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A cross-age study of an understanding of light and sight concepts in physics

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ABSTRACT: The aim of this study is to reveal the students' and pre-service teachers' understanding of light, sight and related concepts at different educational levels, from primary to higher education. A cross-sectional approach was used since the participants were of different age and educational level. The sample of this study consisted of 30 eighth grade primary school students, 26 eleventh grade secondary school students, and 42 student teachers. The data were collected through open-ended, multiple choice questions, and a drawing exercise. Findings showed that the participants' perspective and understanding of light and related concepts generally reflect what their syllabus covered at different educational levels. The participants look at light from two points of views; the effects or function of light and the nature or structure of light as a physical entity. As the participants-education level is advanced, they described light through its effects and interactions as well as its physical nature. A significant number of the participants were found not to be able to explain light related phenomena in scientific language, despite their knowledge about them. Some common misconceptions about light, light sources and sight process have been determined at all levels. This study also revealed some implications for the syllabuses and teaching of the topic.

KEY WORDS: light, sight, cross-age, misconception

INTRODUCTION

Studies have shown that students' conceptions of scientific phenomena often differ from scientists (Osborne & Freyberg, 1995). In the literature students' different conceptions have been called misconceptions, alternative conceptions, and children's science (Driver & Easley, 1978; Helm, 1980; Gilbert & Watts, 1983; Osborne & Freyberg, 1995).

Over the last three decades, much National and International science education research focusing on various subjects of science has been undertaken to explore students' science misconceptions from primary to higher education (Clement, 1982; Şen, 2003; Çepni & Keleş, 2006; Stein, Barman & Larrabee, 2007; Atasoy & Akdeniz, 2007; Gönen, 2008; Ka-

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çan, 2008). Light and sight are two fundamental concepts in science, and particularly in physics. Students' understanding of these concepts is crucial to meaningful learning of physics. Therefore, researchers have focused on students' conceptions of light and sight in many countries. Research on primary school students (Cansüngü & Bal, 2000; Yıldız, 2000; Koray & Bal, 2002; Şen, 2003; Çınar, 2003; Yeşilyurt, Bayraktar, Kan, & Orak, 2005; Şahin, İpek, & Ayas, 2008), secondary school students (Cavell & Jones, 1995; Langley, Ronen, & Eylon, 1997; Galili & Hazan, 2000; Büyükkasap, Düzgün, & Ertuğrul, 2001; Kaçan 2008), and student teachers (Bendall, Galili, & Goldberg, 1993; Galili & Hazan, 2000; Heywood, 2005; Van Zee, Hammer, Roy, & Peter, 2005; Kara, Avcı, & Çekbaş, 2008; Yalcin, Altun, Turgut, & Aggül, 2009) were carried out to determine and eliminate students' misconceptions related to light and sight. Research showed that students hold misconceptions regarding light, source of light, sight and other related concepts from primary to higher education levels. To determine and compare students' understanding and misconceptions at different ages and levels (De Posada, 1997; Furió & Guisasola, 1998; Çalık & Ayas, 2005), cross-sectional studies have been undertaken. Here one produces "a snapshot of a population at a particular point in time" (Cohen & Manion, 1994: 68; Ho, O'Farrell, Hong, & You, 2006).

Cansüngü and Bal (2000) investigated primary students' misconceptions about light and its properties, using multiple choice and open-ended questions. Findings of this study showed that the majority of primary students thought that the distance light travels differs, depending on whether it is night or day-time. Another misconception revealed in this study is that light cannot propagate during day-time.

Langley et al. (1997), on the other hand, examined 10th-grade students' understanding of light propagation and visual patterns by using a questionnaire consisting of nine questions, most of which required the drawing of a diagram that describes and explains a phenomenon. They found that the minority of 10th-grade high school students indicated in a diagram light as emanating from the light source. Also, the majority of high school students did not show directions in their diagrams representing sight process. The researchers also indicated that students had not developed a consistent descriptive and explanatory model of optical phenomena.

Kara et al. (2008), on the other hand, investigated primary science student teachers' knowledge level about the concept of light by using writing and drawing method. In their study, students were asked to write and draw about light. The researchers used a level of knowledge criteria to assess students' explanations and drawings. Findings showed that most of the students had deficient knowledge and misconceptions about light. The researcher reported also that only a small minority of primary science student teachers' answers are acceptable as correct explanations and drawings.

Students' understanding of light and sight are examined by other studies, and a few of them are cross-sectional. Additionally, most of previous cross-age studies are conducted to provide an opportunity to reveal the students' understanding of light and sight concepts at different grades, such as 4th, 6th and 8th grades of primary school covering the same education stage. In this study, considering the sample, student teachers studying programmes of primary science-technology and secondary physics education in higher education level will be teachers in the near future and teach these concepts to students being similar with the group of students in the sample. Thus, taking "a snapshot" of these education levels at a particular point in time becomes more important. Also, the study is intended to reveal which misconceptions or misunderstandings are still the same from the past up to today. For these reasons, it is thought that an investigation of students' understanding of light and sight at different education levels would make a contribution to the current literature and the teaching and learning of those concepts. Therefore, the main purpose of this study is to reveal students' ideas about light and sight and determine whether there are differences between groups of students at primary, secondary and higher education levels. In this vein, answers are sought for the questions:

1. What are the students' ideas about light and its properties at different education levels (primary, secondary, and higher education)?
2. How do students at different education levels describe the process of sight?
3. Do students at different education levels hold misconceptions about light and sight?

METHOD

Cross-age studies help us to understand the fact that some alternative concepts remain the same from kindergarten until university education (Ruane, 2005; Morgil & Yörük, 2006). Therefore, a cross-sectional approach is chosen for this study because the goal is to reveal students' understanding of light, sight and related concepts at different ages and levels.

Sample

The sample of this study consisted of 30 8th grade primary school students (PS), 26 11th grade secondary school students (SS), and 42 student teachers, 18 of them being in a 3rd grade primary science and technology programme (PSST), and 24 of them in a 5th grade secondary physics education programme (SPST) in Trabzon, Turkey. These grades for the sample were chosen because the sample has been taught about "light and sight" topics at those levels.

Data Collection and Analysis Procedures

Based on a detailed literature review, misconceptions about light and sight were recognized and then a test, examining the participants' knowledge of the subject, was designed as the data collection instrument. The test consisted of three open-ended questions, a drawing exercise, and a multiple-choice question and sub-questions about light and sight, as illustrated throughout the results section. Some questions in the test were selected from previous studies in the science education literature (Stead & Osborne, 1980; Guesne, 1984; Yıldız, 2000) and some of them were adapted to the Turkish context. The following steps were taken in translating the original versions of the questions. Firstly, the questions were translated from English into Turkish by one Forward-Translator, proficient speaker of English and familiar with the terminology of the physics. Secondly, another translator having physics teaching background (not familiar with the original versions of the questions) translated the questions back into English (back-translation). Finally, any disagreements were resolved via a reconciliation process resulting in a single translation.

Secondly, a model called SLOLE (Source-Light-Object-Light-Eye) was developed to evaluate students' responses about the process of sight (see Table 1). This model involved showing connections between components that were the source of light (or light that came from a light source), the object, and the eye. According to the definition of sight (as a process in that context), we could see an object when "light from a light source travelled to an object and then it was reflected to the eyes". The model was based on using this definition of sight. Briefly, SLOLE model expressed that in the process of sight a light source (S) emitted light (L) towards an object (O), and then the light (L) was reflected to the eyes (E). The model could be illustrated as "S→ O→E" which resembled a flow diagram, and it emphasised a sequence and direction of light between the components in the process of sight. The "SLOLE" code meant that the connections were correct in the students' responses. In addition, LOLE code had acceptable connections because they made connections between light (L), object (O), and eye (E) as light was reflected from the object to the eyes. The qualitative data was coded by two researchers and analyzed for consistency. An inter-coder reliability measure suggested by Miles and Huberman (1994), reliability = number of agreements/(total number of agreements + disagreements), was used to calculate the level of agreement between the two researchers. The agreement between the researchers' categories was 84%, suggesting that the agreement was acceptable. It was suggested that the measure should yield over 70% inter-coder reliability

(Miles and Huberman, 1994). To confirm reliability further, disagreements were resolved via a reconciliation process.

The drawing question on the process of sight was analyzed using score-categories similar to those used by Jones et al. (1995) (cited from Toh, Boo, & Woon, 1996). Students' drawings about sight were evaluated also through the SLOLE model. To evaluate students' drawings about sight S(L)O, S(L)E, and O(L)E pairs were used. *L* represented an arrow with its direction meaning light ray in students' drawings. According to this, if student drew the correct direction of light between each pair such as S(L)O, S(L)E, and O(L)E, they were awarded a point for each pair. So, the total score was 3 points if students made correct connections between each pair. The code list related to students' written responses about how we could see objects was as given in Table 1.

Table 1. Code list related to students' written responses about how we can see objects

Code List in Process of Sight
SLOLE: Light travels from light source to an object, and then the object reflects the light to the eyes. LOLE: Light comes to an object, and then the object reflects the light to the eyes. OLE: Object send out light to the eyes. (Object is like a light source). SLOL: Light comes from a light source to an object, and then the object reflects the light. SLO: Light come from a light source to an object. SL: Light come from a light source. LOL: Light travels to an object and the object reflects the light. OL: Object reflects light. LELO: Light travels to the eyes, and then the eyes reflect the light to an object SLELO: Light travels from a light source to the eyes, and then the eyes reflect the light to the object SLE: Light travels from a light source to the eyes. LE: Light travels to the eyes. LOE: Light travels to an object and the eyes see the object. E: Eyes see (the object) E(L): Eyes see the object. Also, light is required. (No connection between eyes and light) L: Light is needed. (No connection between eyes and light) S: We see objects through a light source (No connection between light source and object)

Students' scores were defined as follows: 0 points: no connection between component pairs; 1 point: only one correct connection between pairs; 2 points: just two correct connections between pairs; 3 points: totally correct connections between each pair.

RESULTS

The analysis of the gathered data was carried out question by question and thus findings were presented in the same order. The first question was "What does the word "light" mean to you? Please explain". Data revealed that students have diverse definitions for "light". They used various terms to define the light concept such as sight, the sun, illumination, energy, etc. as listed in Table 2.

Table 2. Key concepts used by students and student teachers in their definition of light

Concept of light	PS (N=30) *(%)*	SS (N=26) *(%)*	PSST (N=18) *(%)*	SPST (N=24) *(%)*
Sight	40	77	33	29
Illumination	53	31	39	29
Life	40	8	17	4
Darkness	20	-	17	-
The Sun	33	-	11	-
Energy	-	23	28	42
Light Source	27	39	11	25
Reflection	7	31	11	21
Refraction	-	-	11	8
Wave	-	8	-	25
Particle	-	31	6	25
The speed of light	-	15	6	4
Photon	-	15	22	17

*The sum of percentages may be more than a hundred because students generally use more than one concept in their construction of a definition.

As can be seen from Table 2, primary students mainly used illumination to define and explain the light concept (53%), followed by sight and life (40% for each). 77% of secondary students used sight to define and explain light, followed by light source (39%), illumination, reflection, and particle (31% for each). Primary science teachers used illumination (39%), sight (33%), and energy (28%) concepts in their definitions and explanations. 42% of physics student teachers tried to define and explain light using the energy concept. 29% of them used both sight and illumination concepts. Similar to other participant at all levels; the majority of primary students' definition of light involves sight and illumination concepts mainly through explanations such as, "without light, there would be no sight", "light illuminates our Earth". Some secondary students and science and physics student teachers express their ideas about light using similar reasoning as follows: "Light illuminates the environment", "Light is something that enables us to see objects".

As shown in Table 2, especially primary school students and primary science student teachers, respondents used life concept more frequently than secondary students and secondary physics student teachers in their light definitions as illustrated in the following excerpts. A primary student stresses below.

> If we put a plant in a place without sunshine, the plant will turn pale and will not survive". A science student teacher described light as "it is something that enables us to see objects. If there is no light on earth, life will be impossible. For example, plants need it to make photosynthesis.

Their explanations focused on the idea that people and other living things need light to survive and to continue activities for their life.

Also, the Sun and darkness concepts were used to define light concept by only primary students and primary science student teachers in sentences such as "light illuminates dark places", "light is the opposite of darkness" respectively. The analysis revealed that some science student teachers who define light as "the opposite of darkness" hold misconception about the relationship between darkness and light concepts.

Only secondary students and physics student teachers used the term wave to define light

> Light is an energy, which is made up of photon particles and it behaves as a wave", "light sometimes behaves as a particle and sometimes as a wave. They both can never be seen at the same time.

Furthermore, the sight concept is used to define light by secondary students (77%) much more frequently than the others. More physics student teachers used the energy concept (42%) than the others. A student teacher stressed that "light is energy, which sometimes behaves as a particle and sometimes as a wave", and primary students never used energy to define and explain light even though it is included in the primary science and technology syllabus.

In order to reveal the students' ideas about a light source, the students were expected to choose one of three alternatives given in the multiple-choice question, "Which of following is a light source? Can you explain your reason? The moon, A mirror, A burning candle. The analysis of the student responses to the question above revealed that students at all grades have some misunderstandings or lack of knowledge about light sources at all grades. Students' recognition of light source and percentages are given in Table 3.

Table 3. Students' recognition of light source

Source of light	Level of Education			
	Primary Education	Secondary Education	Higher Education	
	PS (N=30)	SS (N=26)	PSST (N=18)	SPST (N=24)
	(%)	*(%)*	*(%)*	*(%)*
The Moon	40	-	-	-
Mirror	-	-	-	-
Burning Candle*	60	100	83	96
The Moon and Burning Candle	-	-	6	4
All of them	-	-	11	-
Correct answer with acceptable reasons	13	69	61	58

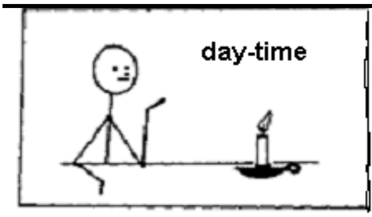
*Correct answer

As shown in Table 3, 60% of primary school students, 100% of secondary school students, 83% of science student teachers, and 96% of physics student teachers selected the correct answer. However, it is seen that some students could not give acceptable reasons appropriately even though their answer is correct. The students' ratios supplying acceptable reasons are only 13%, 69%, 61%, 58% for various groups. It is clearly seen that more secondary students gave the correct answer and explanations than others.

40% of primary school students, 17% of science student teachers and 4% of physics student teachers think that the moon is a source of light. Most primary students who chose the moon as a light source give the following answers: "the Moon illuminates the environment", "the Moon is a source of light because it illuminates the Earth at night" and "because a candle and a mirror are artificial… However, the Moon reflects light coming from the Sun". Some primary school students who chose the moon as the light source think that candles and mirrors are artificial sources and thus they cannot be light sources. A physics student teacher who chose the Moon along with a burning candle as light sources explained his reason as "The Moon and burning candle are light sources because they emit light and illuminate the environment. A mirror doesn't emit light". The common explanations for the correct answer with acceptable reasons given by participants were "the moon and mirror reflect light, so they are not sources of light", "the moon and mirror do not produce their own light" and "...a burning candle generates its own light".

The third question presented below was used to explore the students' understandings of whether there is any difference between the distances travelled by the light of a burning candle in the daytime and at night.

a. You are watching a candle burning during the day. According to the information, choose the best answer/alternative to complete the following sentence.



The light from the candle;
a) stays on the candle.
b) comes out about halfway towards you.
c) goes in all directions.
d) comes out until it hits something but no further.

b. There is a power cut during the night. You are using a candle. According to the information, choose the best answer/alternative to complete the following sentence.

The light from the candle;
a) stays on the candle.
b) comes out about halfway towards you.
c) goes in all directions.
d) comes out until it hits something but no further.

As shown in Question 3, students were asked to select the alternative that best completes the statement. The expected answer was "c", "The light from the candle goes in all directions" for both questions. Table 4 presents the results of day and night comparisons related to these questions.

Table 4. Percentages of given responses for question 3a and 3b

Propagation of light choice		Primary Education	Secondary Education	Higher Education	
		PS (N=30) (%)	SS (N=26) (%)	PSST (N=18) (%)	SPST (N=24) (%)
Day-time	A	80	15	17	17
	B	13	-	-	-
	c*	-	23	61	62
	D	7	54	22	17
	NR	-	8	-	4
Night-time	A	-	-	-	-
	B	-	8	-	-
	c*	73	15	56	67
	D	20	69	44	25
	NR	7	8	-	8

*Correct Response for the question and NR: No Response

As can be seen from Table 4, 80% of primary school students in Question 3a selected alternative “a”, 54% of secondary school students selected “d”, 61% of science student teachers selected “c”, and 62% of physics student teachers selected “c”. 23% of secondary school students, 61% of science student teachers, and 62% of physics student teachers selected the correct answer for question 3a. None of the primary school students selected the correct answer for question 3a. On the other hand, 73% of primary school students selected the correct answer for question 3b. 15% of secondary school students, 56% of science student teachers, and 67% of physics student teachers. It is noteworthy that most of the primary school students think that “the distance the light travelled from the candle would depend on whether it is day-time or night-time”. Most of them think that “light cannot propagate in the day-time”. 15% of secondary school students, 17% of science student teachers and 17% of physics student teachers think that the light of a candle stays on the candle in day-time. Briefly, most of the primary school students think that light of a candle stays on the candle in day-time, but the light goes in all direction at night-time. Students’ misconceptions about the light propagation are given in Table 5.

Table 5. Students’ misconceptions about light propagation

Misconceptions	Primary Education	Secondary Education	Higher Education	
	PS (N=30)	SS (N=26)	PSST (N=18)	SPST (N=24)
	(%)	*(%)*	*(%)*	*(%)*
The distance the light travelled from the candle depends on whether it is day-time or not.	93	46	39	46
Light cannot propagate in the day-time.	80	15	17	17

Question 4 tested the students’ understandings of how we can see objects by using an open-ended question and a drawing. In the first section, the students are expected to express their ideas about the process of sight in the provided blank space. Also the students are expected to explain the roles of the eye, light and an object in the process of sight. Students’ written responses were coded by using the SLOLE model and presented in Table 6.

Table 6. Percentages of students' written responses about how we can see objects

Model SLOLE Codes	Level of Education and School Type			
	Primary Education	Secondary Education	Higher Education	
	PS (N=30)	SS (N=26)	PSST (N=18)	SPST (N=24)
	(%)	*(%)*	*(%)*	*(%)*
SLOLE	7	31	17	33
LOLE	-	8	28	38
OLE	-	15	6	-
SLOL	-	15	6	-
SLO	-	-	-	4
SL	-	-	-	4
LOL	-	8	11	-
OL	-	8	6	13
LELO	7	-	-	-
SLELO	-	-	-	4
SLE	-	-	6	-
LE	-	8	-	-
LOE	-	-	6	-
E	27	-	-	-
E(L)	33	8	11	-
L	13	-	6	-
S	7	-	-	-
NR*	7	-	-	4

*NR: No Response

As shown in Table 6, 7% of primary school students, 39% of secondary school students, 45% of science student teachers, and 71% of physics student teachers defined the process of sight by using components with acceptable connections.

SLOL, SLO, SL, OL, LOL, and LOE codes represent omissions for light being reflected from objects to the eyes in the process of sight. As can be seen in Table 6, 31% of secondary school students, 29% of science student teachers, 21% of physics student teachers omitted the role of light being reflected from objects to the eyes in the process of sight. Also, S and L codes represent that "we need only light to see". According to Table 6, 20% of primary school students and 6% science student teachers stated that light or a light source is enough to see. They didn't mention the other components (object and eye) and their connections with light. Furthermore, the OLE code represents that “Object sends out light to the eyes”. 15% of secondary school student and 6% of science student teachers think that objects send out light like a light source.

E, LE, E(L), and SLE codes represent that “the eyes look at an object and so the object can be seen by the eyes”, without a detailed explanation. According to this, 60% of primary school students, 18% of secondary school students, 17% of science student teachers think “a glance or a view of an object” is enough to see the object. In addition to these, LELO and SLELO codes represent that “the eyes reflect the light on to an object and then the object can be seen”. Strangely, 7% of primary school students and 4% physics student teachers think that light from a light source travels to the eyes and then the light is reflected to an object, so the object can be seen.

The primary students explained the sight process mainly by stressing on components of the sight process such as light source, object and the eyes, focusing on the function of this components rather than providing scientifically acceptable explanation of the sight process. They formulate sentences like, “we need our eyes to see objects. Our eyes see objects...We see objects when we look at them”, “there must be a source of light for us to see an object”. Secondary students, on the other hand, provide more detailed explanation of the sight process, stressing that “...We see through light rays that enter our eyes”. Science and physics student teachers’ explanations of the sight process are quite similar, as illustrated in the following excerpts:

> We see an object because it reflects the light. Objects must reflect light to be seen. (Science Student Teacher)

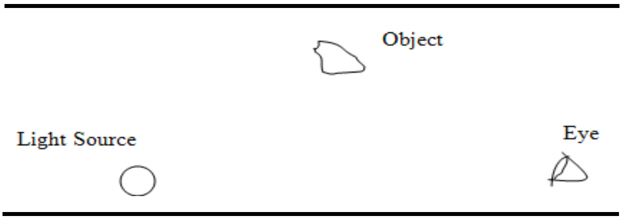
> An object is seen when light is reflected from the object. (Science Student Teacher)

> Light from a source of light goes on a shiny surface and then reflects to the eyes with the angle of incidence, so we see the object. The object is like a mirror. (Science Student Teacher)

> Reflected rays from objects come to our eyes, so we can see. (Physics Student Teacher)

> We see an object when light is reflected from the object. Light must come to an object and then be reflected to the eyes. (Physics Student Teacher)

The participants were also asked to “Draw how we see an object by using arrows to show connections in the following diagram”.



In the second section of Question 4, the students were expected to draw relations between components in the process of sight. The students' drawings are assessed by using the SLOLE model categories and the students' scores are presented in Table 7.

Table 7. Scores of drawings

Drawings / Level of Score	Level of Education and School Type			
	Primary Education	Secondary Education	Higher Education	
	PS (N=30)	SS (N=26)	PSST (N=18)	SPST (N=24)
	(%)	*(%)*	*(%)*	*(%)*
0	20	-	-	4
1	60	15	33	8
2	13	8	17	9
3	7	77	50	79

As can be seen from Table 7, 7% of primary school students, 77% of secondary school students, 50% of science student teachers and 79% of physics student teachers made correct connections between each pair in the process of sight. It is surprising that 33% of science student teachers were awarded just one point for their drawings. In other words, only 33% of science student teachers made a correct connection between the given pairs in the process of sight.

Typical examples of students' drawings related to sight, not compatible with the scientific view, are presented in Figure 1. These examples are selected to show students' perceptions about the process of sight.

As shown in Figure 1, some students drew an arrow to show that light went from the eyes to the object. Moreover, some primary students thought that light went from the eyes to a source in the process of sight. Also, some science and physics student teachers, as seen from Figure 1, thought that light went from the eyes to the object and the object was then seen. All these drawings and perceptions illustrated the participants' misconceptions about sight.

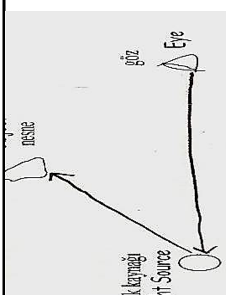
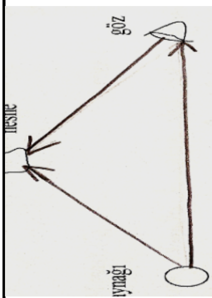
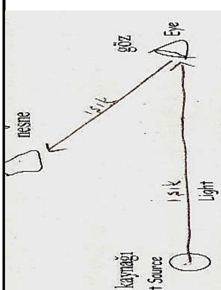
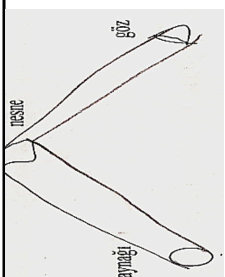
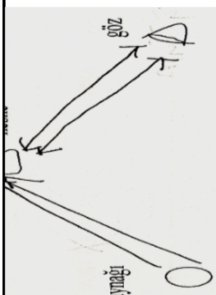
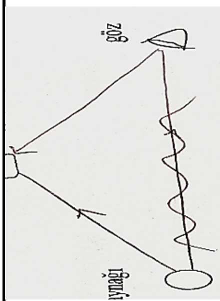
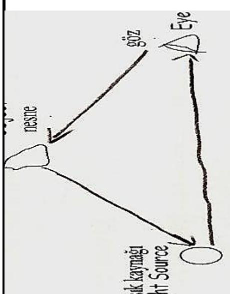
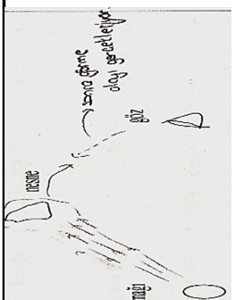
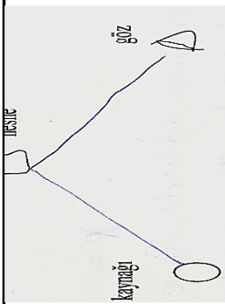
Model of Sight	Examples of Students' Drawings: Primary Students	Secondary Students	Primary Science Student Teachers	Secondary Physics Student Teachers
Source/Light/Eye (S/L/E)		-	-	
Object/Light/Eye (O/L/E)				
Source/Light/Object (S/L/O)		-		

Figure 1. Typical examples of students' drawings relayed to sight not compatible with the scientific view

Figure 2 shows some examples of students' drawings of sight that agree with the scientific view.

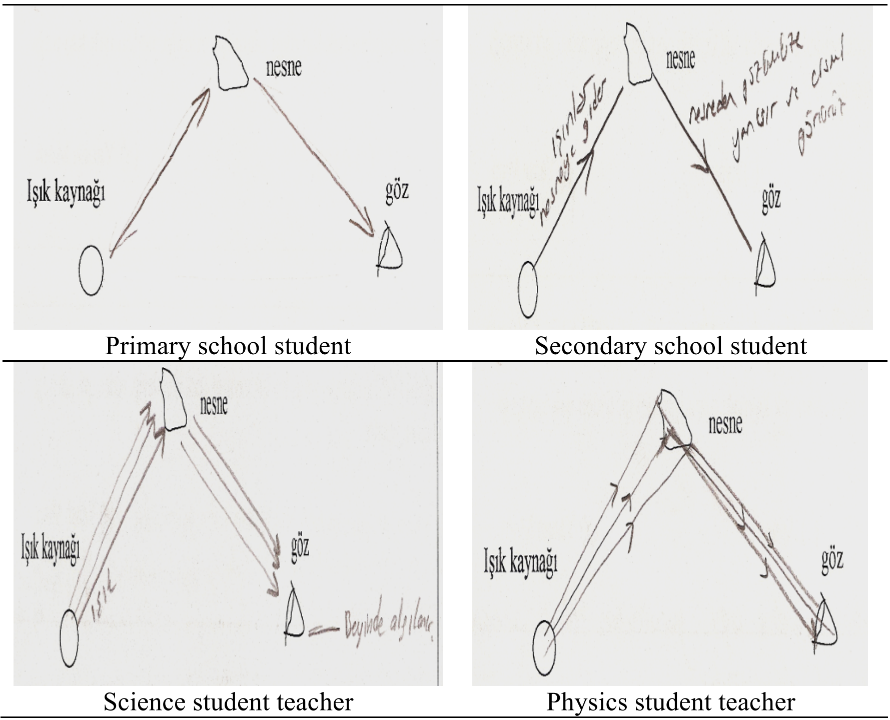


Figure 2. Students' drawings related to sight that agree with the scientific view

As noted above, a minority of primary school students (7%), the majority of secondary school students (77%), half of science student teachers (50%), and the majority of physics student teachers (79%) drew the process of sight correctly. This result was compatible with the results from earlier part of this question.

DISCUSSION AND CONCLUSION

The aim of this study was to reveal students' ideas about light and sight and determine whether there were differences between different groups, at primary, secondary and higher education levels. This study revealed that the majority of participants, at all levels, had similar understanding of light, which meant that their conceptions or misconceptions about light remained similar from primary to university level. From this point, the findings of this study indicated that the participants described light in two ways; one was the structure and nature of light as a physical entity, the other being its interactions with the environment and its effects. This picture was consistent with Galili and Hazan's (2000) findings. In their definitions, the effects of light covered its function to see objects, illumination and an energy transfer for life processes. Findings in Table 2 indicated that the participants were aware of wave and particle (photon) models of light, and they defined darkness as the absence of light. A minority of participants also indicated that light had properties of refraction and reflection, and it travelled with a definite speed, c. The findings revealed that as the participants' age and levels advanced, they perceived light as a physical entity along with the recognition of its interactions with other objects. This result had implications for the syllabuses at various levels. Primary students and science student teachers, in their definitions of light, focused on the idea that people and other living things required light to survive and to continue vital activities for their life. In both the primary science curriculum and thus the primary science teacher training curriculum, biology, chemistry and physics subjects were integrated. At the secondary level, however, science courses were separated and physics student teacher education programmes did not include biology courses. This could indicate how curriculum and inter-disciplinary instruction might affect student conception of light and thus other cross-disciplinary concepts.

Another crucial implication was that both the syllabus at all levels and current teaching of the topics, privilege knowledge prevailed over understanding, as Heywood (2005) expresses it, in which students needed to know about light phenomena without necessarily being able to articulate explanations. This seemed to be a crucial factor and thus the participants did not articulate a clear explanation of the phenomena questioned in this particular study even though their answers to the questions about light, light sources and sight process were correct. Indeed, current syllabuses at both primary and secondary levels demanded a constructivist perspective in teaching which could serve this purpose, in practice. However, hindering factors, such as nationwide exams, teacher training, time and infrastructure, negatively affected the implementation of the syllabuses as intended (Özden, 2007).

Findings revealed that students at all grades had similar misunderstandings or a lack of knowledge about light sources. Even though the great majority of participants pointed out the light source correctly, as can be seen in Table 3, a significant number of them were not able to give scientific reasons. This result was also compatible with the results of Heywood (2005) indicating that students knew about light and related phenomena without a clear understanding of it. On the issue of light source, the participants, especially primary students, thought that the moon was a source of light, which was a common misconception. This result was compatible with Şahin et al. (2008)'s findings. Osborne, Black, Smith, & Meadows (1990) pointed out that many students thought the moon was a source of light rather than a reflector of the sun's light. Indeed, the word moonlight was often used in everyday language (Gillespie & Gillespie, 2007) and it was clear from this study that sometimes the use of concepts, such as moonlight and throw a glance in everyday life, could lead students to hold misconceptions.

Eshach (2003) pointed out that many linguistic constructions such as “we throw a glance” or “give a look” did not conform to today’s scientific knowledge. The majority of the primary students and a serious number of other participants held the misconceptions “the distance the light travelled from the candle would depend on whether it is day-time or not” and “light cannot propagate during day-time”, reported by other researchers as well (Stead & Osborne, 1980; Andersson & Karrqvist, 1983; Fertherstonhaugh & Treagust, 1992; Cansüngü & Bal, 2000; Büyükkasap et al., 2001; Kaçan, 2008).

This study also revealed that not all the participants who drew the sight process correctly were able to provide a clear and scientific explanation of the sight process. As seen from Table 7, a minority of primary school students (7%), the majority of secondary school students (77%), half of science student teachers (50%), and the majority of physics student teachers (79%) drew the process of sight correctly. However, especially with a significant number of secondary students, the sight process was not explained in an acceptable way even though their drawings were correct. This was compatible with results from Heywood’s (2005) study, indicating that even though the students selected or drew the correct scientific representation of the process of sight, when asked to justify their views and provide an explanation, they were not able to articulate scientifically acceptable responses.

The study revealed misconceptions by participants about the sight process. Based on their drawings and explanations of the sight process, these misconceptions were “light goes out from the eyes to the object in the process of sight” and “light goes out from the eyes to a source in the process of sight”. Another crucial misconception or vague explanation was that light travels from a light source to an object and we see the object. In this explanation, participants neglected the light reflected from the object reaching the eyes. It was clear from the literature that light was a difficult concept to understand as also proved to be true in this particular study. This suggested science and technology, and physics, teachers required opportunities to develop their content-specific pedagogical knowledge so as to helps them teach certain concepts appropriately and overcome the issues related to misconceptions.

It is worthy of note here to point out that results of this particular study are limited to those who participated in this study. The results statistically may not be generalized to a larger universe, although it is believed that the study and its results provide significant information about the problematic issues in the light and sight topic across education levels. It is recommended that further studies with a larger sample be undertaken which may be more instructive in determining how to tackle the issue of teaching these fundamental concepts in physics. It is also thought that relying on a single data source could be seen as another limitation in this study. Thus it would be helpful to use clinical interviews to probe for detailed information about the participants' conception of light and related concepts.

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REFERENCES

Andersson, B. & Karrqvist, C. (1983). How Swedish Pupils Aged 12–15 years Understand Light and its Properties. *European Journal of Science Education*, 5(4), pp. 387-402.

Atasoy, Ş. & Akdeniz, A. R. (2007). Newton'un Hareket Kanunları Konusunda Kavram Yanılgılarını Belirlemeye Yönelik Bir Testin Geliştirilmesi ve Uygulanması (Developing and Applying a Test Related to Appearing Misconceptions about Newtonian Laws of Motion). *Türk Fen Eğitimi Dergisi(Journal of Turkish Science Education)*, 4(1), pp. 45-49.

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

Büyükkasap, E., Düzgün, B., & Ertuğrul, M. (2001). Lise öğrencilerinin ışık hakkındaki yanlış kavramları. *Milli Eğitim Dergisi*, 149. http://yayim.meb.gov.tr/dergiler/149/buyukkasap_duzgun_ertugrul.htm (13. 05. 2009).

Cansüngü, Ö. & Bal, Ş. (2000). İlköğretim öğrencilerinin ışık hakkındaki yanlış kavramları ve bu kavramları oluşturma şekilleri üzerine bir araştırma, IV. Fen Bilimleri Eğitim Kongresi, Hacettepe Üniversitesi, Ankara, pp. 156-161,

Cavell, S. & Jones, B. L. (1995). Teaching for Conceptual Change: Light and Vision, University of Tasmania, 25th AARE Conference, Hobart.

Clement, J. (1982). Students' Preconceptions in Introductory Mechanics. *American Journal of Physics*, 50(1), pp. 66-71.

Cohen, L. & Manion, L. (1994). *Research methods in education* (4th ed.). London: Routledge.

Çalık, M. & Ayas, A. (2005). A cross-age study on the understanding of chemical solutions and their components. *International Education Journal*, 6(1), pp. 30-41.

Çepni, S. & Keleş, E. (2006). Turkish Students' Conceptions about the Simple Electric Circuits. *International Journal of Science and Mathematics Education*, 4(2), pp. 269-291.

Çınar, S. (2003). İlköğretim 5. sınıf Fen Bilgisi programında yer alan ışık ünitesi ile ilgili basit araç-gereçler içeren deneysel etkinlikler geliştirme, Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Trabzon.

Driver, R. & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, 5(1), pp. 61-84.

De Posada, J. M. (1997). Conceptions of high school students concerning the internal structure of metals and their electric conduction: structure and evolution. *Science Education*, 81(4), pp. 445-467.

Eshach H. (2003). Small-Group Interview-Based Discussions about Diffused Shadow. *Journal of Science Education and Technology*, 12(3), pp. 261-275.

Fetherstonhaugh, T. & Treagust, D.F. (1992). Students' understanding of light and its properties: Teaching to engender conceptual change. *Science Education*, 76(6), pp. 653-672.

Furió, C. & Guisasola, J. (1998). Difficulties in learning the concept of electric field. *Science Education*, 82(4), pp. 511-526.

Galili, I. & Hazan, A. (2000). Learners' knowledge in optic: interpretation, structure and analysis. *International Journal of Science Education*, 22(1), pp. 57-88.

Gilbert, J. K. & Watts, D. M. (1983). Concepts, Misconceptions and Alternative Conceptions: Changing Perspectives in Science Education. *Studies in Science Education*, 10(1), pp. 61-98.

Gillespie, H. & Gillespie, R. (2007*). Science for Primary School Teachers*. Berkshire: Open University Press.

Gönen, S. (2008). A Study on Student Teachers' Misconceptions and Scientifically Acceptable Conceptions about Mass and Gravity. *Journal of Science Education and Technology*, 17(1), pp. 70-81.

Guesne, E. (1984). Children's ideas about light. In E. J. Wenham (Ed.), *New Trends in Physics Teaching,* Vol 4*,* (pp. 179-192). Paris: UNESCO.

Helm, H. (1980). Misconceptions in Physics amongst South African Students. *Physics Education*, 15(2), pp. 92-105.

Heywood, D. S. (2005). Primary trainee teachers' learning and teaching about light: Some pedagogic implications for initial teacher training. *International Journal of Science Education*, 27(12), pp. 1447-1475.

Ho, H-Z, O'Farrell, S.L., Hong, S., & You, S. (2006). Developmental Research: Theory, Method, Design and Statistical Analysis. In Green, J.L., Camilli, G., & Elmore, P. (Eds.), *Handbook of Complementary Methods in Education Research* (3rd Ed.) (pp. 207-225). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kaçan, B. (2008). Işık hakkındaki kavram yanılgılarının tespiti ve giderilmesine yönelik uygulamalar(Applications Towards Overcoming Misconceptions About Light), Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Ankara.

Kara İ., Avcı D. E., & Çekbaş, Y. (2008). Fen Bilgisi Öğretmen Adaylarının Işık Kavramı ile İlgili Bilgi Düzeylerinin Araştırılması(Investigation of the science teacher candidates' knowledge level about the concept of light). *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, 16, pp. 46-57.

Koray, Ö. C. & Bal, Ş. (2002). İlköğretim 5. ve 6. sınıf öğrencilerinin ışık ve ışığın hızı ile ilgili yanlış kavramları ve bu kavramları oluşturma şekilleri(Primary school 5th and 6th grade students misconceptions about light and speed of light and forms of construction of these conceptions), *G.Ü. Gazi Eğitim Fakültesi Dergisi(Journal of Gazi Education Faculty)*, 22(1), pp. 1-11.

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

Miles, M. B. & Huberman, A. M. (1994). *Qualitative Data Analysis* (2nd ed.). London: Sage.

Morgil, İ. & Yörük, N. (2006). Cross-Age Study of The Understanding of Some Concepts in Chemistry Subjects in Science Curriculum. *Journal of Turkish Science Education*, 3(1), pp. 15-27.

Osborne, R. & Freyberg, P. (1995). Children's Science. In R. Osborne & P. Freyberg (Eds.), *Learning in Science: The implications of children's science*. Hong Kong: Heinemann.

Osborne, J., Black, P., Smith, M., & Meadows, J. (1990). Light-Science Processes and Concept Exploration, Research Report, Primary SPACE Project, Liverpool University Press.

Özden, M. (2007). Problems with Science and Technology Education in Turkey. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(2), pp. 157-161.

Ruane, J. M. (2005). *Essentials of Research Methods A Guide to Social Sciences Research*. UK: Blackwell Publishing,

Stead, B. F. & Osborne, R. J. (1980). Exploring students' concepts of light. *Australian Science Teachers Journal*, 26(3), pp. 84-90.

Stein, M., Barman, C., & Larrabee, T. (2007). What are they thinking? The development and use of an instrument that identifies science misconceptions. *Journal of Science Teacher Education*, 18(2), pp. 233-241.

Şahin, Ç., İpek, H., & Ayas, A. (2008). Students' understanding of light concepts in primary school: A cross-age study. *Asia-Pacific Forum on Science Learning and Teaching*, 9(1), Article 7.

Şen, A., İ. (2003). İlköğretim Öğrencilerinin Işık, Görme ve Aynalar Konusundaki Kavram Yanılgılarının ve Öğrenme Zorluklarının İncelenmesi (Investigation of The Misconceptions and Learning Difficulties of Elementary Students on Light, Vision and Mirrors). *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 25, pp. 176-185.

Toh, K. A., Boo, H. K., & Woon, T. (1996). Gender Differences in Students' Understanding of Light and Sight, ERA/AARE Joint Conference, Singapore.

Van Zee, E. H., Hammer, D., Roy, M.B.P., & Peter, J. (2005). Learning and teaching science as inquiry: A case study of elementary school teachers' investigations of light. *Science Education*, 89(6), pp. 1007-1042.

Yalcin, M., Altun,S., Turgut, U., & Aggül F. (2009). First Year Turkish Science Undergraduates' Understandings and Misconceptions of Light. *Science & Education*, 18(8), pp. 1083-1093.

Yeşilyurt, M., Bayraktar, Ş., Kan, S., & Orak, S. (2005). İlköğretim öğrencilerinin ışık kavramı ile ilgili düşünceleri(Primary Education Students' Views About Light Concept). *Yüzüncü Yıl Üniversitesi, Eğitim Fakültesi Dergisi,* 2(1), pp. 1-24.

Yıldız, İ. (2000). İlköğretim 6. sınıf öğrencilerinin ışık ünitesindeki kavram yanılgıları, Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Trabzon.