Vasiliki Kokologiannaki,
Konstantinos Ravanis
Greece

The New Educational Review

Greek Sixth-graders' Mental Representations of the Mechanism of Vision

Abstract

The presented research concerns 11-year-old Greek students' mental representations of the mechanisms of vision in conditions of natural and artificial light, as well as the persistence of those representations in terms of the two different states of lighting and the expression form of the provided answers (oral speech; sketches). The study consisted of two phases: test interviews and an interview process, where personal interviews were conducted with 30 participants. The results showed that the 11-year-old pupils employed the majority of the vision schemes that are included in the international bibliography; however, they tended to use the Sea of Light mechanism and a new scheme the researchers called Illumination of the Object. The schemes employed, however, are not consistent, either throughout the different states of lighting, or in the 3-D and 2-D world.

Keywords: *mental representations, vision, Science.*

Introduction

Every year, in school classes across countries, teachers make a great effort to transfer a corpus of transformed scientific knowledge to young pupils, which often conflicts with their personal ideas on a scientific subject (Driver, Squires, Rushworth, & Wood-Robinson, 1994). Frequently called mental representations, those ideas are explanatory prototypes according to which experiences are "translated" and in which incoming information is integrated (Ravanis, Koliopoulos & Boilevin, 2008; Ravanis, Zacharos & Vellopoulou, 2010).

As Weil-Barais (2001) explained, mental representations present causality and consistency, thus they are very resistant to teachers' attempts to change them. Therefore, it is extremely important that the mental representations that pupils bring to classroom should be the starting point of the educational process.

What happens, then, when it comes to teaching science? As a school course, science consists of concepts, natural phenomena, theories, models, symbols and specific terms that are not always easily comprehended as we cannot always see or feel a natural phenomenon directly (Koliopoulos, Adúriz-Bravo, & Ravanis, 2011).

The concept studied in this paper is vision, a field that constitutes a large part of the optics curriculum. Vision has been studied since ancient times. Ancient Greek scientists believed that we can see because light is produced and transmitted in a straight line, without knowing either its nature or the direction it is heading for. By the end of the 13th century AD, al-Hasan ibn al-Haytham proposed what is today known as the modern theory of vision. According to this theory, light travels from a light source towards an object. When it reaches the object, a part of it is retransmitted in all directions. Kepler refined this theory of vision: the retransmitted light that meets the eye creates a reversed image of the object in the retina (Kepler 1600/2000 in Dedes, 2005). At this point, some basic features of light should be described. Light is both a wave and a particle. When it is being emitted by a light source, it reaches an object and, depending on its type of surface and according to the object's properties, light of a certain frequency is absorbed and reflected back in all directions. The reflected light reaches the eye of the observer which attributes its colour to the object (Hewitt, 2004). A reaction is caused in the eye retina and it is "translated" by the human brain (Selley, 1996). This represents the scientific model of human vision and is based on three essential principles:

- light is transmitted in a straight line almost instantly,
- an illuminated object retransmits light in all directions, including towards the eye of an observer as that is necessary so as to see an object, and
- the trajectory of the light from the object to the eye is identical to the straight line in which the eye sees the object (Selley, 1996).

The complexity of this mechanism has posed questions about what children seem to think of it. Selley (1996) studied the ideas of children in grade 4 (8 years of age) and how they evolved over the next three years. Nine different versions of the children's interpretative mechanisms for vision and light were revealed (involving factors such as an object, light source and the eye):

1. **Cooperative Emission***:* Both the eye and the light source emit light towards the object.

2. **Stimulated Emission:** The light reaches the eye and is then retransmitted or causes the emission of a light beam towards the object.
3. **Simple Emission:** The eye sends light to the object.
4. **Stimulated Emission with Reflection:** The light leaves the light source, reaches the eye, is then retransmitted or provokes a secondary emission towards the object. The object then retransmits the light, which returns to the eye.
5. **Primary Reception:** The light source lights the eye – this model involves primary light sources.
6. **Secondary Reception:** The light travels from the light source first to the object, then to the eye – this model involves objects retransmitting light from a primary light source.
7. **Secondary Reception-Emission:** The light travels from the light source to the object, then "bounces" towards the eye, the eye then emits something towards the object.
8. **Sea of Light:** The light source generally lights the space and this is the reason why we can see.
9. **Dual Illumination:** The light source lights both the eye and the object at the same time.

Children primarily adopt Mechanisms 2 and 8. With age these mechanisms evolve into Mechanisms 1, 4, 6 and 7 (Selley, 1996). Mechanism 8 primarily appears in children's ideas about vision in night conditions (Kokologiannaki & Ravanis, 2012). Mechanisms 1 to 4, 7 and 9 also appear in the bibliographical study of Dedes (2005), where another interpretative mechanism was introduced, in which light, starting from the light source, simply reaches an object with no further detail provided. Children do not seem to perceive light as an entity and tend to assign an energetic role to the eye. Thus, it is easier for them to accept an emission model over a reception model (Anderson & Smith, 1982; Selley, 1996).

Ravanis (2000) studied the ideas of 58 Greek students (aged from 12 to 13) who had already attended an optics class on the mechanism of vision. The findings revealed that an acceptable number of Greek students of this age had, in fact, a satisfactory idea about the mechanism of vision. Furthermore, they tend to assign an energetic role to the eye.

Pupils do hold specific ideas on science matters that are resistant to change. If we want a science class to be efficient we should first of all lean towards those representational mechanisms and use them as the baseline for our educational efforts. Thus, for this study it was necessary to firstly explore the representational mechanisms that students have for specific scientific phenomena, which, in our case, would be the mechanisms of vision. We then aimed to explore the following questions in more detail:

1. Are the interpretative mechanisms that Greek sixth-grade students adopt in order to explain the way we can see an object in accordance with the ones observed in the published literature?
2. Are they consistent as far as their form of expression is concerned in terms of answers given in the oral form and answers given in the form of drawings?
3. Are they consistent when a different light source is involved (either natural or artificial light conditions)?

Methodology

The participants

In this qualitative study, 30 Greek students were involved, 14 boys and 16 girls, from three different primary schools located in rural and semi-urban areas in the county of Elia in Greece. They all were in the sixth grade and had never been taught about vision before.

The research material

Semi-structured interviews were used. Each participant was given a blue and a white piece of A4 paper and then asked the following questions:

1. Would you be able to see this blue and this white piece of paper if you were outside in the school yard?
2. If the answer to Question 1 is affirmative: What would help you see them and how would the factors you have mentioned contribute to your seeing them?
3. If those two pieces of paper were placed under the light of a study lamp, would you be able to see them in that case?
4. If the answer to Question 3 is affirmative: What would help you see them and how would the factors you have mentioned contribute to your seeing them?

In addition, the pupils were provided with some supplementary pictures so as to determine whether their previous oral answers were in accordance with the ones expressed in the written form (cf., Figures 1–4) and to test the strength of their interpretative mechanisms as far as the form of their expression was concerned (written 2-D world or an oral form representing the 3-D world). These pictures depicted situations similar to the ones asked about by the interviewer, involving an observer, a white egg, a red apple, a primary light source (the sun) and an artificial light source (a lit study lamp) (Web Source1 & Web Source2, 2010). The existence of two different kinds of light source also aimed to put their answers to the test.

The participants were encouraged to draw or write, in order to express in a 2-D world the way the observer sees the object in each picture.

Figure 1. First supplementary picture (natural light source and white object)

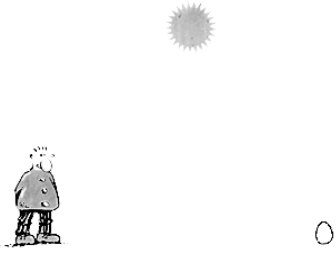


Figure 2: Second supplementary picture (natural light source and red object)

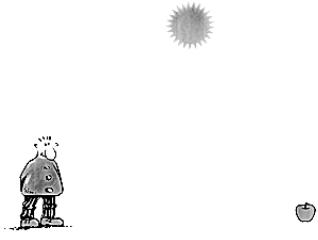


Figure 3: Third supplementary picture (artificial light source and white object)

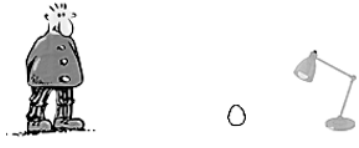


Figure 4: Fourth supplementary picture (artificial light source and red object)

The research procedure

The research procedure involved two phases, and was implemented individually with each participant and within the school time schedule:

- Phase 1: test interviews (elimination of possible defects in the interview design and procedure)
- Phase 2: interview process

In phase 2, the participant sat in a room with the interviewer and the interview commenced with the four questions referred to. In the end, each participant was asked to fill in the pictures so as to explain if and how the observer saw the object. The participant was allowed not to write anything at all, if desired. Notes were kept of the interview and the procedure was recorded.

Results

Data analysis

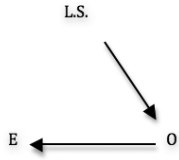
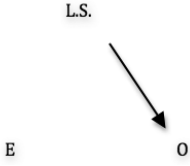
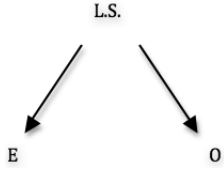
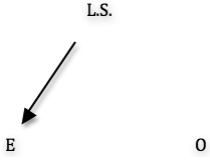
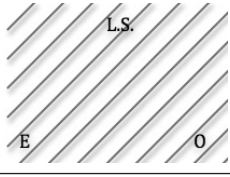
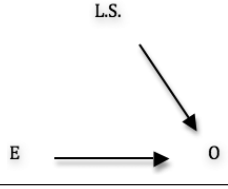
Following the qualitative analysis of the interviews and the pictures given to the participants, a number of categories for the children's interpretative mechanisms of vision were created. Interpretative mechanism tables were then created that portrayed the oral and written answers of each participant as well as the responses for the two lighting conditions: artificial and natural light.

The different categories of interpretative mechanisms that the children employed to explain vision are presented in Table 1 (LS = Light Source, E = Eye, O = Object) in a hierarchical order based on the factor that is most active in the procedure of vision. The mechanisms that attribute vision to the same factor are then also presented in a hierarchical order based on their proximity to Haytham's scientific model.

Interpretative Mechanisms 1 to 5 involve a light source that sends something to the eye. To be more specific, interpretative Mechanism 1 or Secondary Reception represents the scientific model. Mechanism 2 or Illumination of the Object is approximate to the scientific model as the light source sends light to the object. In the third mechanism, Dual Illumination, a supplementary procedure is added to Mechanism 2: the light source also sends light to the eye at the same time. In Mechanism 4, or Primary Reception, the eye sees the object because the light source simply sends light to the eye. In the last category of mechanisms, Sea of Light, the light source generally lightens the space and the object is seen. This must not be confused with Illumination of the Object as there is neither a specific procedure that is described, nor a specific direction of the light.

In the last mechanism (Cooperative Emission), it is the eye that sends something in order to see an object. The light source emits light towards the eye.

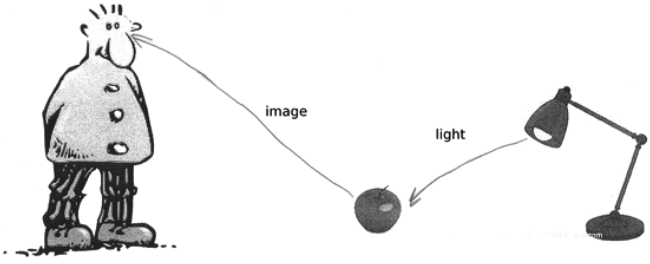
Table 1. Interpretative mechanisms that children employ to explain vision (LS = Light Source; E = Eye; O = Object)

	Interpretative Mechanisms	Name
1		Secondary Reception
2		Illumination of the Object
3		Dual Illumination
4		Primary Reception
5		Sea of Light
6		Cooperative Emission

Examples for each interpretative mechanism are provided below:

1. Secondary Reception:

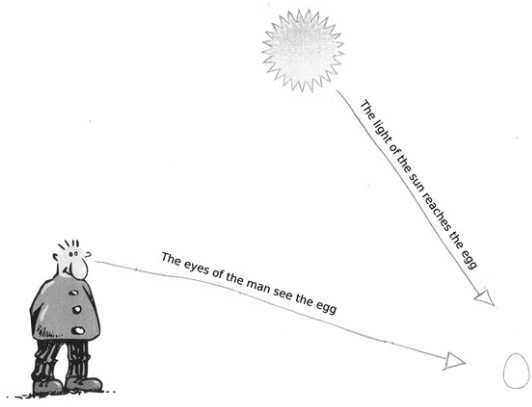
Figure 5: Subject 20, artificial light source. The study lamp sends "light" to the apple and the image reaches the eye of the observer



2. Illumination of the object: Subject 29 explained the artificial light condition as follows: "*By sending its light (the study lamp), I am able to see both of them easily (both white and blue paper) (…), the eyes help me in the same way (as in natural light, the eye sees the paper)*".

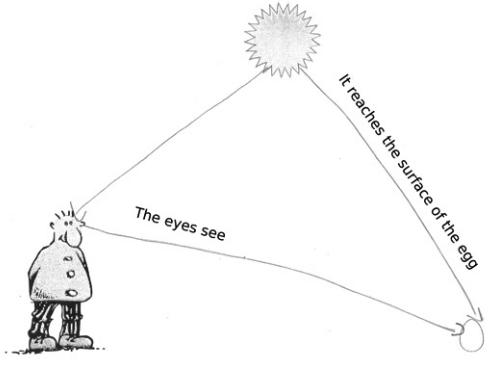
In this type of answer the light source is primarily involved in the process of seeing an object. The eyes also help, but their role is constrained to simply functioning properly. Often, in the drawings, the subjects would draw arrows coming from the light source to the object and from the eye to the object (Figure 6). The subjects explained that the arrow between the eye and the object means that the eye "sees" the object; consequently, such answers should not be confused with those for "Cooperative Emission".

Figure 6: Subject 19, natural light: "The light of the sun reaches the egg" and "the eyes of the man see the egg"



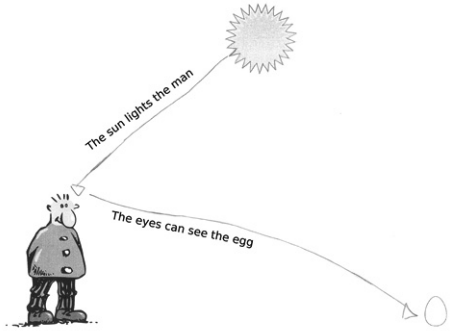
3. Dual Illumination:

Figure 7: Subject 7, natural light: "(The sun light) reaches the surface of the egg", and "the eyes see"



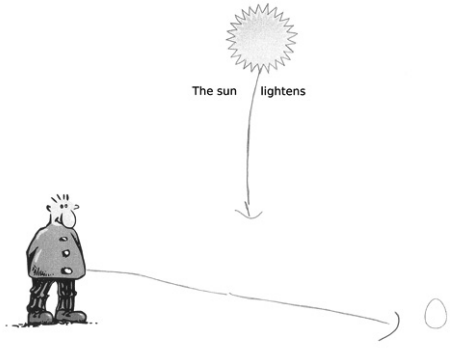
4. Primary Reception: This interpretative mechanism was not mentioned in the oral answers; it was only spotted in the subjects' drawings (cf., Figure 8).

Figure 8: Subject 14, natural light: "The sun lights the man" and "the eyes can see the egg"



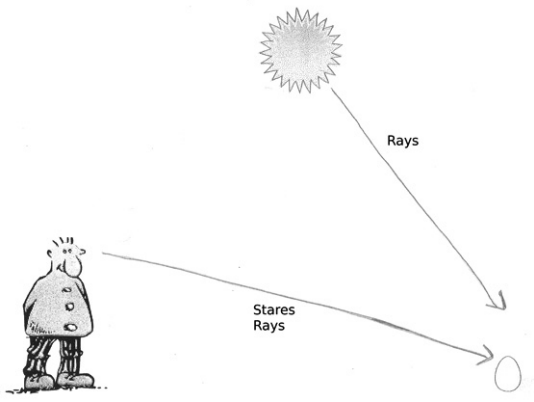
5. Sea of Light: Subject 15 explained the artificial light conditions as follows: *"The light of the study lamp lights it. My eyes help me see it".*

Figure 9: Subject 18, natural light: "The sun lightens (in general)"



6. Cooperative Emission: Subject 8 believed that in order to see in the natural light conditions: *"The eyes (help). The light from the sun (also helps) (…) the sunlight, the sun rays. They (the eyes) send rays".*

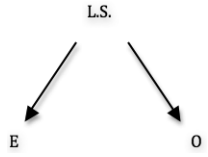
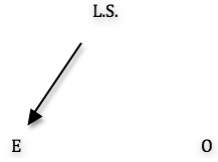
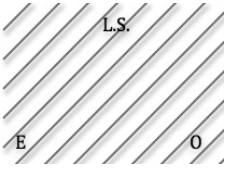
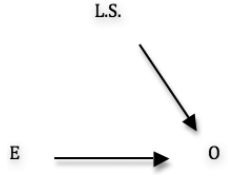
Figure 10: Subject 8, natural light: The sun sends "rays" to the egg and the eye also "stares" and sends "rays"



7. **No answer/no drawing:** Two subjects did not know the answer or did not wish to draw anything. Tables 2, 3 and 4 present the answers given by each subject in detail.

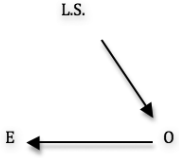
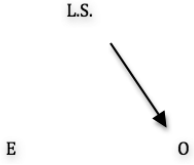
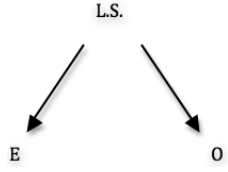
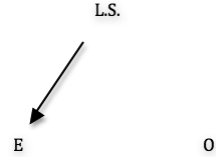
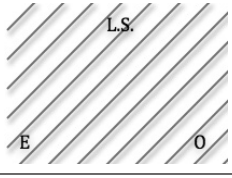
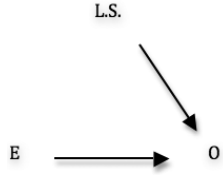
Table 2. Subjects' interpretative mechanisms in 3-D and 2-D world, in natural light conditions

Interpretative mechanisms		3-D world (oral answers)		2-D world (drawings)	
		Subjects	No.	Subjects	No.
1	L.S. E O	20, 24	**2**	3, 4, 20	**3**
2	L.S. E O	4, 6, 7, 9, 10, 17, 26, 29	**8**	2, 5, 6, 9, 10, 11, 12, 15, 16, 17, 19, 24, 25, 26, 29	**15**

	Interpretative mechanisms	3-D world (oral answers)		2-D world (drawings)	
		Subjects	**No.**	**Subjects**	**No.**
3			**0**	7	**1**
4			**0**	14	**1**
5		1, 2, 3, 5, 11, 12, 13, 14, 15, 16, 18, 19, 21, 22, 23, 25, 27, 28, 30	**19**	1, 13, 18, 21, 22, 23, 27, 28, 30	**9**
6		8	**1**	8	**1**
7	No answer/drawing		**0**		**0**

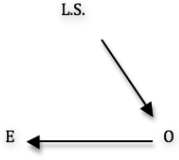
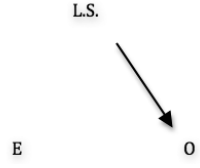
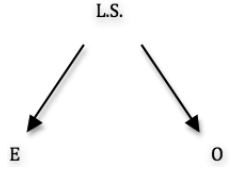
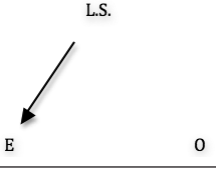
The prevailing mechanisms in the 3-D world were Sea of Light (19/30) and Illumination of the Object (8/30). Two students used the Secondary Reception Mechanism and only one used Cooperative Emission. The same mechanisms were also found to prevail in the 2-D world: Illumination of the Object (15/30) and the Sea of Light (9/30). Here, three students chose the Secondary Reception mechanism, one drew a Dual Illumination mechanism, one a Primary Reception mechanism, and one a Cooperative Emission mechanism. Overall, the responses of 17 out of 30 subjects presented stability between the mentioned interpretative mechanisms in their oral answers and drawings, while instability was presented in the case of 13 out of 30 students.

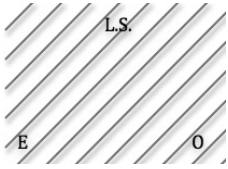
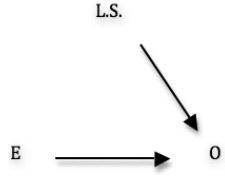
Table 3. Subjects' interpretative mechanisms in 3-D and 2-D world, in artificial light conditions

Interpretative Mechanisms		3-D world (oral answers)		2-D world (drawings)	
		Subjects	No.	Subjects	No.
1			**0**	20	**1**
2		6, 9, 10, 18, 20, 29	**6**	2, 5, 7, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 21, 22, 24, 25, 26, 29	**19**
3			**0**		**0**
4			**0**	3	**1**
5		1, 2, 3, 4, 5, 7, 11, 12, 13, 14, 15, 16, 17, 19, 21, 22, 23, 24, 25, 26, 27, 28, 30	**23**	1, 4, 6, 13, 23, 30	**6**
6		8	**1**	8	**1**
7	No answer/ drawing		**0**	27, 28	**2**

As far as artificial light is concerned, the subjects used the Sea of Light (23/30) and Illumination of the Object mechanism (6/30) to explain orally the way we can see an object. In addition, one student said that we can see an object using the Cooperative Emission mechanism. In the students' drawings, Illumination of the Object (19/30) and Sea of Light (6/30) were the most dominant mechanisms. Also, the Secondary Reception (1/30), the Primary Reception (1/30) and the Cooperative Emission mechanisms (1/30) were used, whilst two students did not draw anything. To sum up, 10 out of 30 students presented consistency in their oral answers and drawings, whereas 18 out of 30 referred to mechanisms in their oral answers different from their drawings.

Table 4. Subjects' interpretative mechanisms in 3-D and 2-D worlds, in both natural and artificial light conditions

	Interpretative Mechanisms	Natural Light		Artificial Light	
		3-D	2-D	3-D	2-D
		Subjects	Subjects	Subjects	Subjects
1		20, 24	3, 4, 20		20
2		4, 6, 7, 9, 10, 17, 26, 29	2, 5, 6, 9, 10, 11, 12, 15, 16, 17, 19, 24, 25, 26, 29	6, 9, 10, 18, 20, 29	2, 5, 7, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 21, 22, 24, 25, 26, 29
3			7		
4			14		3

	Interpretative Mechanisms	Natural Light		Artificial Light	
		3-D	2-D	3-D	2-D
		Subjects	Subjects	Subjects	Subjects
5		1, 2, 3, 5, 11, 12, 13, 14, 15, 16, 18, 19, 21, 22, 23, 25, 27, 28, 30	1, 13, 18, 21, 22, 23, 27, 28, 30	1, 2, 3, 4, 5, 7, 11, 12, 13, 14, 15, 16, 17, 19, 21, 22, 23, 24, 25, 26, 27, 28, 30	1, 4, 6, 13, 23, 30
6		8	8	8	8
7	No answer/ drawing				27, 28

Illumination of the Object and Sea of Light are the dominant mechanisms for both natural and artificial light but their order changes depending on the form of the answer given (oral or drawn). By comparing each subject's personal answers in more detail, we can observe that:

- 8 out of 30 students presented stability in their answers about vision in natural and artificial light.
- 22 out of 30 students presented instability in their answers about vision in natural and artificial light.

Discussion

The findings of our research enable us to reach some conclusions that concern the teaching and understanding of the mechanism of vision. According to these findings, Greek sixth grade students appeared to adopt six interpretative mechanisms in order to explain the mechanism of vision, most of which are also seen in the literature (cf., Table 1).

Unlike Selley's (1996) and Dedes' (2005) findings, the Stimulated Emission, Stimulated Emission with Reflection and Secondary Reception-Emission interpretative mechanisms were not mentioned by Greek students. In addition, Selley mentions that the Primary Reception interpretative mechanism refers to natural

light conditions, which is not the case here. What is interesting is that in these findings, there is a new interpretative mechanism prevailing in the children's answers that has not been mentioned in the literature, which we named Illumination of the Object. This new category can offer a supplementary dimension in understanding the difficulties in children's thoughts on the mechanism of vision.

The dominant interpretative mechanisms are the Illumination of the Object and the Sea of Light. The dominance of the Sea of Light is in accordance with international findings which suggest that students consider light to be a general condition (e.g. general illumination of a certain area; Driver, Squires, Rushworth, & Wood-Robinson, 1994). The Sea of Light was most dominant in the oral answers of the students, whereas Illumination of the Object was dominant in the children's drawings. This could be due to the fact that Illumination of the Object involves a directivity, which is more easily drawn and expressed using arrows and links, and thus it is easily employed in the written form of expression. On the other hand, the Sea of Light is a general condition of illumination and involves no directivity, a feature that is harder to present on paper. Moreover, Greek students do not attribute an energetic role to the eye, at least not to the extent of their fellow students in other countries (Hosson & Kaminski, 2002; Selley, 1996). This finding is important as its utilization could affect the teaching of optics. Thus, the necessity of supplementary research that would include participants of a wider age range arises.

As far as the stability of the children's conceptions is concerned, consistency was observed in the natural light conditions answers, both in the oral form and in drawings, whereas the majority of the drawn answers were inconsistent in the artificial light conditions. What is interesting is the fact that for the inconsistent answers – oral or drawings – the interpretative mechanism that is mentioned in the drawings is more evolved compared to the one described orally for the 3-D world. This may be due to the fact that a strong interpretative mechanism would appear in both expression forms whereas a weaker one would not persist through different forms of expression. In addition, the oral form demands that the child imagines and explains his/her thoughts through words, whereas in drawings, the situation is given in a picture and the student depicts his/her answer using arrows, lines and writing. It is a more concrete and direct way of expression and this may be the reason why in that case more evolved interpretative mechanisms are mentioned.

Last but not least, the findings revealed that a minority of the students preserved the same ideas about vision in both natural and artificial light conditions.

In this research we focused on investigating the interpretative mechanism that sixth-graders use about vision. Fifth and seventh graders should be added to the sample of a future study, and a greater number of participants should be

engaged in order to examine the possible evolution of children's thinking in this age range. Further research should also aim to explore which of these interpretative mechanisms may in fact constitute an obstacle to the educational process and subsequently to the evolution of children's thought. Finally, it would also be very interesting to study the possible changes that specially designed teaching interventions, based on the interpretative mechanisms that have emerged from this study, would promote in students' mental representations about the mechanism of vision.

References

Anderson, C. & Smith, E. (1982). *Student conceptions of light, colour and seeing.* Paper presented at the annual convention of the National Association for Research in Science Teaching, Fontana, Wisconsin.

Dedes, C. (2005). The mechanism of vision: Conceptual similarities between historical models and children's representations. *Science & Education, 14,* 699–712.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science research into children's ideas*. London & New York: Routledge.

Hewitt, P.G. (2004). *The notions of Science.* Iraklio: University of Crete Publications.

Hosson, (de) C., & Kaminski, W. (2002). Les yeux des enfants sont- ils des "porte-lumière"? *Bulletin de l' Union des Physiciens, 96*(840), 143–160.

Kokologiannaki, V., & Ravanis, K. (2012). Mental Representations of sixth graders in Greece for the mechanism of vision in conditions of day and night. *International Journal of Research in Educational Methodology, 2* (1), 78–82.

Koliopoulos, D., Adúriz-Bravo, A., & Ravanis K. (2011). El "análisis del contenido conceptual" de los currículos y programas de ciencias: una posible herramienta de mediación entre la Didáctica y la Enseñanza de las Ciencias. *Enseñanza de las Ciencias, 29*(3), 315–324.

Ravanis, K. (2000). How do we see objects that reflect light? Experiential mental representations of students of 12–13 years old, about vision. In N. Valanidis (Eds.), *Curriculum of Second Panhellenic Conference on Teaching of Science and Application of new Technologies in Education,* vol. I (pp. 214–221) Lefkosia: Department of Education, University of Cyprus).

Ravanis, K. Koliopoulos, D., & Boilevin, J.-M. (2008). Construction of a precursor model for the concept of rolling friction in the thought of preschool age children: A socio-cognitive teaching intervention. *Research in Science Education*, *38*(4), 421–434.

Ravanis, K., Zacharos, K., & Vellopoulou, A. (2010). The formation of shadows: The case of the position of a light source in relevance to the shadow. *Acta Didactica Napocensia, 3*(3), 1–6.

Selley, N.J. (1996). Children's ideas on light and vision. *International Journal of Science Education, 18*(6), 713–723.

Weil-Barais, A. (2001). Constructivist approaches and the teaching of science. *Prospects, 3*(2), 187–196.

Web Source 1: http://www.acclaimimages.com, retrieved on 05/11/2010.

Web Source 2: http://www.clipartsfree.net, retrieved on 05/11/2010.