PROSPECTIVE PHYSICS TEACHERS' MENTAL MODELS ABOUT SHADOW

FİZİK ÖĞRETMEN ADAYLARININ GÖLGE KONUSUNDAKİ ZİHİNSEL MODELLERİ

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ABSTRACT:

Students' mistaken views about explaining the behavior of light due to shadow events based on the ray model are often emphasized by many studies in the related literature. There are also some studies showing that even students at university level have similar misconceptions including the prospective physics teachers. Considering these, we firstly find out the mental models of 20 prospective physics teachers regarding the ray model of light by using 4 open-ended questions. Afterwards, the prospective physics teachers were given experimental work sheets using the ray model of the light during a 3 week period followed by the same open-ended questions as post test. The worksheets were examined to observe some changes in mental models of prospective physics teachers. The results show that students' mental models about shadow are mainly depend on the shape of the mask (or object) rather than the direction of the light. Besides, at the end of the instruction the students still had some wrong mental models they had before the instruction.

Key Words: Prospective physics teachers, mental models, ray model, shadow

ÖZET:

Alan yazınında pek çok çalışmada öğrencilerin ışın modeline dayalı gölge olaylarını çizme konusunda hatalı görüşlere sahip olduklarına vurgu yapılmaktadır. Ayrıca bazı çalışmalarda da, aralarında fizik öğretmen adaylarının da bulunduğu üniversite düzeyinde öğrencilerin bile bu türden yanılgılara sahip olduğu ortaya konulmuştur. Bunları göz önünde bulundurarak, öncelikle ışığın ışın modeliyle ilgili olarak 4 açık uçlu soru yardımıyla 20 fizik öğretmen adayının zihinsel modelleri belirlenmiştir. Ardından, 3 haftalık bir sürede fizik öğretmen adaylarına deneysel çalışma yaprakları uygulanmıştır. Uygulama sonunda başlangıçta kullanılan açık uçlu sorular son test olarak uygulanmıştır. Çalışma yaprakları, öğretmen adaylarının zihinsel modellerinde meydana gelen değişimi gözlemlemek üzere incelenmiştir. Sonuçta, öğrencilerin gölge ile ilgili zihinsel modellerini ışığın doğrultusunu gözeterek oluşturmak yerine cismin şekline göre oluşturdukları görülmüştür. Bunun yanında, uygulama sonrasında öğrencilerin başlangıçtaki hatalı zihinsel modellerinden bazılarına hala sahip oldukları belirlenmiştir.

Anahtar Kelimeler: Fizik öğretmen adayları, zihinsel modeller, ışın modeli, gölge

1. INTRODUCTION

The subject of light and shadow is an interesting phenomenon since it is known by the youngsters from their early ages. Light and shadow are essential future of everyday life. Everybody has an informal understanding of them before formal education at school.

Formally, students are introduced firstly the subject of light at grade level of five in primary school science curriculum. The titles of the topics are as follows: "the light sources around, light can not pass through every object, light propagates in the medium of its source it was emitted from, light reflects on bright surfaces, light can be refracted while passing from air to water, we see the light by our eyes, light also pollutes our environment too". These topics only could give basic ideas about light to the students. The next instructional session for light takes place in high school where they are mostly introduced with the examples of darker and lighter shadow and their area calculations.

People construct their own conception of light and shadow. These constructs are the conceptualizations that provide a specific mechanism for how the image is connected to the object.

In order to understand that a concept whether being understood or not by the students, it is a good way to ask students use, explain or formulate that concept in either verbal explanations or mathematical formulations. While students are putting ahead what they understood, they may present what they learn in the classroom with their own knowledge structure enabling how they built the related knowledge [1]. Besides this, Duit and Glynn [2] stated that meaningful learning depends on the evaluation of the students' mental models based on the conceptual models. It is commonly accepted that students built their own mental models as copies of conceptual/analogical models presented them in the courses.

Mental models are the patterns of associations (i.e., rules, images, maps or analogies) used to guide spontaneous reasoning but, student mental models are often incomplete, self- contradictory, and inconsistent with experimental data [3].

Norman [4] claims that ideally there is a simple and linear relation between a conceptual model and a mental model. In this context, the quality of the mental models formed by students is important as a sign of their level of understanding of the concepts.

The power of a model is in its use to predict and this may lead to new understandings and modified or even radically changed models when is stretched so far that it becomes inappropriate. The explanatory models have oscillated between particle and wave models of light. However, as Rutherford [5] stated that, the ray model of light is simple but powerful. It can be used in conjunction with both wave and particle ideas to explain phenomena. Using the particle model, rays are used to show the path of the particle. Euclid, around 300 BC, studied optical phenomena and used a ray model to explain perception, depth of vision and perspective.

According to Goldberg and McDermott [6], in elementary schools, students are specifically taught the misconceptions such as illuminated objects send forth only parallel rays.

Langley and et al. [7], in their experimental study about revising the instructional approach for geometrical optics in the tenth grade, found that students had not developed a consistent model such as, directionality and distribution of light, illumination patterns for nonluminous objects.

Watts [8], in his case study, concluded that practical activities and observations are more effective for challenging students' views than the evidences which are exposed by the teacher. For having some insight into youngsters' conceptions of light, their beliefs should be taken into consideration seriously; actual experiences should be given to the students.

Ronen and Eylon [9] stated that many of the difficulties students had in understanding of geometrical optics were related to their personal experience of

seeing and an incomplete understanding of the formal representations used in this domain. Therefore, the instructional procedure must be considered well.

Galili and Hazan [10] stated that children perceive shadows in much the same way as optical image and also think that shadows can be manipulated as independent objects and can be added or subtracted. Also, shadows remain randomly oriented in space, regardless of any light source. The shadow of the object represents its shape much as its mirror image does and the light merely "makes it visible".

Explorations of pre-service physics students' understanding of light, how it is shaped, what it is and how it works have been studied by many researchers.

2. METHODOLOGY

The study is based on one group pre-test and post-test design [12]. Subjects were 20 prospective physics teachers from Dokuz Eylul University Buca Faculty of Education of 3rd grade who were currently taking "optics" course. The study group was composed of volunteer students who were really enthusiastic about the subject.

As pre-test, 4 open-ended questions required drawing were given physics teachers in order to identify their existing mental models and prior knowledge about the subject. Afterwards, the experimental work sheets prepared according to the science process skills about the occurrence of shadow using the ray model of the light were given to the students during 6 hours in a 3 week period. After students' completing, the worksheets were collected.

The previously given questions were given students at the end of the teaching period as post-test for triangulating and controlling the data collected.

The pre-test, post-test and worksheets are evaluated separately by each researcher to observe and assess the development and change in mental models. The level of agreement between researchers was found to be .82.

The worksheets were inspired by the study of Wosilait [13]. They were prepared according to three levels: elicit, confront and resolve. In elicit part the prior knowledge and related mental models of the students were identified. Real laboratory experiments took place in confront level allowing students fall into conflicts about their prior knowledge. At the final resolve level, students were free to discuss what they had confronted with their friends. Each level required students draw and write what they thought and then observed.

Bendall and et al. [11] found that, most of the student teachers confused about the shadow area when they were given two lambs and asked to define their shadow. Another interesting finding was the inability of student teachers about the filament as a wide light source that emits light only in the direction of the screen.

The similar misconceptions and errors indicated by the studies above were also confronted with the prospective physics teachers in their optics courses making us to conduct this research. The purpose of this research is to determine the mental models of the prospective physics teachers about shadow. The study also examines the mental models of the student teachers before and after the instruction that was based on real laboratory works

The worksheets are based on four main working stations each having an eight step experimenting sets. A typical working station has a light source and a mask (barrier) or an object whose shadow image would be drawn by estimating before experimenting. In each station, either the light source (point like or wide light) or the mask (point like or L or triangle shaped) were changed and the steps were designed accordingly.

The common mis-understandings gathered in elicit level were tabulated by its frequencies and mental models of the students are determined. Each worksheet was evaluated according to a key derived from the related literatüre. Besides, the answers or drawings those are not identified in the key were also determined. All answers were grouped based on the identification labels. The frequencies were given according to the weeks under each identification label. Identification labels

include typical mental models. The identification labels are source, image, ray, mask (barrier), relation of image and source.

3. FINDINGS

The findings of the research include students' pre-test and post-test results and their mental models based on their answers from worksheets.

Firstly, worksheets were examined. Table 1 shows wrong mental models that students have during the instruction. Students generally think that the shape of the shadow (or image) is independent of the shape of the source. Therefore it can be seen that they developed the idea that set or open space gives its shape to image regardless of the shape of the source. Another point is students' thinking of wider light source giving an image in the same shape with the point like source but which is longer and wider than it. It was seen that students who have that kind of mental models used the beams coming from the source in a wrong way while drawing the shadow in the case of the filament light source. Some of these students sent rays just from the top and bottom of the filament.

Also, some of them just sent from one point of filament thinking that filament is not different from a point like source. Also there is a group of students thinking that filament emits parallel beams and its image is same with the point like source. Besides this, there is another group of students who think the filament emits beams from top and bottom and gives two shadows as formed by two point-like sources one on the top of the other. Some of the students, who are confused about shadows of wide and point like sources, were not able to follow the beams emitted form the wide source and reverse the shadow. Another group of students using point like source instead of wide light source think that when the radius of the split is decreased to half, the shadow length is also decreases.

Table 1. *Mental Models and its Frequencies about Source, Image, Ray, Mask, Relation of Image-Source and Distribution of Mathematical Errors, Incomplete and Irrelevant Answers*

Mental Models About Source	Total
Being unable to think that source does not emit light to every direction.	53
Thinking of top and bottom edges of wide light source as point like source.	46
Thinking of wide light source as a point like source.	31
Filament emits only parallel beams.	9
Being unable to distinguish the effect of wide light source from point like light source on the shadow.	8
Despite thinking of wide light source as it is composed of a lot of cut light sources, being unable form a whole shadow.	6
Thinking of a light source's shadow at infinity as in the form of a point like shadow of a mask.	4
Thinking of the filament emitting light as a point like source at the edges and as parallel in the middle.	2
Being unable to form the image according to the shape of the source.	8
Mental Models About Image	
Shadow size is faulty.	24
Being unable to distinguish full shadow from semi shadow.	19
Being unable to comprehend about the effects of changes in the distances among source, mask and screen on the shadows.	18
Thinking of shadows as smaller than the object.	14
Being unable to distinguish the mixture of colors.	7
Thinking the color of the full shadow being same with the color of the light source which it is formed from.	5
Mental Models About Ray	
Being unable to intersect the beam emitted from the source at the right place.	24
Using the thought of sending two beams from one point.	14
Being unable to draw the maximum illuminated area by the source.	3
Mental Models About Mask (Barrier)	
Being unable to think that beams must be limited for having a mask.	4
Beams take a linear path in small sets.	1
Mental Models About Relation of Image-Source	
Small light source gives smaller, big light source gives bigger image.	23
Obtaining a single image from two or more source.	17
Drawing the shape of mask as shadow shape for wide sources.	7
Being unable to relate the color of shadow with color of source.	6
Mathematical errors	49
Incomplete	38
Irrelevant	7

Table 2. *Comparison Mental Models of Students regarding Pre-test and Post-test Results.*

Pre-tes	**Mental Models**	Post-test
*	Thinking of top and bottom edges of wide light source as point like source.	*
*	Being unable to relate the color of image with color of source.	
*	Drawing the rays mistakenly.	*
*	Thinking of wide light source as a point like source.	*
*	Being unable to think that source does not emit light to every direction.	
*	Being unable to distinguish the mixture of colors.	
*	Being unable to distinguish darker from lighter shadow.	*
*	Obtaining a single image from two or more sources.	
*	Thinking the color of the darker shadow being same with the color of the light source which it is formed from.	
*	Filament emits only parallel beams.	
*	Small light source gives smaller, big light source gives bigger image.	*
*	Drawing the shape of mask as shadows shape for wide sources.	

When the pre-test results are evaluated, it can be seen that generally they have wrong constructed mental models of source, shadow and ray. After the instruction, the post-test results reveal that there is an decrease in the students misconceptions. However, in post-test results, some students' wrong mental models still exist. These models mostly are based on the mis-usage of the light source. In post-test students still have some wrong mental models of source, image, ray, relation of mask-image and source at basic level.

4. CONCLUSIONS and REMARKS

The findings show that, students have some mistaken mental models about the formation of the shadow. Generally, during the instruction students could not develop the idea of wide light source, light travels in linear paths and source emits light in every direction although they had the chance of experimenting those at first hand. Moreover, they thought the shadows as they are the image of an object in an optical system and as a result drew the shadows mistakenly. These mistaken models show that the students have serious problems about basic conceptions of geometrical optics. These results may due to the fact that at high school years students have unsufficient physics course where they usually exercised indifferent examples. One of the most striking misconceptions is about the usage of the wide light source. According to us, the reason for this failure comes from mostly the usage of point like source in text books and schools. This confusion is also supported by the general usage of spherical wide light sources and the circular masks in most of the examples leading students have models of wide light sources as same as they have models of point like sources.

Moreover, the usage of the non-transparent masks in the courses also prevents students from thinking that light sources emit light in every direction so students sent beams just from the top and the bottom of the source and draw the shadow.

Besides this, the reason for the failure in drawing the beam is due to the students' concern of the shadow shape rather than how the beams are drawn. Similarly, Andersson & Bach [14] developed geometrical optics program towards 8th and 9th grade students and test the effectiveness of the program by pre and post tests. They found that while students increased their achievement about the reflection and linear propagation of light, they failed to develop about the image formation, absorption and refraction of light. Hubber [15] also developed an instructional program about seeing, propagation, reflection and refraction of

light, colours and image formation for 10th grade students over a period of 9 weeks. By interviewing before and after the instruction he found that students had stil misconceptions about image formation even they could scientifically explain the events

The probable reason for the existence of these misconceptions even at university years might be due to their simplicity and as a result not being dwelt upon based on assuming to be known by every student at university. This situation prevents the students from being aware of their misconceptions. Kocakülah [16], found out that prospective teachers and primary students have common misconceptions especially on real and imaginary image formation and the colors in light and painting even after the formal education.

The students' continuing wrong mental models in post-test even after the instruction show how difficult it is to change their mental models. As a result, it is necessary to form learning environments where the students would be aware of their wrong ideas and will be given a chance to correct them.

5. REFERENCES:

1- Driver, R. and Guesne E., Tiberghien A., "Children's Ideas in Science". **Open University Press** (1985).

2- Duit, R. and Glynn, S. "Mental Modelling". In G. Welford, J. Osborne and P. Scott (Eds) "Research in Science Education in Europe". **The Falmer Press**, London, (1996).

3- Witmann, M. C., Steinberg, R. N. and Redish, E. F. "Making Sense of How Students Make Sense of Mechanical Waves". **The Physics Teacher**, 37, 15-21, (1999).

4- Norman, D. Some Observations on Mental Models. In D. Gentner and A. Steven (Eds.), **Mental Models**, Hillside, New Jersey, (1983).

5- Rutherford, M. "Models in Explanations of Physics: The Case of Light" in J. K. Gilbert, and C. J. Boulter; **Developing Models in Science Education** (2000).

6- Goldberg, F. and McDermott, L. "The Origin of Misconceptions in Optics". **American Journal of Physics**, 55 (10), 108-119, October, (1997).

7- Langley, D., Ronen M. and Eylon B-S, "Light Propagation and Visual Patterns: Preinstruction Learners' Conceptions". **Journal of Research in Science Teaching,** 34(4), 399-424, (1997).

8- Watts, D. M. "Student Conceptions of Light: A Case Study". **Physics Education**, 20, 183-187, (1985).

9- Ronen, M. and Eylon, B-S. "To See or Not To See: The Eye in Geometrical Optics-When and How?" **Physics Education**, 28, 52-59, (1993).

10- Galili, I. and Hazan, A. "Learners' Knowledge in Optics: Interpretation, Structure and Analysis" **Int. J. Sci. Educ**., 22 (1), 57-58, (2000).

11- Bendall, S., Goldberg, F. and Galili, I. "Prospective Elementary Teachers' Prior Knowledge about Light" **Journal of Research in Science Teaching** 30 (9), 1169 – 1187, (1993).

12- Campbel, D. T. and Stanley, J. C. "Experimental and Quasi-Experimental Designs for Research on Teaching". In N. L. Gage (editor). **Handbook of Research on Teaching**. Houghton Mifflin Company (1963).

13- Wosilait, K. "Research as a Guide for the Development of Tutorials to Improve Students Understanding of Geometrical and Physical Optics". **Doctoral Dissertation, University of Washington**, (1996).

14- Andersson, B. & Bach, F. "On Designing and Evaluating Teaching Sequences Taking Geometrical Optics As Example." **Science Education**, 89, 2, 196-218, (2005).

15- Hubber, P. "Explorations of Year 10 Students' Conceptual Change During Instruction." **Asia-Pacific Forum On Science Learning and Teaching**, 6, 1, 10-16, (2005).

16- Kocakülah, A. Geleneksel Öğretimin İlk, Orta Ve Yükseköğretim Öğrencilerinin Görüntü Oluşumu Ve Renklere İlişkin Kavramsal Anlamalarına Etkisi. **Balıkesir Üniversitesi, Fen Bilimleri Enstitüsü, Yayımlanmamış Doktora Tezi,** (2006).