of pupils, lack of interest for studying and misconceptions of natural phenomena. In order to overcome these difficulties, an instructional strategy to be applied effectively in teaching astronomy concepts is that of modelling. Pierrard pointed out: "Astronomy is a privileged domain for the use of models..... three features can be identified in their use in class activities: a substitute for reality, the existing (reversible) analogy between the model and the

reality and various models can explain the same phenomenon" (1998, p. 96). We would like to emphasize the idea that the study of astronomy in schools can contribute to the understanding of the physical phenomena from the human scale to the macrocosmic one, thus, giving pupils an organized scientific perspective of the world. We note that the studying of astronomy facilitates the grasping of several concepts and theories met in geography: the physical and chemical characteristics of the Earth, the formation and development of planet Earth, the movements of the Earth, etc.

The research we carried out has a few limits: the sample of respondents consisted of pupils from a single class, as there were no parallel classes in the school we work in; the number of participants in the study on pupils misconceptions of astronomy (26) does not allow for an inferential analysis; the tool used in the collection of data was not validated prior to its use; the time over which the study was carried out was relatively limited (one school year).

Taking into account the fact that the research on misconceptions of astronomy was carried out for pupils in the lower secondary school, in a single school, further studies can expand the research to other schools, for larger samples of respondents who do an optional course in astronomy. Also, the study can be expanded to high school students in humanities classes who learn about concepts of astronomy in their Science classes. It can also be expanded to pupils or students from other countries who do similar courses of astronomy.

An example of such country is Canada, where *Science and Technology* comprises knowledge of concepts from various sciences under one large umbrella as a school subject – astronomy, physics, chemistry, biology, geology, technology. The goals are to develop pupils' competence of researching for answers or solutions to scientific problems, to enable pupils to acquire knowledge of science and technology that will facilitate the development and awareness of their intellectual - cognitive capacity. In France, the study of astronomy begins in primary school, using an interdisciplinary approach, the learning about the sky and the earth being aimed at changing wrong perceptions of reality beginning with this level of schooling.

In our opinion, the study of astronomy should start in primary school and continue in further years of schooling. The teaching-learning of astronomy in school will allow professionals to appropriately introduce the concepts of astronomy and of physics within the curriculum content for Sciences, for geography, and will facilitate pupils and students understanding and forming of cognitive constructs and representations of a higher degree of objectivity about the environment we live in.

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Appendix: Questionnaire on pupils' conceptions

1. The alternation of day and night

a) 23rd September and 20th March are calendar dates known as the moments of the Autumn equinox and, respectively, the Spring equinox. What does the word *equinox* suggest and what is the particularity of these two days in as far as the alternation of day and night is concerned?

b) Circle the correct alternative(s) to answer the question: why are days longer in the summer than in the winter?

- The Earth's orbit round the Sun is not circular;
- The rotation axis of the Earth is tilted with respect to the orbital plane round the Sun;
- In summer, the Earth is closer to the Sun.

2. The Seasons

a) Circle the correct choice(s) to answer the question: how can the existence/occurrence of seasons be explained?

- The Earth is closer to the Sun in the summer than in the winter;
- The strong warm ocean currents are more active in the summer than in the winter;

- The rotation axis of the Earth is tilted with respect to the orbital plane round the Sun.

b) Is it true that seasons are reversed in the two hemispheres? (That is, when it is summer in the northern hemisphere, it is winter in the southern hemisphere). Why?

3. The Moon

a) What is a lunar/moon eclipse?

b) Why is the moon bright?

c) Why does the Moon disk change its shape over a month?

Draw all the shapes of the Moon that you know about.

d) Why does the Moon face the Earth with the same side?

4. The Solar System

a) What is the difference between a star and a planet?

b) How many planets are there in our solar system?

5. The Constellations

a) What is a constellation? Why did people invent the constellations and what do these serve for?

b) What characteristic does the Pole Star have?

c) Are constellations the same throughout the year? Are the constellations the same we can see in the sky from wherever we might be located on the Earth's surface at a given moment? Justify your answer.

6. The Speed of Light

a) What is the speed at which the light from the sun travels in the universe to reach the Earth?

b) What is a light -year?

c) How long does it take us to reach the Moon if we fly at the speed of light? The distance between the Earth and the Moon is of approximately 380,000 km.