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THINKING IN TERMS OF VARIABLES: THE CONCEPT OF THE SHADOW

Ayse Oguz Unver

Abstract. *The aim of the research was to explore the ideas prospective science teachers (N=51) had about the variables of object size, shape and light transmission that have an impact on shadow formation, using a scientific activity based on Inquiry-Based Science Education (IBSE). In this qualitative study, the measurement tool comprises 3 questions. The first question examines how the participants define the concept of shadow while the second question focuses on the variables of the size of the object, its shape, and its light transmission. The participants were asked to explain whether these variables would produce a shadow. The last question was devised in the atmosphere of an activities laboratory in which the absorption and reflection properties of light were explored. The NVi10 program was utilized for data analysis. At the end of the research, it was observed that the prospective teachers were not able to define the concept of the shadow in scientific terms and even if they knew the basic variables related to shadow formation, they could not exactly explain new situations when the variables were manipulated.*

Key words: *inquiry, prospective science teachers, qualitative data, shadow science, variables.*

Introduction

In the dark cave underground, there are people sitting with their backs to the entrance of the cave, who have been chained to the room by their necks and feet since childhood (see Figure1). These people, who are unable to turn their heads around, can only, follow the shadows of passers-by that are reflected on the wall across the road in the light of the fire lit above them as they walk on with objects in their hand. The only things the people in the cave have ever seen all their lives are the shadows that are projected from the light of the fire burning across from the cave. And the sounds of the people passing by on the street are the sounds of these shadows. The bravest among them manages to free himself from the chains. The first thing he sees is again the shadows. Then, he sees the reflections in the water of the people and the objects they are carrying. When he goes back in, he begins to tell the others about what he has seen. But it is almost impossible to make them believe that what he has seen on the wall is not actually real and that reality lies beyond the cave (Plato, 1937:514-516; Berting, 2013: 1-6).

Figure 1: A depiction of Plato's allegory of the cave (Saenredam, 1604)

Ayse Oguz Unver
Mugla Sitki Kocman University, Turkey

Although the shadow seems like a very ordinary phenomenon at first sight, it has a much deeper meaning in human life and in the development of philosophical thought. Light, and therefore shadow, appears before us in many different forms in the process of thought. As expressed in Plato's allegory of the cave, the shadow is actually a projection of images. This allegory that Plato used to stress the relationship between the real and the ideal world has had, since it was first introduced, a radical influence on our world in terms of philosophy and scientific thinking. In this allegory that sets forth the limits of the perception and emotions of human beings, the shadows have been expressed as a projection of reality and man's choice to live in a world of ideas. What Plato actually wanted to emphasize was the importance of relying on the mind rather than the emotions. Similarly, Bachelard (2008) has defined the light that forms the shadow as one of the greatest creators of images among the objects that call light into daydreams. He says that the flame forces man to dream and that a person is lost in dreams in the face of a flame, at which moment the object that is perceived with the emotions appears to be nothing compared to what is dreamed. Bachelard believes that science is fundamentally built on dreams. And that only that which can be dreamed may be analyzed. Science is based on a dream rather than on an experiment, he says (Bachelard, 2008; Korkmaz, 2011).

By its very nature, the concept of shadow is not only a philosophical or scientific concept, but it is a phenomenon that also affects the culture of societies, the emotions and the mental state of human beings. In this case, then, it will be useful to talk about how the shadow is used as it influences human life and what it means to individuals. A painter's use of shadows and dark tones may be the expression of his mental state. One can see changes of mood in the works of an artist. It is without doubt, that the use of shadows and colors plays an important role in the expression of mood changes. When there is nothing to affect an artist's emotional state negatively, the artist's paintings are colorful and the texture of the shadows he uses is less pronounced. The artist who feels the burdens and discomfort of life's problems reflects the darkness of black and tones of shadow more forcefully. Tones of black are an outward expression of the artist's pessimism (Kılıç, 2014). In the art of painting, shadow is used to depict opposites, three-dimensionality and depth. Studies that make use of these concepts help us to perceive the volume of objects, the distance between objects and other characteristics (MEGEP, 2007). From a technical standpoint, too, shadows are used to firmly implant a painting's main image and make an aesthetic contribution to the artist's values. If the artist wishes to emphasize a figure in a drawing, he may make the shadow of that figure darker and enlarge the area of shadow (Sanmiguel, 2003:126-140; Kılıç, 2014).

For a photographic artist, however, the shadow is an element that can increase the impact of the photograph (see Figure 2). If the photographer wishes to add melancholy and sadness to the picture, a dark shadow is of infinite value to him. Shadow increases the power of an artist's composition. Sometimes, the source of light may be so strong at the moment the artist has captured the image that the artist may obtain a darkly cast shadow without even trying. Artists may use shadows to emphasize contrasts (Ekici, 2014).

Figure 2: Shadow and Man (Ekici, 2013).

For a street photographer, everything happens all of a sudden. The photographer has no choice but to improvise and internalize that moment. Sometimes he will wait for the right moment and then pour his thoughts and emotions into the photograph. Sometimes he will direct the shadow toward the model or the object. Thus, for the photographer, making his mental image the fundamental element of his photograph, the emotion he is feeling as he captures the moment, is of the greatest importance. Shadows stimulate sadness in the photographer. Sometimes the way the model looks into the shadows may be used as a reflection of the model's psychological state. Contrasts of black and white add an aura of nostalgia to the photograph (Scott, 2009: 174-176; Ekici, 2014).

The shadows that confront us in children's play are also an important element in the culture of a society. The shadows have been an artistic and literary expression that verifies the existence and the development of traditional Turkish theater, which has managed to survive the centuries and still remains an integral part of the power of Turkish humor and imagination (Coşkun, 2010).

When examined from a general perspective, shadows constitute evidence for the scientist exploring nature, an expression of the emotions for an artist, a way of adding unique and creative elements to art, and for the child, an entertaining game, a reflection of happiness and the imagination.

So, how does a shadow come into being? Which variables does the shadow depend on as it occupies such a valuable place in our lives? The shadow is born from the basic variables of a source of light, an object and a reflecting screen. The number of the light sources, their types and colors, the size of the object, its shape, its type and the color of the screen are all factors that affect the size and shape of the shadow. In addition, the distance and direction between the light source, object and screen affect the size of the shadow. When these three variables come together under the right conditions, a dark shadow (umbra) or a partial shadow (penumbra) is formed (Arny, 1994).

Review of the Literature

A scan of the studies on shadows shows that there are references to efforts in astronomy, particularly in the ancient world. These efforts are based on observations of the sky with the naked eye and also on searching for proof to validate a certain belief or to keep watch of natural phenomena. When research related to education is examined, however, the emphasis in these studies has been concentrated more on how the topic of shadows is to be more effectively taught and also which concepts and phenomena may create problems in teaching. This literature is presented in two categories--how the shadow has been used in history and the educational research carried out on the concept of the shadow.

Light carries knowledge to humanity. The shadow, which is formed as a result of the interaction of light and matter, provides a key to interpreting the knowledge that is related to light. Tombs with carvings depicting the Moon and its phases have been found in France dating back to Cro-Magnon man, who is believed to have produced these 30,000 years ago. These structures, which can be interpreted to be lunar calendars, are accepted as being the world's oldest documents on astronomy (Karttunen, Kröger, Oja, Poutanen & Donner, 1996, p. 1-2). The first simple tools of measurement were the Solar Clocks that were used to measure the time. In 585 B.C., Thales of Miletus calculated the time that the Earth's shadow would take to fall upon the Moon. While all of Miletus watched an eclipse in astonishment, the war that had been waging along the shores of the Halys between the Medes and the Lydians had drawn to a close during this phenomenon that was taking place in the skies (Herodotus, 1975;74-75). The Greek philosopher Aristoteles asserted in his treatise "On the Sky" in 340 B.C. that the Earth was not flat but round. He made this deduction by observing that the Earth's shadow on the Moon formed a slanted line during a lunar eclipse (Aristoteles, 1997:141). In 225 B.C. Eratosthenes used the size of the shadows to make sensitive calculations of the length of the Earth's circumference based on simple observations and a fundamental knowledge of geometry (Cited by Kırbıyık, 2001:18). Galileo's sky observations included an interpretation of the shadows on the surface of the Moon, which is accepted as one of the most important bits of evidence to support the thought that the Earth was not the center of the universe (Grego & Mannion, 2010: 62-64).

A scan of the educational research on the concept of shadows brings one to the first work in the literature on this topic, Piaget's study of 1930. Piaget (1930) used the methods of estimation, explanation and clinical interviews in his research, seeking to clarify what children thought about the concept of the shadow. His research classified children's thoughts about the shadow on four levels. The first level referred to the children in the age group 5-6 who thought that a shadow was a substance that came out of an object as soon as the night fell. The children of these ages think that the night is the shadow of the sky or the air and that it is the objects that form the shadows. The second level is related to the children ages 7-8. Children at this level believe that shadows are the only phenomena

that are formed by objects. They are able to make an association between where a shadow will be formed and the direction of the light source. They describe the person's shadow as something that follows him around and think that this shadow is a part of that person. They also think that shadows exist at night, but cannot be seen. The third level is the category of children of the ages 8-9, who describe shadows as things that run away from the light. Children at this level are able to make the deduction that shadows and light sources exist in different directions. In this age group, the belief is quite widespread that the shadows of objects are formed at night, but that they cannot be seen since it is too dark. Also, it is at this age, that the concepts of shadow and partial shadow begin to be differentiated. The last category is the group of children, ages 9-9.5, who are able to exactly define the concept of shadow. At this level, most children are able to think that a shadow is formed when an object obstructs the light. Children also state at this stage that the night is a period of time in which there is no light. When the results of the study are evaluated in general terms, it is seen that children at younger ages commonly think of the shadow as a living and conscious being. Furthermore, it is observed that when the shadow is being explained, thinking geometrically is encouraged and the logic of the spatial relationship between the shadow and the object is the focus.

It can be seen that after Piaget (1930) expressed his belief that thinking in terms of geometry and exercising the logic of spatial relationships, studies based on clinical interviews started taking their place in the literature (Rice & Feher, 1987; Feher & Rice, 1986; Feher & Rice, 1988; Feher, 1990; Feher & Rice, 1992). For example, Rice & Feher (1987) explored how students would define concepts related to light and images in a setup that was based on the methods of estimation and explanation. One study related how clinical interviews for this purpose were carried out while 110 students were visiting a science museum and how the students were asked to perform some experiments. The students were given a piece of carton which had been cut in different shapes and asked to estimate how a light source in the shape of a plus sign would appear on the screen. The children were then given an object and asked to carry out an experiment and then to draw the differences they saw between their estimates and their observations. Some of the more prominent findings were that most of the children could not form a geometrical relationship between the source of light and the image, and that they tried to explain the formation of the image with reflection, magnifying power, and the light absorption of the object.

In another study, Feher and Rice (1988) created a setup consisting of a light source in the shape of a plus sign, a carton with a pinhole on it and a screen. They asked the students in the age group 8-14 to explain and draw how a shadow was formed. Some of the students, it was seen, could describe the phenomenon scientifically, but some described it as an image, a reflection, refraction or the light projected on the object. The other observations reported in the study included the fact that all of the students said that even if shadows existed, they could not be seen at night, while another group of students described a person's shadow as an entity that followed the person.

Feher and Rice (1992), in a setup they created with more than one source of light, tried to determine what students visiting a science museum thought about the concept of color. The study results showed that the participants were unable to exactly explain the combinations of color and could also not provide a reason for why partial shadows were colored.

A general look into these studies reveals that most research about shadows have been influenced by Piaget's (1930) clinical interview technique based on estimating and explaining. Just as Piaget (1930) reported that individuals in different age groups described the shadow as if it were an entity, there have been other studies that refer to the same observation (Rice & Feher, 1987; Feher & Rice, 1988).

As from the 2000's, more studies on how individuals form an image in their minds about the concept of the shadow and how to teach this concept have come to the fore (Galili & Hazan, 2000; Denney, 2005; Chen, 2009; Subramaniam & Padalkar, 2009; Yürümezoğlu, 2009; Starakis & Halkia, 2010; Uzun, Alev & Karal, 2013; Valanides, Efthymiou & Angeli, 2013).

Starakis and Halkia (2010) aimed at revealing the thoughts of elementary school children about the visible movements of the Moon. The semi-structured interview technique was used as a data collection instrument. Interviews held with elementary school fifth- and sixth-graders showed that in general, the children thought that the Moon's visible movements occurred only at night and that the Moon and the Sun usually appeared together at sunset and at sunrise.

Subramaniam and Padalkar (2009), in their study, explored how university students explained the variables that were responsible for the phases of the Moon. To this end, a study group of eight people were asked open-ended questions, measurement tools of semi-structured diagrams were used and interviews with the participants were carried out. The study results revealed that while the participants explained the phases of the Moon or produced drawings of a solar eclipse, they described the phases of the Moon as the Earth's shadow.

Uzun, Alev and Karal (2013) had the objective in their study to reveal the thoughts of people in different age groups--from elementary school to the university--about light and images. The study used measurement tools that comprised open-ended and multiple-choice questions and drawings that were presented to 30 eighth grade, 26 eleventh grade and 42 prospective teachers. The researchers reached the conclusion at the end of the study that as educational levels increased, the tendency to provide an explanation based on the association between the effects of light and its interaction with objects also increased. In addition, a large majority of the participants were not able to provide an exact description of scientific concepts and principles.

Galili and Hazan (2000) devised a teaching activity in which high school students and prospective teachers were queried to determine the level of their ability to describe light and image. The questionnaire of open-ended questions that the researchers developed was administered to 166 students as a pre-test and a post-test. At the end of the study, it was observed that the activity that was used to help the students explain the formation of shadows based on the formation of images was not very effective in terms of their explanations about the concept of shadow formation. The researchers came to the conclusion that in both the pre-test and the post-test, the participants thought the object's shape was the basic element in the formation of shadows and that the type of light source did not affect the shape of a shadow. Moreover, the students expressed their belief that the more powerful the light source, the bigger the shadow would be and additionally could not state the difference between an umbra and a penumbra.

Denney (2005) treated the subject of shadow formation using the concept of sunlight in inquiry-based activities. In this activity, which can be implemented from pre-school all the way up to elementary school 4th grade, evaluation tools such as worksheets and reflective writing techniques were used. It was reported that the activity was quite effective in guiding students to make observations about the concept of the shadow and join in discussions, and that the same method could be used in other subjects such as astronomy.

Yürümezoğlu (2009) has described a setup where light sources of different colors were used to cast colorful partial shadows that would demonstrate shadow formation. The researcher emphasizes that this setup is useful in teaching students the interaction of light and matter and the concept of colors in physics.

Chen in 2009 reviewed the thought of pre-preschoolers about the concept of the shadow. In the first stage of the study, the students were shown cards on shadow formation. In the second stage, experiments were performed with different light sources and objects and an attempt was made to allow the students to express their thoughts. Rubrics were used to assess the interview and activity stages of data collection. At the end of the study, it was seen that some of the students could only associate shadow formation with the light source, and that at older ages, the variables affecting shadow formation were better identified.

Valanides, Efthymiou and Angeli (2013) explored the effect of an activity they had designed on the degree to which students were able to learn the concepts related to the shadow. Toward this end, the researchers developed a measurement instrument that was made up of drawings on shadow formation as well as explanations on the drawings. The tool was used before and after the activity and from the drawings and the related explanations, it was observed that the activity had been effective in helping the students grasp shadow concepts. One of the striking observations of the study was that the students had described the shadow in the pre-test as the reflection of something or an area where there was no light, whereas in the post-test, the students realized that the shadow and the source of light were in the same place.

An overview of the literature points to the fact that most studies are on pre-school level students (Deney, 2005; Chen, 2009; Valanides, Efthymiou & Angeli, 2013). Different data collection instruments have been used together to determine students' thoughts about shadow concepts. Furthermore, in explaining the formation of partial shadows, the emphasis has been more on the number of light sources, whereas the light transmission of objects has been neglected (Yürümezoğlu, 2009). In some studies, an experimental activity has been designed. Of the variables of the light source, the object and the screen that have an impact on shadow formation in the activity, the stress was more on the light source and the object (Galili & Hazan, 2000; Chen, 2009; Valanides, Efthymiou & Angeli, 2013). No attention was paid to whether the object was opaque or transparent. In the present study, our focus in teaching shadow was on the shape of the object, its size and the property of light transmission (opaque or transparent).

The primary school curriculum today is based on a fundamental approach of exploration and inquiry (TTKB-Turkish Board of Education, 2014). The most important step in the inquiry is the ability to inquire. In this context, questions need to address the specific phenomenon. Identifying and manipulating variables occupy an important place in the scientific thinking skills that should be used at this point. The main element of inquiry is to create hypotheses that will form the theoretical framework of the phenomenon in terms of determined variables (creating

questions/inquiring) and to test these hypotheses. In this context, using a scientific activity based on Inquiry-Based Science Education (IBSE), the goal of the research was to explore the ideas Prospective Science Teachers had about the variables of object size, shape and light transmission that affect shadow formation. It was also observed that current studies on colored shadows or the formation of partial shadows centered only on the number of light sources and ignored the variables related to the object (two light sources and partial shadows) in the formation of partial shadows (Feher & Rice, 1992; Yürümezoğlu, 2009). Furthermore, the activity that was developed aimed at teaching the basic concepts of optics, namely, absorption, reflection, shadow, partial shadow, transparency and opacity through the use of simple materials.

Methodology of Research

The aim of the research was to explore the ideas Prospective Science Teachers had about the variables of object size, shape and light transmission that have an impact on shadow formation, using a scientific activity based on Inquiry-Based Science Education (IBSE).

Research Participants

The study group comprised 51 third-year students enrolled in the Science Teaching Program of the Education Department of a university in Western Anatolia in the academic year 2014-2015, all of whom were selected using the technique of convenience sampling. Convenience sampling is advantageous in that it allows the selection of a study group that is accessible and appropriate to the aim of the research and facilitates time scheduling (Frankel, Wallen & Hyun, 2012). The study group comprised 35 women and 16 men. The pre-service teachers were students enrolled in a four-year curriculum who had been placed in the education department program through the national centralized exam system. The prospective teachers were from different hometowns and most of them came from families of average socioeconomic status. Since the pre-service teachers would be teaching Science classes at the primary school level, they would be handling the topic of shadows and this was the fundamental reason the study was conducted with this group. Moreover, the participants had also received instruction in General Physics and the General Physics Laboratory, where the subject of light is taught.

Data Collection Instrument

A measurement tool made up of 3 questions was used as a data collection instrument (Attachment-1). In the process of developing the measurement tool, a review of the literature was first undertaken to get an idea of what concepts and variables were used in teaching the concept of shadows. A focus was placed on variables related to the object, providing the first form of the measurement tool. Later, two science-teaching specialists and a physics-teaching specialist were consulted. This first form of the measurement tool was applied to 16 primary school Science teachers and in the light of the feedback received, the tool was revised until a final form was reached.

The measurement tool comprises 3 questions. The first question examines how the participants define the concept of shadow while the second question focuses on the variables of the size of the object, its shape, and its light transmission. The participants were asked to explain whether these variables would produce a shadow. The last question was devised in the atmosphere of an activities laboratory in which the absorption and reflection properties of light were explored. The participants were asked to answer the question on the measurement tool related to the activity.

Implementation of the Activity

In the experiment that was carried out, a setup was built with the help of a flashlight, a coffee can, a screen and a wall, as in Figure 3.

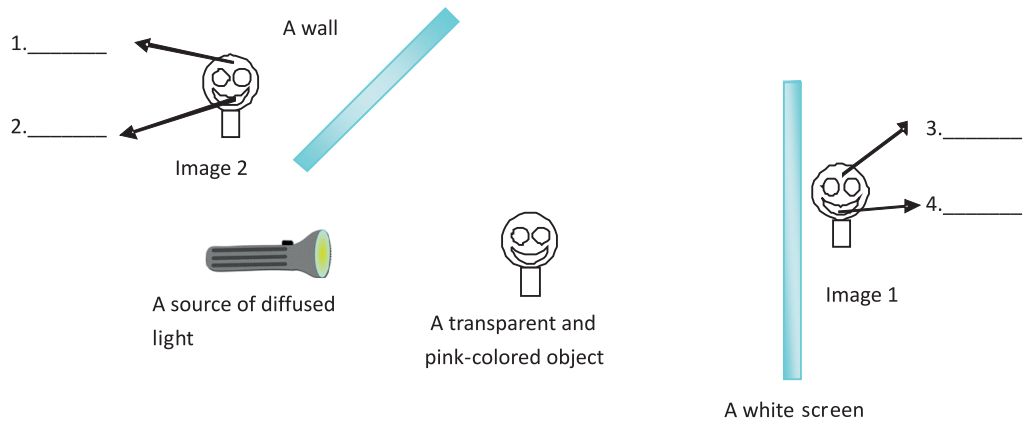

Figure 3: The experiment activity.

The participants were asked to define and draw the shadow and the images appearing on the screen and on the wall using concepts related to light. The implementation of the activity and the application of the measurement tool takes about 50 minutes. The photograph of the activity is shown in Figure 4.

Figure 4: The images on the screen and on the wall.

Data Analysis

The data collected were analyzed using content analysis. The NVi10 program was utilized in the process of encoding and setting up themes with the data. The NVivo10 program facilitates the qualitative research process with its ability to easily encode and arrange comprehensive and varied data. It is also helpful in presenting relationships between themes and codes in a comprehensive manner (Richards, 2002). Two different researchers further analyzed the data separately and Cohen's Kappa was found to be 0.82. According to Landis and Koch (1977), a kappa value of between 0.81-1.00 indicates an almost perfect consistency. The codes from the statements and drawings of the participants were first prepared in the form of free codes and later, depending on the characteristics of these free codes, the data were grouped under certain themes. Frequencies and percentage distribution was used to make the themes and codes more comprehensible. Also, each participant was assigned a number that was helpful in the presentation of the statements of the respondents. The codes and themes arising from the content analysis were turned into a model with the help of the NVivo 10 program.

Results of Research

The results of the research, which aimed at revealing what kind of ideas Prospective Science Teachers had about the variables related to the concept of the shadow are presented below.

Results on the Definition of Shadow

The definitions the participants offered about the concept of shadow have been classified according to the degree of their consistency with the scientific literature. Also, an evaluation was made of which phenomena the participants associated the concept of shadow with and this has been presented in the form of a model.

Whether or not the participants were able to define the concept of shadow scientifically is shown in Table 1.

Table 1. Classification of definitions of the concept of shadow.

	Scientific definition	Unscientific definition
f	8	43
%	15.6	84.4

When Table 2 is reviewed, it can be seen that of the participants (N=51), 8 (15.6%) defined the concept of shadow by associating it with the source of light, the object and the screen, and that 43 (84.4%) defined the concept of shadow without associating it with the source of light, the object or the screen or defined it by providing an unscientific definition. For example, S_1 defined the concept of shadow scientifically: *"The dark area at the back of an obstacle that has prevented the passage of the rays emitted by the light source."* Another participant, S_{12}, again defined the concept of shadow in accordance with the scientific literature: *"A shadow is the dark area formed by an object in the area of light that is placed between the area lit up by the light and the light source."* On the other hand, S_{19} and S_{33}did not define the concept of shadow scientifically and said, respectively, *"It's the reflection of the light source appearing on the opposite side from the light source when it falls upon the object"* and *"When light streaming out from a source of light is refracted and falls on the object, the symmetry that the object forms is called a shadow."*

The way the participants defined the concept of shadow by associating it with the variables of the light source, the object and the screen has been shown in Figure 5.

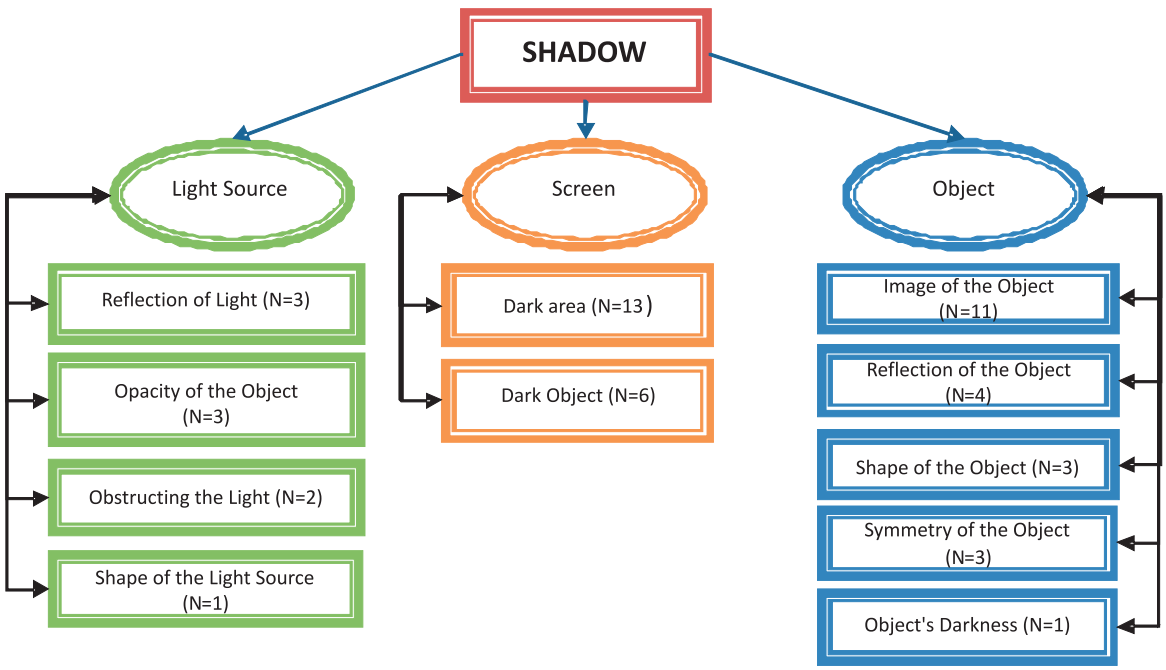

Figure 5: The variables with which the participants associated the concept of shadow.

A review of Figure 3 shows that the participants who associated the concept of shadow with the light source associated it with the variables of reflection of light (N=3), opacity of the object (N=3), the obstruction of the light (N=2), and the shape of the light source (N=1), while those that associated it with the variable of the screen made the association with a dark area (N=13) and a dark object (N=6). In addition, the participants who associated shadow formation with the variable of the object made the association with the image of the object (N=11), the reflection of the object (N=4), the shape of the object (N=3), the symmetry of the object (N=3) and the darkness of the object (N=1). For example, S_{49}, associating shadow formation with the light source and describing it as the reflection of light said: *"A shadow is the reflection around an object of the light sent out from a source of light."* S_{20}, who associated shadow formation with the screen, describing it with the dark object concept, said the following: *"It's the darkness in the reverse direction after the light source has shone over the object."* $S_{15,}$ on the other hand, associated shadow formation with the variable of the object and described the shadow as the image of the object, stating, *"When an opaque object is placed in front of a light source, the image that will reflect on a screen is called a shadow."*

The Size, Shape and Light Transmission of an Object in Shadow Formation

The responses of the study participants on whether a shadow would form according to the variables of size, shape and light transmission of an object are shown below.

Table 2. Distribution of responses on whether a shadow can form according to the size and shape of an object.

Size of the Object				Shape of the Object		
Walnut	Shadow will Form	f	49	Nut	f	47
		%	96.1		%	92.2
	Shadow will not Form	f	2		f	4
		%	3.9		%	7.8
Apple	Shadow will Form	f	49	Rock	f	50
		%	96.1		%	98,0
	Shadow will not Form	f	2		f	1
		%	3.9		%	2.0
Basketball	Shadow will Form	f	51	Perforated Metal Pencil Holder	f	48
		%	100.0		f	94.1
	Shadow will not Form	f	-		f	3
		%	-		%	5.9

Looking at Table 2, it can be seen that of the participants (N=51) responding to whether they thought a shadow would form according to the size variable of the object, 49 (96.1%) said about the walnut that it would form a shadow, 2 (3.9%) said a shadow would not form, 49 (96.1%) said about the apple that a shadow would form while 2 (3.9%) said it would not and all 51 participants (100.0%) said that a shadow would form in the case of the basketball. In addition, of the participants (N=51) responding to whether they thought a shadow would form according to the shape of the object, 47 (92.2%) said about the nut that a shadow would form, 4 (7.8%) said it would not, 50 (98.0%) said about the rock that a shadow would form, 1 (2.0%) said it would not, and in the case of the metal pencil holder, 48 (94.1%) said the shadow would form while 3 (5.9%) said it would not.

Examining the responses, it was seen that S_{49}expressed the view that the walnut's shadow would not fall *"Because a shadow does not form when an object is smaller than the light source."* $S_{17,}$ meanwhile, said the shadow of the apple would not fall because *"When the object is bigger than the light source, the light cannot cover all of it."*

S_{3}, who said that shadows do not form according to the variable of shape, said about the rock, *"A shadow won't form because it has an irregular shape."* Agai, S_{3} said about the perforated metal pencil holder, *"A shadow won't form because of its shape."* Similarly, S_{9} said about the nut, *"A nut transmits the light."* The same respondent's comment on the perforated metal pencil holder was *"It won't reflect the light, it will transmit it,"* expressing his belief that a shadow would not form.

Table 3. Distribution of participant responses as to whether an object's light transmission would allow a shadow to form.

An Object's Light Transmission			
Transpar-ent Balloon	Shadow will Form	f	22
		%	43.2
	Shadow will not Form	f	29
		%	56.8
Red Transpar-ent Balloon	Shadow will Form	f	44
		%	86.3
	Shadow will not Form	f	7
		%	13.7
Jellybean	Shadow will Form	f	43
		%	84.3
	Shadow will not Form	f	8
		%	15.7
Microscope Slide	Shadow will Form	f	8
		%	15.7
	Shadow will not Form	f	43
		%	84.3

When Table 3 is examined, it can be seen that of the participants (N=51) who provided responses regarding the variable of light transmission, 22 (43.2%) said about the transparent balloon that a shadow would form, 29 (56.8%) said it would not, 44 (86.3%) said about the red transparent balloon that a shadow would form, 7 (13.7%) said it would not, for the jelly bean, 43 (84.3%) said a shadow would form while 8 (15.7%) said it would not, and for the slide, 8 (15.7%) said a shadow would form and 43 (84.3%) said it would not.

S_{42} had this to say about the transparent balloon: "*It's transparent and the light will pass through to the other side so a shadow will not form.*" S_{25} expressed himself in this way: "Even if the balloon is transparent, the light will have a problem passing through it so a shadow will form."

In the case of the transparent red balloon, the participant S_{30} said, *"The balloon has a shadow. Because it has a volume and it will reflect the light."* The participant S_{11} expressed his thoughts by saying, *"A shadow won't form because light can pass through it."*

S_{38} said about the jelly bean, "*A shadow will form because it's not a transparent object.*" S_2 said, "*It will absorb the light. And because of this, a shadow will form.*"

S_{21} said about the slide, *"A shadow won't form because it transmits the light."* The participant S_5 expressed his thoughts by saying, *"A shadow won't form because it doesn't reflect the light fully."*

Results Obtained from the Activity Performed on Shadow Formation

The results obtained from the definitions and drawings in the activity performed with the participants on shadows and images projected on a screen and on the wall are presented below. The participants in the activity were asked to provide definitions by looking at the images projected on the screen and on the wall. The images on the wall, resulting from the absorption and reflection of light were expressed as Image 1 and Image 2; the images on the screen were designated as Image 3 and Image 4 (as in Figure 3). The results of the participants' definitions of the images are presented in Table 4.

Table 4. Distribution of participant responses regarding the images on the screen and wall.

		Reflection	Refraction	Shadow	Dark Shadow (Umbra)	Partial shadow (Penumbra)	Light	Dark	Color of the wall	Color of the screen	Other
Wall	Image 1	23	6	7	1	6	5	-	-	-	1
	Image 2	5	4	21	5	1	-	7	3	-	4
Screen	Image 3	15	-	18	1	10	1	1	-	-	1
	Image 4	12	1	8	2	1	9	-	-	6	3

An examination of Table 5 shows that of the participants (N=51), the definitions provided for Image 1 on the wall were: 23, reflection; 6, refraction; 7, shadow; 1, dark shadow; 6, partial shadow; 5, lightness. The responses to Image 2 were: 5, reflection; 4, refraction; 21, shadow; 5, dark shadow; 1, partial shadow; 7, darkness; and 3, the color of the wall. As for Image 3 on the screen, of the participants (N=51), 15 called this reflection; 18, shadow; 1, dark shadow; 10, partial shadow; and 1, lightness. For Image 4, the responses were the following concepts: 12, reflection; 1, refraction; 8, shadow; 2, dark shadow; 1, partial shadow, 9, light; and 6, the color of the screen.

The participants were also asked in the activity to draw the light source, the object, the screen and the light rays in-between. In evaluating the data, four different categories were created. These categories were created after an evaluation of the participants' drawings of the space in between the light source and object, the light source and screen, the object and wall, and the screen and wall. The light rays the participants drew between the light source, the object, the curtain and the screen are presented in Table 5.

Table 5. Distribution of categories determined according to the drawings of the light rays by the participants.

		Light source-Object	Light source-Screen	Object-Wall	Screen-Wall
Correct drawing	f	49	43	14	-
	%	96.1	84.3	27.5	-
Incorrect drawing	f	2	8	-	37
	%	3.9	15.7	-	72,5

A look into Table 5 indicates that of the participants (N=51), 49 (96.1%) drew the light rays between the light source and the object correctly but 2 (3.9%) drew them incorrectly. In the drawings of the rays between the light source and the screen, 43 (84.3%) of the participants made a correct drawing but 8 (15.7%) produced incorrect drawings. It was also seen that of the participants (N=51), 14 (27.5%) correctly drew the image on the wall with its light rays reflecting from the object while 37 (72.5%) made an incorrect drawing of the image on the wall with the light rays reflecting off the screen. The drawing of the participant S_8 provides an example, seen below.

Figure 6: The drawing of S_{38} on the light rays.

Looking into Figure 6, it can be seen that the participant S_{38}thought the image on the wall was the image formed on the screen and made the drawing to depict this.

Discussion

The aim of the research was to explore the ideas Prospective Science Teachers had about the variables of object size, shape and light transmission that have an impact on shadow formation, using a scientific activity based on IBSE. At the end of the research, it was observed that the prospective teachers were not able to define the concept of the shadow in scientific terms and even if they knew the basic variables related to shadow formation, they could not exactly explain new situations when the variables were manipulated. One of the most important reasons for this was that the prospective teachers did not take the variables into account when defining the concepts, meaning that they were not able to transfer knowledge that they had learned and adapt this to new situations. Feher and Rice (1988) reported that children focused on only a single variable when defining the concept of shadows. In the present study too, the prospective teachers more commonly focused on the object or the image and tried to associate the shadow with this, which was an indication that they had trouble differentiating between the variables and were not able to think from an integrated perspective.

The definitions the prospective teachers offered about the concept of shadows showed that their explanations more commonly encompassed everyday terms rather than scientific terminology. This situation exhibits similarity with the work of Uzun, Alev and Karal (2013), who reported that prospective teachers and high school students defined the concept of light by associating it with the topic of sight using everyday language. In addition, the participants (S_{33}, for example) offered explanations such as *"When light streaming out from a source of light is refracted and falls on the object, the symmetry that the object forms is called a shadow,"* which revealed the importance of explaining the concept of shadow by forming a geometrical association between the object and its shadow. This is because the way to understand the shape of the shadow and the role of the light source in this process derives from the individual's placing himself in place of the screen and imagining that the light cannot be seen from that point. An individual who discovers the three-dimensional logic of the relationship between the variables involved in shadow formation may be able to imagine whether the light source will be seen when he/she turns the object around (Piaget, 1930).

When the responses of the prospective teachers are examined with respect to whether they thought shadows would form according to the shape of the object or its ability to transmit light, it is seen that the most striking confusion the students experienced was regarding the matter of light transmission. For example, when considering the object's size and shape variables, the students were able to classify these into opaque and transparent categories and decide whether or not a shadow would form. But when an object defined as translucent was used as a barrier, the prospective teachers were unable to sort out their thoughts about whether or not a shadow would form. This is because transparent objects too may not transmit light and turn into opaque objects. For example, although glass is defined as a transparent article, when a few pieces of glass are put together, one on top of each other, they may turn into an opaque object (P.S.S.C., 1976: 174-176). Another problem the prospective teachers had with the topic of light transmission and shadow formation was understanding whether or not light could be transmitted through an object.

The main role played by an object in shadow formation is refraction or reflection of light (Subramaniam & Padalkar, 2009). The prospective teachers, however, used the concepts of refraction of light and reflection of an object to explain what they saw. In situations where the nature of light and its interaction with matter is not known, this type of scientific error is commonly encountered (Chen, 2009; Valanides, Efthymiou & Angeli, 2013). Lastly, it was seen from an evaluation of the drawings of the prospective teachers that they more commonly thought that the image on the wall was from the image forming on the screen and they therefore explained this image as a reflection of the object. This was a striking to observe. This misinterpretation may cause problems, particularly in the teaching of topics such as the phases of the Moon or a Lunar eclipse (Subramaniam & Padalkar, 2009; Starakis & Halkia, 2010).

Conclusions

In a science activity derived from the educational philosophy of inquiry-based learning, an exploration was made into the thoughts of prospective science teachers regarding the concept of shadows and related variables.

The conclusions reached are; the activity is based on inquiry-based education and aims to enable individuals to develop problem-solving skills, focusing on the importance of thinking in terms of variables. Moreover, categorizing objects into transparent, translucent and opaque is not appropriate to the concept of shadows. Because of this, such a differentiation should not be used. In the teaching process, the light transmission levels of objects should be stressed. What is more, the examples of a dark shadow or umbra are very limited in nature. However, the examples given pupils in elementary school science classes about dark shadows cause concept confusion. The approach of simplifying scientific knowledge leads not into simplifying science so much as it creates concept pollution. Scientific knowledge should be taught in its clearest form. Finally, activities designed for the concept of shadows are basic to astronomy teaching as well and can be used as an introductory activity.

Recommendations

The recommendations below have been given based on the research, which aimed to reveal the ideas of prospective science teachers about the variables related to the concept of the shadow. The concept of shadows should be taught in association with the concepts of light and color. The teaching process should first focus on the concepts of light and color and then the transition to the concept of shadows should be made. If the student is not familiar with the concepts of light and color, it will be difficult for him/her to internalize the concept of shadows. Furthermore, in the activity that was developed, a single setup was used to teach the concepts of optics and the participants were urged to make their interpretations on the basis of their observations. The activity emphasized the importance of higher-level cognitive thinking and interpretation from an integrated perspective on science. Real inquiry-based science education should also stimulate the teacher's higher-level cognitive system of thought. Scientific knowledge (logos) is not just an aggregate of information. Additionally, scientific thinking, scientific methodology and scientific knowledge is an integrated whole. It is because of this that a thought system-based method to enhance understanding should be adopted in the teaching of science. Lastly, the present study focused on the size, shape and level of light transmission of objects with respect to shadow formation. Future studies will focus on the variables of the light source and screen.

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Attachment 1. Data Collection Instrument.

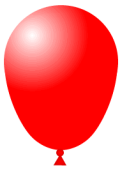
Name: School Number: Date:

1) Define the concept of shadow.

_____
_____
_____

2) The following objects are located at equal distance from the light source and screen, please explain whether these variables would produce a shadow.

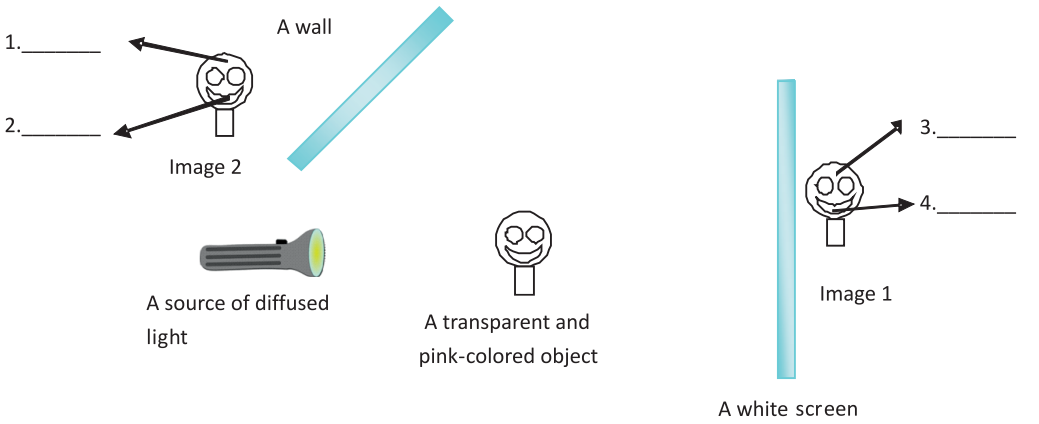
Light source	Objects	Shadow	Why?
	 (Walnut)	Shadow will form ☐ Shadow will not form ☐	
	 (Apple)	Shadow will form ☐ Shadow will not form ☐	

Light source	Objects	Shadow	Why?
	 (Basketball)	Shadow will form ☐ Shadow will not form ☐	
	 (Nut)	Shadow will form ☐ Shadow will not form ☐	
	 (Rock)	Shadow will form ☐ Shadow will not form ☐	
	 (Pencil holder)	Shadow will form ☐ Shadow will not form ☐	
	 (Transparent balloon)	Shadow will form ☐ Shadow will not form ☐	
	 (Red transparent balloon)	Shadow will form ☐ Shadow will not form ☐	
	 (Jellybean)	Shadow will form ☐ Shadow will not form ☐	
	 (Microscope Slide)	Shadow will form ☐ Shadow will not form ☐	

3) First the activity drawn form below was carried out in the classroom.

a) Draw the light rays from the light source.

b) Please write what are the images projected on the screen and on the wall.



You can add your comments below in terms of the images.

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_____

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Ayse Oguz Unver PhD., Associate Professor, Mugla Sitki Kocman University, Faculty of Education, Science Education Department, 48000 Kotekli, Mugla, Turkey.
E-mail address: ayseoguz@mu.edu.tr
Website: http://www.mu.edu.tr/personel/-ayseoguz