JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

MENTAL REPRESENTATIONS OF LIGHT PROPAGATION TIME FOR 10- AND 14-YEAR-OLD STUDENTS: DIDACTICAL PERSPECTIVES

Konstantinos Ravanis

Abstract. *Student's mental representations of physical concepts are often different from those of scientists. The research aimed to identify and compare mental representations of light propagation time by school children aged 10 (132 subjects), and 14 (109 subjects) years old. This research was conducted through individual interviews in which the students were asked to locate light propagation time in various tasks-experimental situations. The results of this research show that even though the students of two groups face difficulties in understanding light propagation time, as they grow older, they make statistically significant progress in constructing the conception of light propagation time. These findings allow to seek out educational perspectives on the understanding of the conception of light propagation time in organised scholastic environments.*

Keywords: *cross-sectional research, light propagation time, science education, students' representations.*

Konstantinos Ravanis
University of Patras, Greece

Introduction

The issue of the understanding of time is a significant field of study for developmental psychological and epistemological research during the past hundred years. Issues such as the understanding of temporal conceptions and of the symbols-words which describe them, such as the associations "past-present-future", "before and after", "while, now, and soon", duration, age, time perception, logical abilities, namely various aspects of physical, biological and historical time, were the subjects of systematic theoretical pursuits and research (e. g., Fraisse, 1963; Friedman, 1977, 1986; Levin, 1992; Montangero, 1984; Piaget, 1969; Richie & Bickhard, 1988; Samartzi, 2011). A problem examined within the framework of this subject matter is the understanding of two basic dimensions of time, duration, and sequence (e. g. Fraisse, 1984; Montangero, 1985a; Piaget, 1969, 1966; Richie & Bickhard, 1988; Samartzi, 2008). The present study seeks to explore the issue of students' mental representations about the propagation time of the natural entity of light through tasks based on event duration and sequence.

Theoretical Framework

The study of students' mental representations is possibly the most essential field of research within Science Education. In this framework, instead of the term "mental representations", terms such as "ideas", "misconceptions" or "alternative conceptions" are mainly used. However, concepts such as "time" are included into a cognitive system with concrete structures, "processing and mapping" procedures. In that kind of systems, the term of "mental representations" is considered more suitable since it approaches not only entity but the structural as well as the functional interrelations of a wider system (Hubbard, 2007).

We are nowadays well aware that the naïve mental representations of students engender difficulties regarding the understanding of sciences such as Physics, Chemistry, Biology, or Astronomy (Borgerding & Raven, 2018; Ouasri, 2017), which we are attempting to overcome with specialized teaching interventions (Delegkos & Koliopoulos, 2018; Kalogiannakis & Violintzi, 2012; Unal, 2008).

https://doi.org/10.33225/jbse/19.18.276

There has been successive research regarding the concepts and phenomena of Geometrical Optics within this framework. In some of these studies mental representations and obstacles for the understanding of light as an autonomous entity (Guesne, 1985; Osborne, Black, Meadows, & Smith, 1993; Ravanis & Boilevin, 2009), of light propagation (Saxena, 1991; Métioui & Trudel, 2012), of shadow formation (Delserieys, Impedovo, Fragkiadaki, & Kampeza, 2017; Ravanis, Zacharos, & Vellopoulou, 2010), of vision (Selley, 1996; Dedes, 2005), of image formation, and of reflection and diffraction (Kaewkhong, Mazzolini, Emarat, & Arayathanitkul, 2010; Kaltakci-Gurel1, Eryilmaz, & McDermott, 2017) have been recorded and classified. Other studies utilized teaching interventions in order to transform naïve mental representations and construct others that are compatible with scientific models. Examples of these studies are the ones regarding light as entity (Ntalakoura & Ravanis, 2014), shadow formation (Herakleioti & Pantidos, 2016), light propagation (Ravanis & Papamichaël, 1995), as well as reflection and refraction (Aydin, 2012; Singh & Butler, 1990).

A noticeably small amount of studies had the understanding of light propagation time as its subject. The propagation time of a natural entity derives from a relationship defined by speed and distance travelled, while it is constituted simultaneously as logico-mathematical and physical knowledge (Métioui & Baulu MacWillie, 2013). Regarding light specifically, experience does not offer any duration data, while light propagation appears to be instantaneous, taking into account the greatness of its propagation speed in relation to distance as encountered and perceived in daily life.

Stead and Osborne (1980) associated issues of light propagation with the light source's power, since they observed that 7-10-year-old children attribute phenomena of greater intensity to the light source when its power is elevated. Guesne (1984, 1985) found that the majority of 13- to 14-year-old children recognize light propagation time, albeit solely in the case of large distances. Another research has shown that 10-year-old children's perception of light propagation as instantaneous derives from the brevity of the distance between the light source and the receiver, or from the stronger power of the light source (Ravanis, 1991). Another current in research scholarship, albeit with a different direction than ours, is concerned with the understanding of relativistic time in the framework of Classical Physics and the Special Theory of Relativity (Otero, Arlego & Prodanoff, 2016; Otero & Arlego, 2018; Villani & Pacca, 1987).

Since experience does not provide any data concerning light propagation time, the understanding of this phenomenon requires exclusively logical processes which are difficult to realise by a developing child. Within the framework of Piagetian theory, the conception of light propagation time is approached functionally. For Piaget, the construction of the conception of time is closely interrelated with the concept of space. Space-time co-ordinations lead to the construction of the conception of time during the period of concrete operational thought, which is differentiated from the relevant conception during pre-operational thought regarding the encounter with relations of duration and succession. This occurs because pre-operational thought is not capable of leading to the formulation of reasonings on the simultaneity or successiveness of events and the equivalence or lack thereof of durations. The development of concrete operational thought forms the necessary connections which allow for correct estimations. During pre-operational thought, cognition does not possess reversibility, and therefore time estimates remain connected with the content of the examined problem. Thus, the comparison between durations is not carried out successfully. The accuracy of duration estimates requires the construction of a system of reversible relations, namely, on the one hand, arrangement and matching, and on the other hand equivalences and inequalities, the combination of which renders time independent of phenomena and specific situations. As a result, this fact signifies the transcendence of pre-operational thought (Piaget, 1969).

Similar conclusions were reached by other studies, supporting that pre-operational thought does not allow the subject to correlate all of the parameters (i.e. speed, space, start and end point, duration) that constitute the conception of time (Brown, 1976; Fraisse, 1984; Montangero, 1985b).

In order to estimate the light propagation time between light source and final receiver, it is necessary to be able to mentally process the conception of duration. However, while thought remains pre-operational, children attempt to estimate time based exclusively on external cognitive data and characteristics of the problem they encounter. Therefore, their estimation of light propagation time is naturally independent of the length of traversed trajectories and based i.e. on centrations on the setup of the experiment's objects.

Research Questions

Within this framework, which reflects the internationally limited number of researches on this issue, two research questions were posed:

https://doi.org/10.33225/jbse/19.18.276

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

1. What are 10- and 14-year-old student's mental representations of light propagation time in situations related with distance, the power of the light source, and the setup of objects in space?
2. Are there any differences between the mental representations of 10- and 14-year-old children?

Research Methodology

Design

The research was quantitative in approach and was carried out during the academic year 2017/2018 in public schools of Patras (Greece). The research of the students' mental representations was carried out through structured individual interviews which were approximately 20 minutes long, in the school's sciences laboratory. During these interviews the students were presented with three consecutive tasks, were asked certain questions and then had a discussion with the researcher based on the thoughts they expressed. The replies of the students to the interview questions were coded in order to form relevant categories based on the research questions and allow analysis. Students differing in one (1) key characteristic such as age participated in the study. Thus, a cross-sectional research design (Bethlehem, 1999) along with a comparative-content data analysis technique (Glaser & Strauss, 1967) was used.

Sample

The research sample included 132 students aged 10 years (5 grade) from eleven classes of public primary schools (Group 10: Student 1 – S 132), and 109 students aged 14 years (9 grade) from nine classes of public secondary schools (Group 14: S 133 – S 241), in an urban area of Patras in Greece. The students (about 12 from each class) were sampled among those willing to cooperate and had ensured their parent's agreement. With a purposive sampling (Guarte & Barrios, 2006) it was confirmed that all socio-economic levels (low, middle, and high) and all levels of students' performance (low, middle, and high) were represented equally in the sample.

The students that took part in the research had chosen courses covering the fundamentals of Geometrical Optics in grade 5 (the 10 old years) and in grades 5 and 8 (the 14 old years) but had not attended any organized teaching activity on light propagation time, since this issue was not part of the program at any level of education.

Tasks

Task 1

Through this task it was attempted to ascertain whether children's estimations on light propagation time are transformed when the distance between the light receiver and a stable light source is changed, as well as how this happens. The completion of this task required the facing of certain methodological problems. Stead and Osborne (1980) observed that students believe that the distance in which light is propagated depends on whether it is daytime or nighttime. Thus, when a child stated that the light coming from the lamp would not reach us ("up to our eyes") because it is daytime, we did not press for any explanations. Instead, we asked the child to suppose that it was nighttime and no sunlight existed; therefore, the false perception of daytime or nighttime propagation of light would not constitute an obstacle.

A second difficulty encountered at this stage is the tendency of students to base the propagation of light on the size of the source, namely on the light source's power (Stead & Osborne, 1980). We chose to utilise a rather powerful light source in all three questions in order to avoid an entanglement of this kind. Finally, it is known (Guesne, 1984) that the majority of 13- to 14-year-old students recognise light propagation time, albeit only regarding great distances. For this reason, we placed the light source in three different positions in order to test the existence or lack of consistency in the recognition of light propagation time as a function of distance.

Therefore, a table lamp (220V, 80W) that remained switched off for the duration of the experiment was used. The light source was consecutively placed in three positions, 30cm (Task 1a), 2m (Task 1b), and approximately 10m (Task 1c) away from the student. For each different positioning of the lamp, we asked the student: "If we switch on the lamp, will the light reach our eyes instantly or will it need some more time to do so?".

https://doi.org/10.33225/jbse/19.18.276

Task 2

In the second task, the study explored the effect of a powerful light source such as the sun on children's representations regarding light propagation time in rather great distances. The children were asked to make the following estimation: "Will the sunlight reach our eyes, or the earth, instantly or will it need some more time to do so?".

Task 3

In this task, which consisted of two experimental situations, the study explored whether light propagation is perceived strictly according to light propagation time estimation in issues where there is a sequence of events during light propagation. For these experimental situations a setup comprised of the following materials was used: an improvised light source (non-functional) called "lighthouse"; two human figures (toy soldiers); a cardboard box 16cm tall which we called "mountain"; a paper tape 18cm wide and 55cm long, 42cm of which are blue and 13cm are brown, so that they can represent the sea and the shore respectively. A special setup of the objects for each experimental situation was used. In the first situation (Task 3a) human figures A and B stand on the shore respectively 42cm and 50cm away from the lighthouse (Figure 1). In the second situation (Task 3b) the first human figure (A) is on the shore 42cm away from the lighthouse, while the other human figure (C) is "on a mountain" behind A, 52cm away the lighthouse and at a height of 16 cm (Figure 2). After having explicitly explained the characteristics of the objects and setups found in Task 3a and 3b to each child, we asked: "If the lighthouse starts emitting light, who will see it first? A, B (or C), or both simultaneously? Why? How can you explain your answer?".

Asking these questions, we attempted to examine the problem of light propagation time from the perspective of time period estimation in cases where we have a sequence of events. Piaget (1969) observed that, during a certain course, the recognition of sequence in events is not sufficient so as to conclude that there exists an adequate construction of temporal relations. This occurs because temporal relations are confused with the setup of objects in space, because that setup possibly leads to an intuitive cognitive entanglement. Purely temporal relations begin to be constructed in thought through the coordination of at least two movements with different speed. Therefore, in order to ascertain whether students formulate answers which are dictated by the cognitive constitution of real temporal relations, or if the objects' setup in space affects their reasonings, we utilized Task 3a and 3b. Indeed, it is possible to formulate through Task 3a a seemingly correct answer based on the cognitive adherence to the succession of positions A (first position) and B (second position), and not based on the comprehension of light propagation time. However, in Task 3b it is impossible to formulate a correct answer without systematic reference to the relationship between distance and light propagation time.

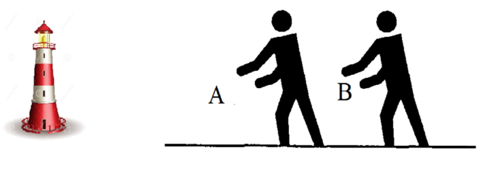

Figure 1. The experimental setup used in Task 3a.

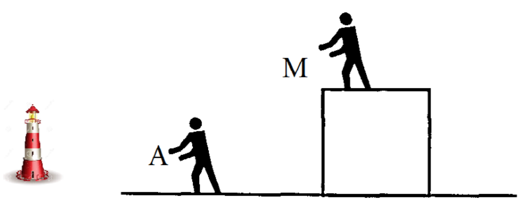

Figure 2. The experimental setup used in Task 3b.

https://doi.org/10.33225/jbse/19.18.276

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Data Analysis

The interviews were carried out by a researcher and were analysed independently by two researchers (the degree of consensus between the two researchers was 96%). A qualitative conversational micro-analysis (Hazel & Bolden, 2013) of the data sets collected during the interview dialogues between the subject and the researcher at both groups was made. Data analysis was based upon the audio recorded dialogues and individual observation protocols. During the interviews, protocols of nonverbal observations were followed by the second researcher. In order for them to be analysed, the dialogues were transcribed and were prepared to be encoded; consequently, they were encoded and organised into categories. Data from the two groups were analysed and treated statistically. In order to compare the answers of the students of the two groups, a goodness-of-fit chi-square test was performed. The participants were labelled "research subjects" and were incidentally represented with a number from 1 to 241.

Research Results

The categories of answers in each task are shown below, including examples of the clarifications offered by the students or of the dialogue that took place between the children and the researcher.

Task 1: "If we switch on the lamp, will light reach our eyes instantly or will it need some more time to do so?"

The students' answers are based on the same mental representations for all three distances (Task 1a-30cm, 1b-2m, 1c-10m), and therefore were classified into three categories:

a) Answers which recognise that light propagation in space requires time. For example, "Some time will pass (1a) … some time will pass again (1b) … again, sometime will pass (1c)" (Subject 53), "… it needs time because it has some distance to cover (1a) … now it needs more time (1b) … and now it needs even more time (1c)" (S. 201).

b) Answers of students who believe that light does not need time for its propagation. For example, "It reaches our eyes immediately (1a) … it reaches us immediately (1b) … some time will pass because of daylight, which does not let it reach us immediately … (if it is nighttime) it will reach us immediately (1c)" (S. 24), "It reaches our eyes immediately (1a) … it will reach us immediately (1b) … it will reach us immediately … it always does… (1c)" (S. 174).

However, a significant number of children provided answers in which they support that regarding the 30cm or/and 2m distances light travels instantly, while it requires time to travel in the case of the 10m distance. For example, "… it will reach us immediately (1a) … some time, not a lot though… because it is a bit farther away, if it is closer no time passes (1b) … a lot of time… it will take a lot of time (1c)" (S. 61), "… it reaches us immediately (1a) … now it takes some time, not a lot … but it needs some time … before … when it was closer it did not need any time at all (1b) … now it will take a lot of time … it is quite far away … (1c)" (S. 153).

Table 1 presents the frequency of the children's answers to the questions regarding the three different distances.

Table 1. Frequency of the children's answers in Task 1 (T1a, T1b, T1c).

Light time propagation between light source and eyes	10-year-olds			14-year-olds		
	T1a	T1b	T1c	T1a	T1b	T1c
A. Light needs time	25	72	91	39	81	99
B. Light does not need time	107	60	41	70	28	10
Total	132	132	132	109	109	109

As can be seen in Table 1, students' reasonings found in both teams exhibit that when the light source's distance from the receiver is increased, then the propagation of light requires time. To be sure, while among the team

https://doi.org/10.33225/jbse/19.18.276

of 10-year-old children only 18.9% of subjects recognise the propagation time regarding the 20cm distance (Task 1a), the relevant percentage is 35.8% among the team of 14-year-old children. Regarding the longest distance, namely 10m (Task 1c), the respective percentages were 68.9% and 90.8%. Comparing the children's answers, we observe that the differences encountered were statistically significant for all three Tasks (Task 1a: χ^2=8.68, df=1, p< .007, Task 1b: χ^2=10.06, df=1, p< .005, Task 1c: χ^2=25.41, df=1, p< .0001).

Task 2: "Will the sunlight reach our eyes, or earth, instantly or will it need some more time to do so?"

In the second task, the children's answers were classified into four categories:

a) Answers which recognise that light propagation requires time. For example, "Some time passes because the sun is farther away from the Earth … so … until sunlight arrives…" (S. 78), "It takes some time… the sun is too far away… Light takes some time to reach the Earth…." (S. 165).
b) Answers in which light propagation is considered to be instantaneous. For example, "It does not take time… we see it immediately… (S. 12), "… (Sunlight reaches us) instantly… as soon as the sun rises… it does not take any more time… I think it reaches us immediately… (S. 233).
c) Answers in which light propagation is considered to be instantaneous due to the great power of its light source. For example, "No, it (sunlight) reaches our eyes instantly because it comes to us in a straight line… if the sun is… since it is so high up… it reaches us instantly because there is plenty of light…" (S. 106), "Sunlight reaches our eyes instantly because… because the sunlight is very strong and thousands of degrees of heat…" (S. 176).

Table 2 presents the frequency of the children's answers.

Table 2. Frequency of the children's answers in Task 2.

Sunlight time propagation	10-year-olds	14-year-olds
	T2	T2
A. It requires time	66	71
B. It does not require time	46	28
C. It does not require time because of its power	20	10
Total	132	109

Table 2 shows hat the light source's power has an effect on children's thought. In this case, the percentages of students who recognise the time needed for light propagation are 50% for the 10-year-old student group and 65.1% for the 14-year-old student group. This effect becomes apparent through special mention of answer category C, where the answers in which the power of the sun is used as to argue for the instantaneous propagation of light is 15.2% and 9.2% respectively. In the case of Task 2 the differences encountered in the answers of students of both teams are not statistically significant (Task 2: χ^2=5.72, df=2, p> .05).

Task 3: "Who will see the light coming from the lighthouse first?"

In both setups (Task 3a, 3b) children's mental representations are frequently affected by the arrangement of objects in space.

In Task 3a, the children's answers were classified into the following categories:

a) Answers in which it is clearly stated that the first one to see the light is the receiver closest to the light source due to reasons associated with light propagation time. For example, "… the first one will see it… because the light comes quickly and comes to the first person, and it takes longer to come to the one in the back…" (S. 54), "… A will see it first… because light reaches the first one more quickly, while it will reach B, who is behind A, later" (S. 151).
b) Answers of students who recognise that the first one to see the light is the receiver closest to the light source but are unable to provide an explanation. For example, "The one in the front will see the light

https://doi.org/10.33225/jbse/19.18.276

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

first, and then B, who is farther back… (Researcher: 'And why will A see first?')… The one in the front will see the light first…" (S. 122), "A will see the light first because he is closer. B will see it… because… because the lighthouse is farther away… (Researcher: 'And what happens with the light since B is so far away?')… It will… It will be more difficult for B to see since he is farther away… Anyway, not so fast as A" (S. 149).

c) We classify in the third category answers in which it is estimated that the receivers will see the light simultaneously, independently of their distance from the light source. For example, "Both at the same time" (S. 64), "Both will see it together… they are on the same level and can see the lighthouse together" (S. 226).

d) A small number of students express the idea that light will reach the person farther away from the light source first. For example, "… B… the one farther back (Researcher: 'Why? What are you thinking about it?')… I am thinking that he can probably see easier from where he is…" (S. 67), "… the one farther back can see the lighthouse better… he has a better view of the sea. (Researcher: 'What is of interest, though, is who sees first - not who sees better…')… B… can see the lighthouse first" (S. 211).

In Task 3b the following categories of answers were recorded.

a) Answers in which it is recognised that the first one to see the light is the receiver closest to the light source. For example, "A… because the one who is high up seems to be too far away" (S. 52), "A. He is much closer to C and the light will reach him much quicker" (S. 186).

b) Answers in which students recognised that the first one to see the light will be the receiver closest to the light source but are unable to provide an explanation. For example, "The one below… because he is… because the other one is higher up (C) he cannot come down… A was below…" (S. 130), "A, who is below… and then C will see, who is higher up. (Researcher: 'Why does this happen?')… Because… they are probably in the same straight line with the lighthouse… while the other one is higher up… I am sure A will see…" (S. 194).

c) Answers in which it is estimated that the receivers will see the light simultaneously, independently of their position in regard to the light source. For example, "Both will see at the same time… as the light reaches them, they see the same" (S. 33), "I think both at the same time… they can see the lighthouse equally well" (S. 239).

d) Answers of students in which it is predicted that the first one to see the light is C. For example, "Him, because he is higher up… the higher up he is, the more he sees… because he his higher up than here, and he is elevated" (S. 87), "He will see it first (C) because he is higher up… the higher up he is, the better he sees…" (S. 229).

Table 3 presents the frequency of the children's answers given for Task 3a and 3b.

Table 3. Frequency of the children's answers in Task 3 (T3a and T3b).

Light time propagation serial receivers	10-year-olds		14-year-olds	
	T3a	T3b	T3a	T3b
The closest to the light source	44	5	44	15
The closest to the source (without explanation)	1	5	17	12
They will see both together	82	59	46	47
The most distant from the light source	5	63	2	35
Total	132	132	109	109

As can be seen in Table 3, Task 3 exhibits that the answers of students of both teams are based on the same mental representations recorded in the two previous Tasks. Thus, 33.3% of students belonging to Group 10 and 40.4% of students belonging to Group 14 appear to formulate a correct spatial-temporal reasoning. Furthermore, 62.1% (Group 10) and 42.2% (Group 14) of students do not comprehend light propagation time. The difference between these two groups was statistically significant (Task 3a: χ^2=23.62, df=3, p< .0001).

https://doi.org/10.33225/jbse/19.18.276

However, in Task 3b it has been ascertained that a different setup of objects leads students' thought in centrations which do not facilitate correct estimations of light propagation time; only 3.8% (Group 10) and 13.8% (Group 14) of students, connect time and distance. Nevertheless, the differences between the two groups remains statistically significant (Task 3b: χ^2=15.29, df=3, p< .0007).

Discussion

The aim of this research was to explore and compare 10- and 14-year-old students' mental representations of light propagation time.

Firstly, as indicated in the first task's results, the estimations of a large number of children in both groups regarding light propagation time are affected by the distance between light source and receiver. To be sure, there is a difference between the two groups, one that is also statistically significant; however, the fact that a large number of children does not regard time as necessary for the propagation of light through space signifies the presence of a powerful intuitive thought pattern. This result is compatible with the findings of earlier research, which either collects qualitative data through simple conversations with the children (Guesne, 1984, 1985), or limits the samples to younger ages (Osborne, Black, Meadows, & Smith, 1993; Ravanis, 1991).

The intuitive nature of the students' estimations in both groups appears to be validated in the second task as well. In this case, the distance between the sun and the Earth is enormous, and it is therefore reasonable to expect that the great majority of children would sustain a reasoning which correlates time and distance. Nevertheless, we observed that the sun's power helps children form another intuitive reasoning, based on which sunlight moves instantly. This is clearly stated by a number of students, but it appears that focus on the sun's power does factor in the thought of those children which believe in instantaneous propagation as well. What is more, in the second task there was not a statistically significant difference found between the two groups' answers. Stead and Osborne (1980) had also similar findings in their earlier research.

The findings of the third task shared the same orientation. In this case, it appears that, when light propagation occurs towards a direction along which objects are linearly situated in space (Task 3a), children utilize the sequence in which light meets the objects in order to formulate spatial-temporal reasonings. However, these reasonings are not based on "distance-time" criteria, but on the intuitive criterion of sequence. Therefore, when objects are no longer linearly situated in space (Task 2), an empirical, day-to-day image is formed in children's thought: according to this image, when one is positioned on a higher level, one sees better. Thus, intuitive and pre-logical representational thinking generates an equivalence between "better" and "faster". In the third task, the difference between the answers of students in both groups is statistically significant, while intuitive thought patterns are dominant in the thought of the older children.

However, it is worth noting that a small number of students in all three tasks present adequate explanations concerning light propagation time, systematically connecting distance and space. As exhibited by the research's findings, this number of students is larger in the 14-year-old group, while the difference between the two groups is statistically significant in 2 out of the 3 tasks. Nevertheless, given that such a close adherence to the problems' perceptual data is not expected of 14-year-old children, it appears that this difference exists in a distinct relationship with light itself which, naturally, is not a typical moving object. So it seems that when the mental representations have not only a physical content but also a strong logic-mathematical basis, the expected evolution is slower and more difficult and therefore a complex and multi-dimensional teaching intervention is necessary.

Conclusions

In this research students' mental representations regarding light propagation time, an issue which is part of propagated natural entities' properties in space, such as heat, sound, or energy were approached. Given the fact that developing children's thought encounters known difficulties in organizing sufficiently the relationships between speed, time and space for a moving object, this issue is also characterized by another peculiarity. Namely, the difficulty encountered in the motion of an invisible entity, our inability to adjust its movement speed but also our inability to record its propagation time in conventional, every-day distances or within the framework of a school laboratory setting. Thus, representations of light propagation time are effectively clear cognitive entities lacking an empirical content and the possibility of an experimental approach.

This constitutes a significant difficulty, especially regarding younger children's thought, since the cognitive

https://doi.org/10.33225/jbse/19.18.276

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

tools potentially able to facilitate reasonings based on the relationship between space and light propagation time remain intuitive and pre-logical. Therefore, it is possible that their estimations regarding durations and sequences are not based on logical relationships but are based on the external characteristics of situations and problems that they encounter. What is more, this applies specifically up to 14-years-old, an age in which the construction of logical thought patterns would be expected.

This issue is closely connected to the understanding of the conception of "light". Light propagation time constitutes one of its fundamental qualities and is certainly a manner of approaching light as an autonomous entity existing in space independently of light sources and potential receivers. Truly, in the relevant research within the framework of Science Education there exists a one-sided emphasis on light propagation in space, while the issue of propagation time is not discussed. This applies possibly due to the complexity of the phenomenon, as well as due to an implicit certainty that light propagation time constitutes a research subject for other cognitive fields such as Psychology. Nevertheless, the understanding of any conception presupposes an approach from all possible aspects; therefore, it would certainly be meaningful to incorporate the construction of the "light propagation time" conception in children's thought, within the framework of Geometrical Optics. Besides, as long as the study Relativistic Physics is introduced in programs, the issue of light propagation time effectively becomes a central problem; to be sure, time as a conception within this framework acquires a different conceptual content.

Competing Interests

Konstantinos Ravanis is a member of editorial board of *Journal of Baltic Science Education*, but he has not reviewed, neither edited this article.

References

Aydin, S. (2012). Remediation of misconceptions about geometric optics using conceptual change texts. *Journal of Education Research and Behavioral Sciences, 1* (1), 1-12.

Bethlehem, J. (1999). Cross-sectional Research. In H. J. Adèr & G. J. Mellenbergh (Eds.), *Research methodology in the life, behavioural and social sciences* (pp. 110-142). London, UK: Sage.

Borgerding, L. A., & Raven, S. (2018). Children's ideas about fossils and foundational concepts related to fossils. *Science Education, 102*, 414-439.

Brown A. L (1976). The construction of temporal succession by preoperational children. In A. D. Pick (Ed.), *Minnesota symposia on child psychology* (vol. 10, pp. 28-83). Minneapolis, USA: University of Minnesota Press.

Dedes, C. (2005). The mechanism of vision: Conceptual similarities between historical models and children's representations. *Science & Education, 14* (7-8), 699-712.

Delegkos, N., & Koliopoulos, D. (2018). Constructing the "energy" concept and its social use by students of primary education in Greece. *Research in Science Education.* doi: 10.1007/s11165-018-9694-y.

Delserieys, A., Impedovo, M.-A., Fragkiadaki, G., & Kampeza, M. (2017). Using drawings to explore preschool children's ideas about shadow formation. *Review of Science, Mathematics and ICT Education, 11* (1), 55-69.

Fraisse, P. (1963). *The Psychology of Time*. New York, USA: Harper & Row.

Fraisse, P. (1984). Perception and estimation of time. *Annual Review of Psychology*, *35*, 1-36.

Friedman W. J. (1977). The development of children's knowledge of cyclic aspects of time. *Child Development, 48*, 1593-1599.

Friedman W. J. (1986). The development of children's knowledge of temporal structure. *Child Development, 57*, 1386-1400.

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York, USA: Aldine.

Guarte, J. M., & Barrios, E. B. (2006). Estimation under purposive sampling. *Communications in Statistics - Simulation and Computation, 35* (2), 277-284

Guesne, E. (1984). Children's ideas about light. In E. J. Wenham (Ed.), *New trends in Physics teaching* (vol. IV, pp. 179-192). Paris, France: UNESCO.

Guesne, E. (1985). Light. In R. Driver, E. Guesne & A. Tiberghien (Eds.), *Children's ideas in Science* (pp. 10-32). Philadelphia, USA: Open University Press.

Hazel, A., & Bolden, G. (2013). The conversation analytic approach to transcription. In J. Sidnell & T. Stivers, *The handbook of conversation analysis* (pp. 56-76). Malden, USA: Wiley-Blackwell.

Herakleioti, E., & Pantidos, P. (2016). The contribution of the human body in young children's explanations about shadow formation. *Research in Science Education, 46* (1), 21-42.

Hubbard, T. L. (2007). What is Mental Representation? And how does it relate to consciousness? *Journal of Consciousness Studies*, *14*(1-2), 37-61.

Kaewkhong, K., Mazzolini, A., Emarat, N., & Arayathanitkul, K. (2010). Thai high-school students' misconceptions about and models of light refraction through a planar surface. *Physics Education, 45* (1), 97-107.

Kalogiannakis, M., & Violintzi, A. (2012). Intervention strategies for changing pre-school children's understandings about volcanoes. *Journal of Emergent Science, 4* (2012), 12-19.

https://doi.org/10.33225/jbse/19.18.276

Kaltakci-Gurel1, D., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *Research in Science & Technological Education, 35* (2), 238-260
Levin, I. (1992). The development of the concept of time in children: An integrative model. In F. Macar, V. Pouthas, & W. J. Friedman (Eds.), *Time, action, and cognition: Toward bridging the gap* (pp. 13-32). Dordrecht, The Netherlands: Kluwer.
Métioui, A., & Trudel, L. (2012). The model of the rectilinear propagation of light and the study of the variation of the size of a shadow. *US-China Education Review, 2* (9), 173-186.
Métioui, A., & Baulu MacWillie, M. (2013). Children's beliefs about the concepts of distance, time and speed. *International Journal of Education, Learning and Development, 1* (2), 24-38.
Montangero, J. (1984). Perspectives actuelles sur la psychogenèse du temps [Current perspectives on the psychogenesis of time]. *Année Psychologique, 84*, 433-460.
Montangero, J. (1985a). The development of temporal inferences and meanings in 5 to 8 years old children. In J. A. Michon & J. L. Jackson (Eds.), *Time, mind and behavior* (pp. 279-287). Berlin, Germany: Springer Verlag.
Montangero, J. (1985b). Current perspectives on the development of the concept of time. In T. S. Evans (Ed.), *Genetic Epistemology: Yesterday and today* (pp. 63-91). New York, USA: The Graduate School and University Center City University of New York.
Ntalakoura, V., & Ravanis, K. (2014). Changing preschool children's representations of light: A scratch- based teaching approach. *Journal of Baltic Science Education, 13* (2), 191-200.
Osborne, J., Black, P., Meadows, J., & Smith, M. (1993). Young children's ideas about light and their development. *International Journal of Science Education, 15* (1), 83-93.
Otero, M. R., Arlego, M., & Prodanoff, F. (2016). Teaching the basic concepts of the Special Relativity in the secondary school in the framework of the Theory of Conceptual Fields of Vergnaud. *Il Nuovo Cimento, 38C* (108), 1-13.
Otero, M. R., & Arlego, M. (2018). Relativity of simultaneity in secondary school: An analysis based on the theory of the conceptual fields. *Review of Science, Mathematics and ICT Education, 12 (1), 61-83.*
Ouasri, A. (2017). Study of Moroccan pupils' difficulties at second Baccalaureat year in solving chemistry problems relating to reactivity of ethanoate ions and to Copper-Aluminium cell. *Chemistry Education Research and Practice, 18*, 737-748.
Piaget, J. (1966). Problèmes du temps et de la fonction [Problems of time and function]. In J. Piaget et coll. (Eds.), *L'épistémologie du temps* [The epistemology of time] (vol. 20, pp. 2-66). Paris: Presses Universitaires de France.
Piaget, J. (1969). *The child's conception of time*. London, UK: Routledge & Kegan Paul.
Ravanis, K. (1991). Mental representations of students of the fifth grade on the concept of light propagation time. *Physics Review, 7* (20), 17-21.
Ravanis, K., & Papamichaël, Y. (1995). Procédures didactiques de déstabilisation du système de représentation spontanée des élèves pour la propagation de la lumière [Didactic destabilization procedures of the system of pupils' spontaneous representation for the propagation of light]. *Didaskalia, 7*, 43-61.
Ravanis, K., & Boilevin, J. M. (2009). A comparative approach to the representation of light for five- eight- and ten-year-old children: Educational perspectives. *Journal of Baltic Science Education, 8* (3), 182-190.
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.
Richie, D. M., & Bickhard, M. H. (1988). The ability to perceive duration: Its relation to the development of the logical concept of time. *Developmental Psychology, 24*, 318-323.
Samartzi, S. (2008). Étude développementale des notions de durée et d'âge: temps physique et temps biologique [Study of duration and age concepts' development: Physical time and biological time]. *Bulletin de Psychologie, 61* (6), 498, 551-560.
Samartzi, S. (2011). Children's cognitive development of lived-experienced time and physical time. *Studia Psychologica, 53* (3), 307-311.
Saxena, A. B. (1991). The understanding of the properties of light by students in India. *International Journal of Science Education, 13* (3), 283-289.
Selley, N. J. (1996). Children's ideas on light and vision. *International Journal of Science Education, 18* (6), 713-723.
Singh, A., & Butler, P. H. (1990). Refraction: Conceptions and knowledge structure. *International Journal of Science Education, 12* (4), 429-442.
Stead, B., & Osborne, R. (1980). Exploring students' concepts of light. *Australian Science Teacher Journal, 26* (3), 84-90.
Unal, S. (2008). Changing students' misconceptions of floating and sinking using hands-on activities. *Journal of Baltic Science Education, 7* (3), 134-146.
Villani, A., & Pacca, J. (1987). Student's spontaneous ideas about the velocity of light. *International Journal of Science Education, 9*, 55-66.

Received: *October 21, 2018*

Accepted: *March 26, 2019*

Konstantinos Ravanis	Ph.D. in Science Education, Professor in Science Education at the Department of Educational Sciences and Early Childhood Education, University of Patras, Rion-Patras, 265 04 Greece. E-mail: ravanis@upatras.gr Website: http://www.ecedu.upatras.gr/ravanis

https://doi.org/10.33225/jbse/19.18.276