



## Teaching Optics: Light sources and Shadows

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### ABSTRACT

The study of students' representations of physics concepts and phenomena constitutes a central part of Physics Education research, as they play a critical role in teaching. In the study presented here, we investigate 120 ninth grade students' mental representations of the formation of shadows. The empirical data was gathered through an interview using four tasks which involved the evaluation of hypothetical situations. The research data included representations that cause difficulty in the comprehension of the position of a light source in relevance to the shadow.

### Indexing terms/Keywords

Light sources, shadows, mental representations



# Council for Innovative Research

Peer Review Research Publishing System

Journal of Advances in Physics

Vol 2, No.2

[editor@cirworld.com](mailto:editor@cirworld.com)

[www.cirworld.com](http://www.cirworld.com), [member.cirworld.com](http://member.cirworld.com)



## INTRODUCTION

The study of representations of students of all ages and school levels within the context of Physics Education points to the need for the creation of special teaching interventions in a wide spectrum of subjects in the teaching of Physics (Gilbert & Watts, 1983; Ravanis & Papamichaël, 1995; Tsatasaroni, Ravanis & Falaga, 2003; Kampeza, 2006; Ravanis, Koliopoulos & Boilevin, 2008; Tiberghien, 2008; Robbins, 2009; Otero & Fanaro, 2011). These representations, which are often in contradiction to the explanations given by Physics in regard to these phenomena, are referred to in literature as ideas, misconceptions, preconceptions or alternative conceptions. The problem of the formation of shadows is critical in the learning and teaching of Optics because the development of a qualitative description of shadow creation needs a synthesis of knowledge including light as an entity produced by a light source and propagated in space, blocked by an opaque object (Ravanis, Zacharos & Vellopoulou, 2010). In this article we will study the mental representations of 15-year-old children about the formation of shadows by point light sources and an object in the shape of a stick.

The children's explanations of the natural phenomena are neither arbitrary nor casual estimations; they result from a series of intellectual achievements of a psychological nature, which we must become aware of in order to predict and interpret correctly the alternative conceptions and also for reasons concerning teaching methods. Data taken from relevant research agree that 5- to 16-year-old children face the problem of the shaping of shadows by a pre-operational way of thinking. Some of the earliest interpretations of children's representations about shadows can be found in Piaget's research and theoretical work (Piaget, 1930; Piaget & Inhelder, 1967). "The Piagetian research approach identified four different stages or levels of concept development for children aged five and over. The four stages of physical explanations of shadows are as follows: "The shadow of an object is regarded as emanating from both internal (the shadow emanates from the object) and external sources; the shadow emanates from the object; the shadow emanates from the object but the emanation drives away the light; and the formation of shadows is due to the light being blocked by the objects" (Chen, 2009). Other researchers have found that shadows as reflections of objects, the prediction of the shape of a shadow, the explanation of how the shadow was formed, the relation of the light source(s) to the shadow and the size or the orientation of the corresponding shadows can pose problems in understanding and learning (Tiberghien et al., 1980; Guesne, 1985; Feher & Rice, 1988; Ravanis, 1996; Parker, 2006; Resta-Schweizer & Weil-Barais, 2007; Dedes & Ravanis, 2009a, 2009b; Chen, 2009; Gallegos Cázares et al., 2009; Ravanis et al., 2013).

In the current research we attempt to study the mental representations of students 15 years old. Our hypothesis is that, in the event that the shadow and the object making it are visible, a significant number of students make evaluations regarding the position of the light source which are influenced by conceptual centrations, and are not based on the model of Geometrical Optics.

## METHODOLOGY

### The sample

The sample consisted of 120 subjects (58 boys and 62 girls), aged 15 years and 2 months (S.D. 2,5 months), from 6 different school classes. All socio-economic levels (low, middle, high) and all levels of students' performance (low, middle, high) were represented equivalently in the sample.

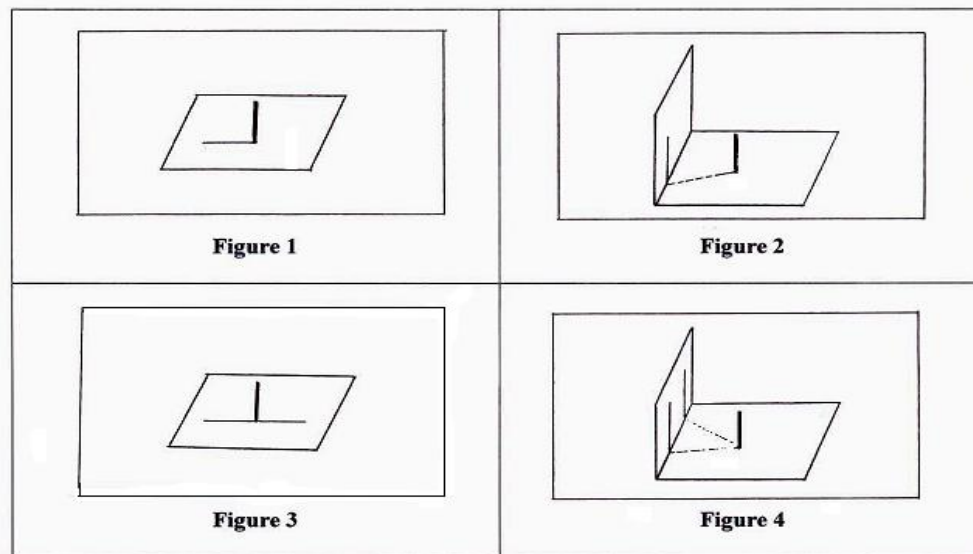
### The research procedure and the tasks

The technique we used in our research was the directive individual interview. Each interview lasted approximately 15 minutes and was held in the schools' laboratories. In this research we partially adopted the protocol proposed by the research of Ravanis, Zacharos and Vellopoulou (2010) having requested and got the permission of the authors

We presented successively to the children four figures in which one can observe a shadow on a horizontal plane (Figure 1), a shadow on a vertical plane (Figure 2), two shadows on a horizontal plane (Figure 3) and two shadows on a vertical plane (Figure 4). All the shadows are formed by a torch and a baton made of cardboard, 12cm in height, which is visible in all figures and is placed as an obstacle between the torch and the plane. In each case we ask the children to show us the place from which the torch is lighted, i.e., the position and the number of the light sources. In all these tasks we posed an initial question and then, based on each subject's answer, a dialogue ensued which was completed when we had a clear picture of each child's representation.

The creation of these four tasks serves two purposes. The distinction between the horizontal and the vertical plane is made because the shaping of the shadow on the two planes requires projective coordinates of a different kind. Being able to change the topological relations into projective ones constructs a representation which has to correspond to this change (possibility), regardless of the kind of projection, since it is formed during the stage of concrete operations.

The first distinction aims to locate the functional use of the projective activity of the child's thought process in regard to the formation of shadows, in order for us to draw conclusions regarding the integration and stability of the conception. The second distinction, i.e., the repetition of the questions about figures with two shadows, aims at the same purpose mentioned above. We can locate a factor which might lead to the revelation of difficulties of a functional nature, since our task does not allow any other possibility but the corresponding light sources and shadows, one-to-one; this factor is the number of shadows and consequently the number of light sources.



Figures. The four tasks

If the mechanism forming the shadow is recognized, an estimation of the exact position of the light source is possible and the student will have no difficulty in discerning the number of light sources, since the number of shadows has already been discerned.

## RESULTS

For the first two tasks (Task 1 & 2), during which the children are asked to comment on the figures showing one shadow, the answers given by the children can be classified into two categories (Table 1):

1. Answers showing that the student correctly locates the position of the light source in relevance to the obstacle and the shadow. For example: “The lamp will be here ..... in line with the baton..... and the shadow” (Student 35, Task 1). “The lamp will be in this position ..... we see two shadows ..... a shadow on the floor and an on the wall because the wall is close to the baton (*shows the path by hand*)” (S. 111, Task 2).
2. Answers showing that the student does not correctly locate the position of the light source. For example: “The lamp will be opposite in spades (shows wrong position)” (S. 76, Task 3). “To produce a shadow on the wall the lamp should be high .....” (S. 24 , Task 2).

Table 1. Results of locating the position of the light sources causing the formation of the shadows in the Tasks 1 & 2

Task	Answer	N	%
1. One shadow horizontal plane	Correct position of the light source	105	87,5
	Incorrect position of the light source	15	12,5
2. One shadow vertical plane	Correct position of the light source	101	84,2
	Incorrect position of the light source	19	15,8

During the next two tasks (Task 3 & 4), the children see figures showing two shadows. In this case the answers given are classified into three categories (Table 2):

1. Answers showing that the child correctly locates the position of the light sources. For example, “There should be two lamps. From here the first shadow..... and from there the other ... (*the student shows the positions correctly*)” (S. 49, Task 3). “Since we have two shadows, we will have two lamps.... (*shows correctly*)” (S. 114, Task 4).
2. Answers showing that the child correctly locates only one of the two light sources. For example, “The light coming from the lamp, pounding on the baton and reflected on both sides .....” (S. 39, Task 3). “The light interacts with the cane and gives two shadows on the wall” (S. 74, Task 4).
3. Answers showing that the student locates wrongly the position of the light source as being between the two light sources. For example, “The lamp should be here in the middle ..... since become two shades should be here .....” (S. 62, Task 3). “If the lamp is in the middle and ..... somewhat low ..... can make two shadows on the wall ....” (S. 76, Task 4).

**Table 2.** Results of locating the position of the light sources causing the formation of the shadows in Tasks 3 & 4

Task	Answer	N	%
3. Two shadows horizontal plane	The light comes from two correct positions	88	73,5
	The light comes from one side-position	2	1,5
	The light comes from a middle position	14	11,5
	No answer	16	13,5
4. Two shadows vertical plane	The light comes from the correct position	82	68,5
	The light comes from one side-position	2	1,5
	The light comes from a middle position	17	14,2
	No answer	19	15,8

## DISCUSSION

Results show that our hypothesis is confirmed. As for the first two tasks which correspond to familiar images, a significant number of the answers are compatible to the model of Geometrical Optics (87,5 % and 84,2 %); however, the percentages of correct answers in the third and fourth task are low taking into account the age of the students (73.5 % and 68,5 %). Because of incomplete construction of reversibility, children of this age can not put shadows and light sources into a one-to-one correspondence. As a result, children face great difficulties in trying to understand the mechanism which causes shadows. This fact influences procedure, since teaching the formation of shadows must not only lead to the understanding of the relation: light source  $\Rightarrow$  obstacle  $\Rightarrow$  shadow, but also to the understanding of the relation shadow  $\Rightarrow$  obstacle  $\Rightarrow$  light source. These results show the strong psychological background of the representations which the children use in the question of the formation of shadows.

Our research is currently directed towards the study of the evolution of spontaneous representations for children ages 5 to 16. In addition our orientations tend to the construction and application of teaching interventions for the initiation of students from kindergarten through high school to the phenomena of geometrical optics.

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