

## Prospective Science Teachers' Metaphorical Images about 'Light'

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**Abstract.** The metaphors are powerful mental materials to employ when one wants to explore and understand something esoteric, abstract or highly speculative. And, metaphors build a non-literal relationship between abstract concepts and something that is more familiar, concrete and visible according to individual metaphorical images. Besides, it helps one make sense of the world and reality and of the circumstances he or she is currently involved in. Owing to metaphors, the unknown things are described with the concepts that we know and understand, and that is an unusual juxtaposition of the familiar with the unfamiliar. In this context, the metaphors could be useful to facilitate the teaching process and also, to determine learners' lack of knowledge and misconceptions. The aim of this study is to reveal the metaphorical images by using metaphors to identify the lack of knowledge and misconceptions of prospective science teachers. The study was conducted with 228 volunteer prospective science teachers. After eliminating the invalid metaphors, 201 of prospective science teachers were participated to the study. The data was collected by a form including a question which is asking to complete the phrases of 'Light is like ..., because... /Light is similar to ..., because...' in Turkish. The content analysis was used to interpret the data. According to the findings, 95 valid metaphors about 'light' concept were determined. These metaphorical images were categorized with respect to statements of the study group. The diagram of prospective science teachers' metaphorical images was drawn. It is identified that prospective science teachers have various misconceptions about 'light'. Implications of metaphor and metaphorical imagines for science teacher education are discussed.

### 1. Introduction

What is light that appears before us from realizing the presence of the planets to lunar and solar eclipses that were believed to be the punishment of Gods to humans, from the discovery of the shape of the Earth that made the Galileo face the risk of death to measurement of distances, from the formation of rainbow that was seen as a magical power to the formation of the images and in lots of technological devices that are the indispensable part of modern life from past to the present? This question surely has a physical answer. Well, what is the relation between the answers of students and the answer of science? When the literature is analyzed, the studies about light concept show similarities in indicating the various misconception and the learning disabilities of the students. These misconceptions and the learning disabilities are the ones such as; light is an apparent presence that takes a place in the space [1], the light is an object that fills the atmosphere [2], which show that light is perceived as an object or an item that has a volume; the ones that the light is seen equal with its source or its function such as trying to explain the light as a structure that works with electricity [3], with candle or lamp [1] or with seeing or illumination; last of all is the

difficulty to understand that the light covers a certain distance in a certain time [1]. Besides that, in a study done with university and high school students, it was discovered that the students perceive light not only as something physical but also something emotional [4].

Both taking an important place in the daily life and being used in lots of disciplines of science and engineering, it is necessary for students to perceive the light correctly; but, in a study done with the prospective science teachers (PSTs), it was found that these PSTs had a quite low knowledge about light and there were mistakes and deficiencies in their pre-knowledge [5]. So, it is important to research what the PSTs think about the concept of light and how they perceive it.

Another finding about this topic is that students' concepts about the light are affected by daily life in a great extent [6]. Because of the light's nature, which is a concept different from anything else that we see around, became meaningful in the 20<sup>th</sup> Century as a result of Einstein's different point of view towards this phenomenon. This situation sometimes causes the events and facts of daily life to have a preventer role in terms of understanding what the light is rather than helping to understand it. When the concepts like the light which is difficult for students to be understood well-prepared allegories can be used. But it is important to know the students' pre-knowledge, misconceptions and the experiences related to the topic to prepare these allegories. In this point, the metaphors developed by students can be useful.

According to Lakoff and Johnson [7], metaphor is to understand and to experience a phenomenon vis-à-vis another phenomenon. Metaphor is also expressed as to relate abstract things to common concrete things [8]. From this aspect, metaphor is a thought or a vision symbolizing an individual's perception of the world [9]. In the process of forming metaphors, individuals tend to express the realities and the truths of their own by relating the concept to their experiences consciously or unconsciously [7]. Because of this, metaphor studies in the field of education can be used as a way to understand the results of the practices of teaching and learning [10].

According to Forceville [11], there are three main elements in any metaphor relations: (a) target, (b) source and (c) interrelation. This metaphor structure is presented in Figure 1.

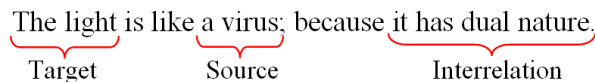


Figure 1. The metaphor's structure

In the literature, although there are metaphor studies about educational concepts such as teachers [8,9,11,13,14], students [13,15], schools [9,13,15,17], classes [18,19], manager [13], education program [20]; about subjects such as Science and Art Center [21], Geography [12,22], Maths [23], Biology [24], Science and Technology [25,26]; and about the concepts like knowledge [16], environment [27], and the world [28]; there is no studies about the concept of light. In this aspect, it is thought that this study will fill a gap in the literature.

In this study, by taking the advantage of metaphors that can be used as powerful mental materials to understand a highly abstract, complicated and theoretical phenomenon [29], the PSTs' perceptions and misconceptions about the concept of light are aimed to be found out by means of metaphors.

## Method

In this study, one of the qualitative research methods, phenomenology pattern is used to describe the current situation. Phenomenology pattern focuses on the facts we are aware but that we do not have a deep perception. In Phenomenological studies, it is generally aimed to find out and comment on the individual perception about a phenomenon [30]. The data of the study were analyzed with content analysis method. The content analysis method aims to reach the concepts and relations that can explain the collected data [30].

## 1.1 . Working Group

The working group of the study is 201 volunteer PSTs in the department of Elementary Science Education in 2013-2014 fall term at Faculty of Education at a university.

## 2.2. Collecting Data

As a means of collecting data, a form is used that has a metaphorical phrase “*Light is like ...; because .../Light is similar to ...; because ...*” in Turkish. PSTs were let to complete one or both of these phrases at their will and there was not a time limit. Before the application, the feature of the metaphorical phrase was explained briefly and the PSTs were warned to complete the form only with their own ideas.

## 2.3. Analyzing and Interpreting of the Data

The metaphors formed by the PSTs were analyzed in three levels respectively:

### 2.3.1. Elimination and Codification

In this process, the data that are not suitable with the aim of the study were eliminated and rest of the data was coded. To eliminate the data, following aspects were considered.

- The metaphors that stated the source but not the target-source interrelation were eliminated.
- The metaphors that used more than one source in a metaphor were eliminated. For example, “*Light is like an atomic particle. It appears energy as a result of decaying of atoms of nuclear particles. Light is energy*” (Is light related to atomic particle or energy?) In this example, using more than one source make analysis difficult.
- The metaphors that target-source interrelations are not related to the target were eliminated. For instance, “*Light is like life; because, there are negative and beautiful things in life.*” or “*Light is like an eye; because, unless there is light, having eyes is not important at night*”. The interrelation is not related to the target.
- The metaphors that target-source interrelations are not clear were eliminated. For example, “*Light is like a cell; because, it consists of photon particles, the smallest structure, like cells*” (Do cells consist of photons or is it the building block of something else?). In these metaphors, feature of the source which is related to the target is not clear.

The study started with 228 PSTs and continued with the metaphors of 201 PSTs after the election of 27 metaphors. 95 sources were set in the rest of the metaphors and the metaphors that shared the same source were brought together. After that, for every source, the interrelation between the target and the source were listed by given codes.

### 2.4.2. Developing categories

The inductive method was used in this level. The codes that were formed in the previous level collected under 28 categories according to their similarities (illumination, image formation, shape ...). After these categories could be collected under three headings “*light’s function*”, “*light’s structure*” and “*light’s motion*”; the study continued with calling these three headings as categories and other 28 as sub-categories. As they were categorized according to the codes, the metaphors among our findings can be under more than one category or sub-category. This can be exemplified with the ‘Sun’ metaphor: while under the function category, the metaphor “*Light is like the Sun; because it lightens.*” takes part under the sub-category of *illumination*. Under the category of motion “*The light is similar to the Sun; because, it spreads everywhere*” metaphor takes place under the sub-category of *radiation*.

### 2.4.3. Providing validity and reliability

To provide the validity of the results is tried to explain the categorization process that forms the data analysis. To provide the reliability of the study, the opinion of an expert was taken to confirm that the metaphors really represent the categories and examine the suitability in terms of the codes (formed according to the interrelation of target-source), sub-categories (formed from the codes) and the categories.

## 2. Findings

In this part of the study, 258 metaphors were explained by showing categories, codes, sources and frequency. In these tables, if (\*) symbols are in the code column it shows the misconception about light; if they are in source column, it shows the misconception about source.

**3.1. PSTs’ Metaphors in the Light’s Function Category**

176 metaphors, 11 sub-categories, 43 codes and 68 sources constitute the category of the *function of light* in Table 1. When Table 1 is analyzed, it is remarkable that there are sub-categories of *lightening* (62,5%), *forming image* (6,8%), *heating* (5,1 %), *having importance* (7,9%), *being source of energy* (63%), *having energy* (2,1%), *making feel positively* (2,3%), *having a source* (1,1%), *reflection* (1,1%), *being directive / guide* (2,3%), *making something clear* (3,4%) and the frequency of sub-category of *lightening* (f=110) is higher than the other categories.

In the sub-category of *lightening* (1), the codes of the sources “Sun, moon, water, firefly, star, source of energy, sky, torch and lamp” show that PSTs consider the source of light and the concept of light equal and in consequence of this thought they think that not only light but also light sources lighten like it is in the study of Guesne [1]. Besides these, there is a study found out that primary school students perceive the Moon as a source of light [6].

Table 1. The categorization of metaphors in the light’s function category

S.C.	Code	Source	f	S.C.	Code	Source	f		
1	Lightens.	Sun*	39	2	Makes us see.	Eye*	4		
		Firefly*	3			Sun	1		
		Moon*	2			Moon	1		
		Candle*	1		Makes us see by forming images.	Sun	1		
		Water*	1			Makes us perceive images*	Eye	1	
		Star*	1			Glass	1		
		Source of energy*	1		Reflects images.*	Mirror	1		
		Sky*	1			Mirror	1		
		Torch*	1		Makes us see by reflecting.*	Lens*	1		
		Lamp*	1			Sun	7		
		Knowledge	2	Heater		1			
		Lightens in darkness.	Lightens our life.	School	1	3	Radiates.*	Radiator	1
				Family	1			Water	5
				Humans	1			Time	1
				Science	1		It is necessary for life / living beings.	Oxygen	1
				Beloved ones	1			Air	1
				Scientist	1			Water	1
				Love	1			Food	1
				Thought	1		It is need of everyone.	Sun	1
				Hope	1			Technology	1
	Righteousness			1	Need			1	
	Snow			1	4		Maintains continuity of vital activities.	Limitless power	1
	Love			1		A lot of activities can done with it.			1
	Lightens our soul / horizon			Lightens our future.		Moon *	7	5	It is a source of light.*
		Water	1			Irradiates infinitely.	Cloud		1
	Mother	9	Irradiates.	Laser		1			
	Teacher	4	It is a natural source of heat*	Sun		1			
	Beautiful girl/woman	1	It is a source of energy.	Sun		1			
	Smiling	1	Spreads energy.*	Sun		1			
	Our achievements	1	6	Has certain heat.		Source of energy	1		
	Book	1		Has energy.		Particle	1		
	Lover	1	7	Makes happy with its presence.	Goodness	1			
	Love	1		Makes us peaceful	Happiness	1			
	Hope	1		Provides comfort in places.	Air	1			
	Thought	1	8	When it appears, we have a good time.	Friend	1			
	Inspiration	1		Has a source.	Heat	1			
	Salvation	1	9	Goes out of a source	Sound	1			
	Freedom	1		Has a feature of reflection*	Transparent *	1			
	Lightens our soul / horizon	Lightens our future.	Book	1	10	Reflects everything*	Mirror	1	
			Love	1		Shows the right way.	Mother	1	
	Past	2	Directs.	Past		1			
	Lightens our future.	History	History	1	11	Guides life.	Mother	1	
						Guides	Guide	1	
					Shows everything with positive and negative sides.	Friend	1		

Lightens our way.	Guiding	1	In the place where there is friend, everything is very clear.	Friend	1
	Sun	1		Makes images clear.*	Eye
Shines.*	Compassionate person	1	Makes us see details		Lens
	Successful students	1		Monitor	1
Sparkles.	Life	1	S.C.: Sub-category, 1: Lightening, 2: Forming image, 3: Heating, 4: Having importance, 5: Being source of energy, 6: Having energy, 7: Making feel positively, 8: Having a source, 9: Reflection, 10: Being directive / guide, 11: Makes [something] clear	Different point of view	1
	Beautiful girl/woman	1			
	Heavenly light	1			
	Heaven	1			

In the sub-category of *forming image* (2), the metaphor “*Light is like an eye; because it makes us perceive images.*” shows that the PSTs have a misconception about light in making images perceive. Yet, conical cells in eyes participate in perceiving images, light creates image. Şen [2] also in his study with primary school students found out that in seeing, the role of receiver is left out and it is thought that the only necessary thing is light to be able to see. We can see the similar situation in the metaphor “*Light is like eye/lens; because, it makes images clear.*” in the sub-category of making something clear. On the other hand, the metaphors like “*Light is like glass/mirror/lens; because, it reflects images.*” show that PSTs think that light reflects images. But light does not reflect images, it creates them. In the sub-categories of *heating* (3) and *being source of energy* (6), codes of light such as radiating, being source of heat, spreading energy and being source of energy point out that the PSTs have an idea that light is a source of energy. Nevertheless, light is not a source of energy but it consists of photons which are energy particles. Watts [31] also states that some teachers and course books describe light something different from a form of energy.

Apart from these, the codes of the sources of “mother, beloved, smiling, our successes, book, ...” in *lightening* (1); “kindness, happiness, air and friend” in *making feel positively* (7); “mother, guide and past” in *being directive / guide* (11); “a different perspective and close friend” in *making (sth) clear* (12) show exactly like the study of Galili and Hazan [4] with the students of high school and college that the PSTs also ascribe not only physical but also emotional meanings to the concept of light.

### 3.2. PSTs’ Metaphors in the Light’s Structure Category

25 metaphors, 10 sub-categories, 23 codes and 19 sources constitute the light’s structure category in Table 2.

Table 2. The categorization of the metaphors in light’s structure of light category

S.C.	Code	Source	f	S.C.	Code	Source	f
12	It does not have concrete structure	Sound	1	18	Dual-nature.	Virus	1
13	Pure/clear.*	Water	1		Not explored completely.	Subconscious	1
14	Does not have color.*	Water	1	19	Complicated, highly beneficial	Physics	1
	Includes different colors in itself.	Rainbow	1		Non-dimensional.	Space	1
	Its wavelength is measured.	Water	1		No beginning and ending.*	Long path	1
15	IT has specific wavelengths.	Rainbow	1	Eternal / No ending.	Eternal path	1	
	It has granular form.	Sand	1		Line	1	
16	It is consisted of infinite number of particles.*	Sand	1	Its ending is not seen. *	Eternity	1	
		Sea	1	We cannot know its end.	Eternal path	1	
17	Invisible.	LASER	1	Comes from a particular source, continues to eternal.	Beam	1	
17	Takes up space.*	Particle	1	Endless	Love	1	
	Takes the shape of its container.*	Water	1	20	Permeable.	Glass	1
				21	Transparent.	Glass	1

12: Shape, 13: Purity, 14: Color, 15: Granular form, 16: Diaphaneity, 17: Volume, 18: Nature, 19: Dimension, 20: Permeability, 21: Transparency



When Table 2 is analyzed, it is observed that there are the subcategories of *shape* (4%), *purity* (4%), *color* (16%), *granular form* (12%), *clearness* (4%), *volume* (8%), *nature* (12%), *dimension* (32%), *permeability* (4%), *transparency* (4%). It draws attention that the sub-category of *dimension* (f=8) that matches in light with eternity has a higher frequency than the others. The metaphor “*Light is similar to water; because it is pure/clear.*” in the *purity* (13) proves that the PSTs draw a parallel between the light and a pure substance. However, the light is not substance but energy. It is found in the studies with primary school students that the students perceive the light as a substance [3,6]. Although the metaphor “*The light is like water; because it has no color.*” in the *color* (14) shows that the PSTs think that the light does not have a color, the light has colors changing between red and purple depending on the frequency of light and has secondary colors formed by the combinations of those colors. The metaphor “*Light is like sea; because it is formed of eternal number of particles.*” in *granular form* (16) shows that PSTs know the light has granular form but try to express its quantity as it is equal to eternity. However, the light has intensity according to light’s particle model. This intensity can be thought as proportional with the number of particles constituting the light. That is why, it cannot be said that the light is consisted of eternal number of particles. It is observed that the PSTs who made the metaphor “*Light is similar to water; because it takes the shape of its container.*” have the thought that the light has a volume. The metaphor “*The light is like long path; because it does not have a beginning and ending.*” shows that the PST does not think that the light is formed by a source and will disappear in time by losing its energy by interacting with substance unless it is in space. However, the thought of PST that the light will eternally travel in space is correct for this metaphor. Accordingly, also in the metaphor “*The light is like eternity; because its ending is not seen.*”, the PST might be thinking about the motion of light in space. For this reason, it is not clear that whether there is mistake in these metaphors.

### 3.3. PSTs’ Metaphors in the Light’s Motion Category

48 metaphors constitute the light’s motion category. 7 subcategories, 24 codes and 19 sources in this category are presented in Table 3.

Table 3. The categorization of the metaphors in the light’s motion category

S.C.	Code	Source	f	S.C.	Code	Source	f
22	Spreads/Scatters.	Sound	3	23	Very fast.	Jet	2
		Wind	1			Plane	1
		Sound wave	1		It has speed.	Sound	1
	Scatters in space.	Sound	1		It has a particular speed.	Sound	1
		Water	1		Fast.	LASER*	1
	Spreads/ Scatters as waves	Waves	3		Proceeds fast.	Fast particles	1
		Water	2	Proceeds in a specific way.	Water	1	
		Sound wave	2	Proceeds in a specific direction.*	Path	1	
		Sound	1		Line	1	
	Scatters by passing through substances.	Water wave	1	25	Fragile	Cam	6
		Sound	1			Heart	1
	Scatters in everywhere.	Sun*	1	26	Its direction changes when air density changes.	Plane	1
		Water*	1				
Scatters around	Information	1	Reflection occurs	Wave	1		
Scatters in air.	Gas	1	Reflects	Sound	1		
Bulldozes through the obstacles in front of it.*	Water	1	Reflects when hits the mirror	Plastic ball	1		
Flows when there is nothing in front.	Water	1	27	Strikes and returns	Feedback	1	
			28	Makes diffraction	Wave	1	
				Makes interference	Wave	1	

22: Propagation, 23: Having speed, 24: Direction, 25: Refraction, 26: Reflection, 27: Diffraction, 28: Interference

When Table 3 is analyzed, it is observed that there are *propagation* (50%), *having speed* (15%), *direction* (6,25%), *refraction* (17%), *reflection* (8,3%), *diffraction* (2%), and *interference* (2%) sub-categories in the light’s motion category. It draws attention that half of the metaphors constituting this category are in *propagation* (22).

The metaphor “*The light is like water; because it bulldozes through the obstacles in front.*” in *propagation* (22) shows that the PST associates the light’s proceeding in substance with water’s bulldozing through the obstacles in order to make room for itself volumetrically. However, rather than make room for itself, the light proceeds by making energy transfer among the particles. The metaphor “*Light is like path/line, because it proceeds in a specific direction.*” in *direction* (24) indicates that the PSTs have the thought that the light can only proceed in one direction. However, the light can spread in every direction in every three dimensional space. Here it can be thought that the teacher might also be trying to explain that the light spreads through the lines. The metaphor “*The light is similar to Sun; because it spreads in everywhere.*” in *propagation* (22) stresses that the Sun has the feature of spreading. It is considered that the PST, who made the metaphor “*The light is like water; because it flows in everywhere.*”, ignores the water can also proceed in the solid substances. The metaphor “*The light is like LASER, because both are fast.*” in *having speed* (23) proves that the PST, who made that metaphor, is not aware of that the LASER is an intensive light beam and that they are trying to explain the light with light’s speed.

#### 4. Result and Suggestions

As a result of the study, it is determined that the PSTs make metaphors by interrelating the light with light’s function, motion and structure to explain the concept of light. While the light’s function stands out among the interrelations, light’s motion and structure follow that interrelation. This situation shows that mental images of the PSTs stress on the function of light. It is deduced from target-source interrelation in the metaphors of the PSTs that in terms of creating their own conceptual structures, the individuals are affected from the situations and events they come into in daily life. In many researches about the concepts and misconceptions, similar results about the effects of daily life on conceptual structures showed up [32,33]. Besides, in this study it is observed that emotional meanings are ascribed to the concept of light with the effect of the language used in daily life, beyond physical meanings. This may digressed the PSTs from using scientific language when making metaphors. It is determined that the PSTs’ misconceptions about the function of light are more than their misconceptions about the light’s function and light’s structure. When the target-source interrelation in the metaphors made by PSTs are analyzed, it is revealed that their knowledge of light’s function is mainly about the information obtained in daily life and that their knowledge of light’s motion is mainly based on the information obtained in school. A part of misconceptions about the light determined in this study were also explored in different studies conducted with the students of primary school before. The fact that PSTs, who will be the teachers of future, have similar misconceptions is a serious problem by creating a vicious cycle. One may acquire information about how the students perceive the concept within the frame of the depiction they use while making metaphors and why they perceive it as such. Therefore the flaws in concept teaching can be determined and sounder judgements can be made about what are needed to be done in teaching process. Besides, allegories can be developed by availing from the metaphors of students and these allegories can be used for concept teaching.

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