Eurasia Journal of Mathematics, Science & Technology Education, 2015, **11**(6), 1677-1695

An Evaluation of the Instruction Carried Out With Printed Laboratory Materials Designed in Accordance With 5E Model: Reflection of Light And Image on a Plane Mirror

Hakan Sevki Ayvaci & Mehmet Yildiz
Karadeniz Technical University, TURKEY
Hasan Bakirci
Yüzüncü Yıl University, TURKEY

•*Received 22 March 2014*•*Revised 4 August 2014* •*Accepted 22 January 2015*

This study employed a print laboratory material based on 5E model of constructivist learning approach to teach reflection of light and Image on a Plane Mirror. The effect of the instruction which conducted with the designed print laboratory material on academic achievements of prospective science and technology teachers and their attitudes towards physics laboratory was questioned. The study was carried out with 98 prospective teachers who attended the course named General Physics Laboratory III and undergraduate students at the Department of Science Education at Karadeniz Technical University during 2011-2012 fall semesters. The study was conducted by adopting semi-experimental method. Experimental group instructed with the designed print laboratory material whereas control group instructed in through traditional laboratory practices. The Achievement Test, Physics Laboratory Attitude Scale, and Reflective Writings were used as data collection tools. It was proved that the instruction carried out with print laboratory materials based on 5E model contributed to academic achievements of prospective teachers and their attitudes towards physics laboratory more than the instruction based on traditional approach. Based on the research results, it was recommended that print materials prepared based on the constructivist learning theory could be generalized in the Physics Laboratory courses.

Keywords: Constructivist Learning Theory, 5E learning model, Prospective Science and Technology Teachers, The Reflection of Light, Image on A Plane Mirror, Teaching Material

Correspondence: Hakan Sevki Ayvaci,
Karadeniz Technical University, Fatih Faculty of Education, Department of Primary Teacher Education, Trabzon/Turkey
E-mail: hsayvaci@gmail.com
doi: 10.12973/eurasia.2015.1496a

ISSN: 1305-8223

INTRODUCTION

State of the literature

- Many studies proved that learners studying at various levels have been having difficulty in learning reflection of light and image on a plane mirror (e.g., Yıldırım Benli, 2010; Tekos & Solomonidou, 2009; Andersson & Bach, 2005; Chen, Lin & Lin, 2002). In addition, it was detected that prospective teachers develop negative attitudes towards physics laboratory (e.g. Açışlı & Turgut, 2011; Saxena, 1991).
- There is an increasing need for the conducted in order to reveal the effect of experimental activities based on constructivist approach on the learning of reflection of light and image on a plane mirror.
- There is also a need for the studies that aims raise the quality of the instruction given in physics laboratories.

Contribution of this paper to the literature

- This study proved that learning process based on 5E learning model of constructivist approach have a positive effect on academic achievements of prospective teachers as well as their attitudes towards physics laboratory.
- Print teaching material based on 5E learning model of constructivist approach which can be used for Physics III laboratory course was developed during this study.
- It was proven that experimental activities based on 5E learning model of constructivist approach raised the quality of the instruction given in Physics laboratories.

Science education is generally based on deductions inferred from data obtained through observations and experiments (Toplis & Allen, 2012; Bahadır, 2007; Clement, 1982). Deductions are commonly associated with complicated and abstract issues. Learners make sense of complicated issues more by personal observation. Since laboratory practices can enable learners to have a first-hand access to scientific knowledge via observations and experiments (Ayvacı, 2013; Trumper, 2003), laboratory practices are of great importance during the process of science education. Despite their role and function in science education, laboratory practices are not effectively used in science classroom (Ayvacı, 2013; Toplis & Allen, 2012; Yeşilyurt, 2003). There are many theories covering laboratory practices. One of these theories, which is also the most commonly used, is constructivist learning theory.

Various learning cycle models such as 4E, 5E and 7E based on constructivist learning theory were developed. Among these models, the most widely used one is the 5E model. It consists of the following 5 stages: Engage, Explore, Explain, Elaborate, and Evaluate. The stage of engage raises the attention and motivation levels of learners. During engage pre-knowledge of learners are questioned as well. The stage of explore presents learners a problem, and learners are expected to solve this problem based on their pre-knowledge. The stage of explain involves presentation of the ways leading to the solution of the problem, how learners solved the problem, and the findings obtained as a result of the solution. The stage of elaboration involves association of newly constructed knowledge with various disciplines. During the stage of evaluation, new knowledge construction levels of learners are tried to be identified (Bakırcı & Çalık, 2013; Bybee, 1993). In this sense, it is esteemed that learners will be able to construct the science subjects which are hard to comprehend in their minds in a more qualified manner thanks to activities carried out during these stages. Stages of 5E model may cover laboratory activities. For example, learners' curiosity may be raised via an experiment during the stage of engage. In addition, it is possible to enable learners to design different experiments during the stage of explore. Moreover, learners may analyze the relationships between the concepts or variables regarding the subject. These kinds of practices may easily be carried out for all disciplines of science education.

Physics subjects are stated to be one of the science subjects in which students have most difficulty. It was found out in numerous studies about the teaching of geometrical optics that students from various learning levels did not have enough conceptual development about the subjects of "The Reflection of Light" and "Image on a Plane Mirror" (Tekos & Solomonidou, 2009; Andersson & Bach, 2005; Hubber, 2005). This result indicated that non-scientific pre-knowledge of learners have a

Table 1. Learning Difficulties and Misconceptions Regarding the Subjects "Reflection of Light and Image on Plane Mirror"

Learners' Learning Difficulties and Misconceptions Regarding the Reflection of Light	
• In relation to reflection of light; it was detected that learners have difficulty in defining the elements of reflection, express the angle of reflection as the angle emerging between reflective light and the mirror and confuse the reflection with refraction.	1, 3, 5, 7, 14
• It was specified that learners have difficulty in expressing the principles of reflection.	2, 7, 10, 14
• It was detected that learners have non-scientific opinions regarding regular and diffuse reflections.	3, 9, 11
Learners' Learning Difficulties and Misconceptions Regarding the Image on a Plane Mirror	
• It was found that learners have non-scientific opinions regarding the position of the image on a plane mirror, its reversion or erectness, the length, and its virtuality or reality.	1, 4, 6, 7, 8, 10, 12, 14
• It was detected that learners do not have enough conceptual development regarding the field of vision on a plane mirror.	2, 3, 10, 12, 13

negative impact on new learning. In addition, it is suggested that non-scientific knowledge of learners are claimed to stem from their daily experiences (Anıl & Küçüközer, 2010; Epik, Kalem, Kavcar & Çallıca, 2002). It is acknowledged that another reason leads learners to have difficulty in learning is instruction designs which provide a framework for learning process. Based on this fact, it is suggested that materials based on various instruction designs should be developed for teaching the reflection of light and image on plane mirror (Anıl & Küçüközer, 2010; Andersson & Bach, 2005; Akdeniz, Yıldız & Yiğit, 2001). At the end of literature review, it was seen that there is no study based on 5E model of constructivist approach specifically designed for subjects of reflection of light and image on plane mirror.

The studies in order to investigate the learning obstacles of the students and the misconceptions are listed(Table 1) as; 1:Palacios, Cazorla & Cervantes, (1989); 2:Saxena, (1991); 3:Akdeniz, Yıldız & Yiğit (2001); 4: Chen, Lin & Lin, (2002); 5: Colin, Chauvet & Viennot (2002); 6:Epik, Kalem, Kavcar & Çallıca (2002); 7: Andersson & Bach (2005) 8:Heywood (2005); 9:Hubber (2005);10:Alptekin & Yılmaz (2007); 11:Tekos & Solomonidou (2009); 12:Anıl &Küçüközer (2010); 13:Kocakülah & Demirci (2010); 14:Yıldırım Benli (2010).

There is a need for teaching materials in order to sustain an appropriate conduction of teaching process based on learning models. Based on this fact, it is possible to encounter various practices with different contents which were designed in accordance with 5E model. Learning materials supported with animations or simulations, enriched teaching materials and printed teaching materials can be listed as examples of these kinds of practices. Açışlı and Turgut (2011) stated that the use of print materials for laboratory practices provide learners an effective learning environment, enable learners to achieve the objectives more easily and have a vital role in leading the current program to success. In this sense, there can be said that print laboratory materials which were developed in accordance with 5E learning model have hold the potential to make positive contributions to academic achievements of prospective teachers as well as their attitudes towards physics laboratory.

Aim of the study

The purpose of this study was to determine the effects of the teaching process conducted through the teaching material developed in accordance with the 5E learning model on the academic achievements and attitudes towards physics laboratories of prospective science teachers.

METHODOLOGY

Research Design

In educational institutions, education and training are conducted in a planned and programmed manner. Educational institutions divide students into sections or groups within the scope of such plans and programs. Since the groups are established through a non-random selection during the formation of sample in semi-experimental studies (Tharenou, Donohue, & Cooper, 2007), educational research mostly prefer semi-experimental studies that are an alternative to full experimental methods (Çepni, 2010). Thus, in this study, semi-experimental method was adopted. Before and after experimental procedures, Achievement Test (AT) and Physics Laboratory Attitude Scale (PLAS) were administered to experimental group and control group. Detailed information about the experimental design provided in Table 2.

Sample

This study was conducted with the 2nd grade undergraduate students attended in Science and Technology Teaching Program of Department of Elementary Education at Fatih Faculty of Education at Karadeniz Technical University in the fall semester of the 2011-2012 academic years. 138 students, who were taking the General Physics Laboratory III course, participated in the study. The 25 of those students were included in the pilot study group at material development stage. The experimental process of the study was carried out with 113 students. However, the data from 98 students were taken into consideration based on the attendance of students. During sample selection, curriculum and instructional plan of the relevant educational institution, the suitableness of the study for application processes, and the voluntariness of students were taken into account. Table 3 provides the distribution of study group among pilot study, experimental group, and control group by gender and age range.

Data collection

Achievement Test (AT), Physics Laboratory Attitude Scale (PLAS), and Reflection Papers were used as data collection tools.

Achievement Test: It was developed for determining the achievement levels of prospective science and technology teachers on "The Reflection of Light" and "Image in a Plane Mirror". The questions were formed through the transformation of acquisitions expected to be obtained through experiments contained in the material into questions. The opinions of 4 instructors specialized in their fields were considered in order to investigate the reliability of the test. The Achievement Test consists of 4 questions. While the items "2-a" and "2-b" in the achievement test involve explanation and original drawing, 3rd question requires explanation and figure completion. In addition, the items "1-a" and "1-b" are open-ended questions, and the 4th question is based on figure interpretation. Table 4 presents the distribution of these questions by subjects and acquisitions.

Physics Laboratory Attitude Scale: The Physics Laboratory Attitude Scale (PLAS) developed by Nuhoğlu and Yalçın (2004) was administered to the experimental group and control group as pre-test and post-test in order to determine the attitudes of prospective teachers towards physics laboratory. The PLAS consists of total 36 items, 19 of them are positive, and 17 of them are negative. The scale contains likert-type items involving five choices (I strongly agree, I agree, I am neutral, I do not agree, I strongly disagree). The Cronbach's alpha reliability coefficient of the PLAC was found to be $\alpha = 0.89$ by researchers.

Table 2. Experimental design

Group	Pre-Test	Experimental Procedures	Post-Test
Experimental Group	AT, PLAS	The teaching conducted through the teaching material developed based on the constructivist learning theory	AT, PLAS
Control Group	AT, PLAS	Traditional teaching	AT, PLAS

Table 3. The demographic characteristics of the prospective science and technology teachers participating in the study

Groups	Gender						Age Range
	Female		Male		Total		
	N	%	N	%	N	%	
Pilot Study Group	16	64	9	36	25	100	19-22
Experimental Group	27	56	21	44	48	100	19-22
Control Group	30	60	20	40	50	100	19-23

Table 4. The distribution of questions in the achievement test by subjects and acquisitions

Subject	Acquisitions	Question No
The Reflection of Light	1. The student discovers the incident of reflection of light by conducting an experiment.	1-a
	2. The student discovers reflection rules by conducting an experiment.	1-b
	3. The student discovers regular reflection by conducting an experiment.	2-a
	4. The student discovers diffuse reflection by conducting an experiment.	2-b
Field of Vision	5. The student discovers field of vision in a plane mirror by conducting an experiment.	3
Image in a Plane Mirror	6. The student discovers the properties of image in a plane mirror by conducting an experiment.	4

Reflection Papers: During the teaching material design process, reflection papers were used so that student opinions had an influence of the development of material (Ayvacı, 2007). Reflection papers were collected from the pilot study group students to contribute to the development of teaching material at the pilot study stage. In addition, reflection papers regarding teaching method and teaching material were collected from the experimental group students at the main study stage. A reflection paper sample collected from students is as follows:

> *It was the first time that we used a printed material in a laboratory course in our educational life. The experimental leaflets we had used before mostly explained the experiments. However, this material enabled us to comprehend the subject as a whole. Normally, our teachers had demonstrated and explained the experiments during laboratory course. However, in that course, we covered the subjects in accordance with the guide material under the guidance of our instructor. The fact that our teacher stepped in and controlled us only at the points where we had difficulty enabled us to discover the subject in group. I do not think I will forget what I learnt in that course. The teaching material was well-prepared. However, the picture in the first section of the material seemed bad. I think it should be changed. I will definitely teach the experiments which I learnt in that course hour to my students in my teaching life. Especially the candle experiment was very successful.*

The Development Process of Teaching Material

In this study, teaching materials were developed through three basic stages. Firstly, the preliminary template of the material was designed. The opinions of two instructors specialized in their fields were taken during the arrangement of the template version of the material prior to pilot study. After necessary arrangements were made in the preliminary template, the researchers proceeded to pilot study. The deficient aspects of the material were determined at the end of the pilot study, and various arrangements were made in the material. Upon the completion of the pilot study, some changes were made in the material based on the opinions of specialized instructors, the notes taken by the researcher in the teaching process, and the reflection papers concerning the teaching material collected from students. Then, the researcher proceeded to the main study stage. Upon the completion of the main study, the material was finalized based on the opinions of specialized instructors, the notes taken by the researcher in the teaching process, the reflection papers concerning the teaching material and teaching process collected from students, and the opinions of a linguist. The Annex-1 shows the changes made in the content of the teaching material during teaching processes in accordance with the stages of the 5E learning model. Annex-2 presents the general changes made in the teaching material.

Data analysis

The understanding level categories set by Abraham et al. (1992) were used for evaluating the achievement test. The distribution of the prospective science and technology teachers in the experimental group and control group according to understanding level categories was tabulated in percentages. The tables formed were supported through sample answers from prospective teachers. At this stage, some abbreviations were used. For example, E-1 refers to the first prospective teacher in the experimental group while C-1 refers to the first prospective teacher in the control group. Then, these understanding levels were scored, and the pre-test achievement levels and post-test achievement levels of the experimental group and control group were calculated by means of the independent t-test. Statistical analyses were conducted through SPSS 15.0. Table 5 shows the evaluation criteria and points which are used in analyzing the questions included in the achievement test. The highest score achievable in the Achievement Test is 24, while the lowest one is zero.

The items in the Physics Laboratory Attitude Scale were scored based on student answers (I Strongly Agree: 5 points; I Agree: 4 points; I am Neutral: 3 points; I Do Not Agree: 2 points; I Strongly Disagree: 1 point). Then, the pre-test and post test attitude levels of the experimental group and control group were calculated in order to conduct the t-test. Statistical analyses related to the Physics Laboratory Attitude Scale were carried out through SPSS 15.00.

RESULTS

The understanding levels of prospective teachers on "The Reflection of Light" and "Image in a Plane Mirror" were determined through the achievement test. The questions in the test were analyzed through categorization under "The Reflection of Light" and "Image in a Plane Mirror".

The questions about the subject of "The Reflection of Light" were categorized within themselves. In the pre-test and post-test, the conceptual perceptions of students about the definition of reflection and the laws of reflection were determined through the items "a" and "b" of the first question. Understanding levels concerning the concepts of regular reflection and diffuse reflection were determined through the items "a" and "b" of the second question. Table 6 presents the frequency and percentage distribution of the understanding levels of the prospective teachers in the experimental group and control group on "The Reflection of Light" from the pre-test and post-test results (see Table 6).

The conceptual perceptions of prospective teachers about the definition of reflection were determined through the item 1-a in the Achievement Test. Pre-test results about this subject showed that a great majority of the prospective teachers in the experimental group and control group were at the level of not understanding (45.8%-40%). Post-test results demonstrated that the prospective teachers in the experimental group were mostly at the levels of partial understanding (39.6%) and

Table 5. The evaluation criteria and points used in analyzing the questions in the test

Understanding Levels	Scoring Criteria	Point
Complete Understanding	Answers including all aspects of the valid answer	4
Partial Understanding	Answers including some aspects, but not all aspects of the valid answer	3
Partial Understanding Accompanied by a Particular Misconception	Answers showing that the concept has been understood partly though including a misconception	2
Misunderstanding	Scientifically wrong answers	1
Not Understanding	Situations in which no answer is provided; answers including expressions such as "I do not know", "I have not understood", etc.; and cases in which the question is repeated exactly the same way, or irrelevant or unclear answers are provided	0

Table 6. The distribution of the understanding levels of prospective teachers on the subject of "the reflection of light"

Question No.	Understanding Level	Pre-Test				Post-Test			
		Experimental Group		Control Group		Experimental Group		Control Group	
		f	%	f	%	f	%	f	%
1-a	Complete Understanding	0	0.0	0	0.0	15	31.3	7	14.0
	Partial Understanding	5	10.4	6	12.0	19	39.6	12	24.0
	Partial Understanding Accompanied by a Particular Misconception	8	16.7	10	20.0	11	22.9	16	32.0
	Misunderstanding	13	27.1	14	28.0	2	4.2	8	16.0
	Not Understanding	22	45.8	20	40.0	1	2.1	7	14.0
	Total	48	100	50	100	48	100	50	100
1-b	Complete Understanding	0	0.0	0	0.0	17	35.4	15	30.0
	Partial Understanding	6	12.5	8	16.0	21	43.8	17	34.0
	Partial Understanding Accompanied by a Particular Misconception	17	35.4	15	30.0	8	16.7	11	22.0
	Misunderstanding	13	27.1	16	32.0	2	4.2	6	12.0
	Not Understanding	12	25.0	11	22.0	0	0.0	1	2.0
	Total	48	100	50	100	48	100	50	100
2-a	Complete Understanding	4	8.3	1	2.0	21	43.8	16	32.0
	Partial Understanding	6	12.5	8	16.0	15	31.3	18	36.0
	Partial Understanding Accompanied by a Particular Misconception	8	16.7	15	30.0	11	22.9	11	22.0
	Misunderstanding	14	29.2	9	18.0	1	2.1	3	6.0
	Not Understanding	16	33.3	17	34.0	0	0.0	2	4.0
	Total	48	100	50	100	48	100	50	100
2-b	Complete Understanding	0	0.0	0	0.0	11	22.9	8	16.0
	Partial Understanding	1	2.1	3	6.0	16	33.3	14	28.0
	Partial Understanding Accompanied by a Particular Misconception	10	20.8	6	12.0	19	39.6	16	32.0
	Misunderstanding	16	33.3	14	28.0	1	2.1	8	16.0
	Not Understanding	21	43.8	27	54.0	1	2.1	4	8.0
	Total	48	100	50	100	48	100	50	100

complete understanding (31.3%) while the prospective teachers from the control group were at the level of partial understanding accompanied by a particular misconception (32%). C-7 who was found to be at the level of partial understanding accompanied by a particular misconception in pre-test defined reflection by saying, "...The light is hitting on a point (place) and coming back..." The same prospective teacher was found to be at the level of partial understanding in post-test, and defined reflection by saying "...Light rays are hitting a shiny surface and returning to the medium of departure...” During pre-test and post-test, C-7 stated nothing about the media where reflection takes place and the reflection manners of the light rays reflecting. Similar misconceptions were encountered in the answers of many prospective teachers. For example, E-18 who was found to be at the level of partial understanding accompanied by a particular misconception in post-test explained the reflection of light as follows: “...Light progressing through a transparent medium is hitting a non-transparent medium and coming back...”

The understanding levels of the prospective teachers in the experimental group and control group concerning the laws of reflection were investigated through the item 1-b. Within the scope of that question, the prospective teachers were asked to explain the laws of reflection. Pre-test results indicated that most of the prospective teachers in the experimental group were at the level of partial understanding accompanied by a particular misconception (35.4%) while most of the prospective teachers in the control group were at the level of misunderstanding (32%). It is remarkable that no prospective teacher from the experimental group was at the level of not understanding, according to the post-test results. However, table 6 demonstrates that there were prospective teachers from both the experimental group and the control group who were found to be at the levels of misunderstanding (4.2%-12%) and partial understanding accompanied by a particular misconception (16.7%-22%) based on post-test results. C-32 who was found to be at the level of misunderstanding in pre-test described the laws of reflection as, “...The height of image is equal to that of object, and both of them are real images...” E-45 who was found to be at the level of partial understanding in post-test answered the question as follows “...The angle of incidence is equal to the angle of reflection...”

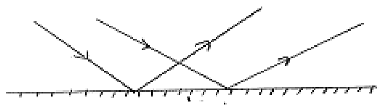
The understanding levels of the prospective teachers in the experimental group and control group on regular reflection were investigated through the item 2-a. In that question, the prospective teachers were asked to explain regular reflection through drawing and writing methods. Pre-test results concerning the question showed that the most of the prospective teachers in the experimental group and control group were at the level of not understanding (33.3%-34%). Post-test results indicated that most of the experimental group prospective teachers were at the level of complete understanding (43.8%) while most of the control group prospective teachers were at the level of partial understanding (36%). C-19 who was found to be at the level of misunderstanding in pre-test described regular reflection as, “...The light is coming onto mirror during its flat motion...” though s/he did not draw anything about regular reflection. The same prospective teacher was found to be at the level of partial understanding in post-test. In the drawing section of the question, s/he drew the figure normally, but did not mention angular values.

The understanding levels of the prospective teachers in the experimental group and control group on diffuse reflection were investigated through the item 2-b. In that question, the prospective teachers were asked to explain diffuse reflection through drawing and writing methods. Pre-test results demonstrated that approximately half of the prospective teachers in the experimental group (43.8%) and more than half of the prospective teachers in the control group (54%) were at the level of not understanding. However, post-test results indicated that the most of the prospective teachers in the experimental group and control group were at the levels of partial understanding accompanied by a particular misconception (39.6%-32%) and partial understanding (33.3%-28%). In general, the students in the experimental group and control group made mistakes in the drawings. For example, C-33 who was at the level of partial understanding accompanied by a particular misconception according post-test results provided a deficient and wrong definition and drawing of diffuse reflection. The drawing of that student suggested that a light ray hitting a rough surface during diffuse reflection moves forward through surface in a curved manner.

2. Explain regular reflection and diffuse reflection through writing and drawing methods.

A. Regular reflection:

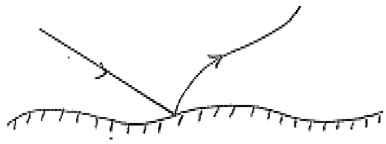
A light ray sent to a smooth surface reflects back by creating regular and equal angles. This kind of reflection is regular refection.



Smooth area

B. Diffuse reflection:

The reflection taking place on rough surfaces is called diffuse reflection. In diffuse reflection, light does not reflect by creating regular and equal angles

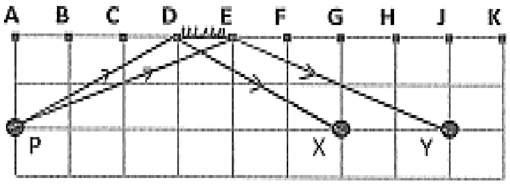


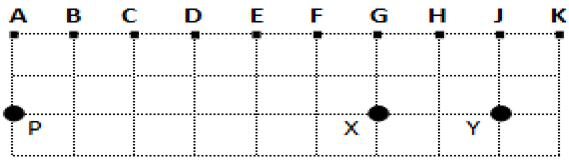
Rough area

Figure 1. Sample student answer concerning the second question

3. *A person looking from the point P can see the area between X and Y objects by looking at the plane mirror in the direction of A to K.*

Accordingly, between which points does the plane mirror stand? Make necessary explanations through drawing on the picture.





The plane mirror stands between the points D and E.

Figure 2. Sample student answer concerning the third question

Figure 1 provides a sample from prospective teacher answer to the items "2-a" and "2-b" of the 2nd question in the Achievement Test. While C-33 was found to be at the level of partial understanding with his/her answer to the item "2-a" of the question in post-test, s/he was found to be at the level of partial understanding accompanied by a particular misconception with his/her answers to the item "2-b".

Table 7 provides the findings obtained through the analysis of the 3rd and 4th questions on "Image in a Plane Mirror" taught to the experimental group and control group. These findings are presented in frequencies and percentages based on pre-test and post-test results.

The understanding levels of prospective teachers concerning the field of vision in a plane mirror were determined through the third question in the achievement test. Pre-test results about this question showed that the most of the prospective teachers in the experimental group and control group were at the level of not understanding (45.8%-40%). However, post-test results showed that the most of the experimental group prospective teachers were at the levels of complete understanding (37.5%) and partial understanding (29.2%), while the most of the control group prospective teachers were at the levels of partial understanding (34%) and partial understanding accompanied by a particular misconception (28%). In the pre-test, the most of the prospective teachers in the experimental group and control group left the question unanswered. Table 7 shows a clear rise took place in the understanding levels of the prospective teachers from both groups. It was observed that prospective teachers had a deficiency or mistake in the drawing section of the question, and did not provide complete explanations concerning the question. E-14 who was found to be at the level of misunderstanding in pre-test sent a light ray to the midpoint of mirror in the drawing section of the question though s/he had to send a light ray to both ends of mirror, and s/he did not make any explanation. While the same prospective teacher was at the level of partial understanding according to post-rest results, s/he did not show any angular value though s/he performed drawing correctly. In addition, s/he did not explain his/her answer by associating the question with the laws of reflection. Figure 2 provides a sample prospective teacher answer to the third question in the Achievement Test. E-14 was found to be at the level of partial understanding in post-test based on his/her answer to the third question.

The understanding levels of the prospective teachers about the position, size, and properties of image in a plane mirror were determined through the fourth question of the Achievement Test. Pre-test results about this question suggested that the most of the prospective teachers in the experimental group and control group were at the level of partial understanding accompanied by a particular misconception (33.3%-38%). Post-test results showed that the most of the prospective teachers in the experimental group and control group were at the level of complete understanding (47.9%-34%). It was observed during the pre-test and post-test that the prospective teachers had difficulty in giving the correct answer in that question because they turned to misconceptions about virtual image and real image, the position of image, the reverse or regular nature of image, the size of image in a plane mirror, etc. It was found out in particular that the prospective teachers in the experimental group and control group perceived the image was formed inside or on the surface of plane mirror, but not behind it. For example, E-41 who was determined to be at the level of partial understanding accompanied by a particular misconception in pre-test found the image asked in the question. However, s/he said, "...The image in a mirror plane is virtual, and it is on the surface of the mirror..." In addition, C-24 who was at the level of misunderstanding according post-test results made a wrong choice by saying, "...The image in a plane mirror is behind the mirror, and is real and reverse..."

In this section, the arithmetic averages of the pre-test and post-test total scores of the experimental group and control group students related to the same questions were statistically compared. In this respect, analyses were performed based on the pre-test and post-test results of the experimental group and control group. The t-test

Table 7. The distribution of the understanding levels of prospective teachers on the subject of "image in a plane mirror"

Question No.	Understanding Level	Pre-Test				Post-Test			
		Experimental Group		Control Group		Experimental Group		Control Group	
		f	%	f	%	f	%	f	%
3	Complete Understanding	0	0.0	1	2.0	18	37.5	8	16.0
	Partial Understanding	4	8.3	7	14.0	14	29.2	17	34.0
	Partial Understanding Accompanied by a Particular Misconception	10	20.8	13	26.0	8	16.7	14	28.0
	Misunderstanding	12	25.0	9	18.0	6	12.5	6	12.0
	Not Understanding	22	45.8	20	40.0	2	4.2	5	10.0
	Total	48	100	50	100	48	100	50	100
4	Complete Understanding	0	0.0	0	0.0	23	47.9	17	34.0
	Partial Understanding	13	27.1	9	18.0	6	12.5	12	24.0
	Partial Understanding Accompanied by a Particular Misconception	16	33.3	19	38.0	11	22.9	10	20.0
	Misunderstanding	12	25.0	14	28.0	5	10.4	6	12.0
	Not Understanding	7	14.6	8	16.0	3	6.3	5	10.0
	Total	48	100	50	100	48	100	50	100

was employed for the statistical analysis. In accordance with those analyses, tables were created and interpreted.

The arithmetic averages of the pre-test total scores obtained by the experimental group and control group prospective teachers in the Achievement Test were statistically compared through the independent groups t-test. Table 8 provides a comparison via independent groups t-test of the total scores obtained by the experimental group and control group through the implementation of Achievement Test as a pre-test.

The examination of table 7 shows that the arithmetic average of the total scores of 48 prospective teachers in the experimental group was 7.06 before the experimental study while the arithmetic average of the total scores of 50 prospective teachers in the control group was 7.34. Standard deviation value was calculated to be 3.14 in the experimental group, while it was found 2.91 in the control group.

The examination of Table 9 demonstrates that the arithmetic average of the total scores of 48 prospective teachers in the experimental group was 17.66 after the experimental study while the arithmetic average of the total scores of 50 prospective teachers in the control group was 14.84. Standard deviation value was calculated to be 3.10 in the experimental group, while it was found 4.22 in the control group. In addition, t value was found to be 3.75, and p significance level was 0.000. Since the result of the independent groups t-test conducted over these values was as follows: ($t(96)= 3.75$; $p<.05$), a statistically significant difference in favor of the experimental group was found between the post-test scores of the experimental group and control group related to questions.

The attitudes of the prospective teachers in the experimental group and control group towards physics laboratory were tested before and after experimental procedures. The initial attitudes towards physics laboratory of the students in both groups were determined through pre-measurement. After experimental procedures were carried out, an attempt was made to determine whether there was any change in the attitudes of students towards physics laboratory. To this end, the arithmetic averages of the total scores of students were analyzed based on the pre-test and post-test results of the experimental group and control group. Based on those analysis, tables were created and interpreted.

The arithmetic averages of the pre-test scores obtained by the experimental group and control group prospective teachers in the Physics Laboratory Attitude Scale were statistically compared through the independent groups t-test. Table 10 provides a comparison via independent groups t-test of the scores obtained by the experimental group and control group through the implementation of Physics Laboratory Attitude Scale for pre-measurement purposes.

The examination of Table 10 demonstrates that the arithmetic average of the scores of 48 prospective teachers in the experimental group was 2.83 before the experimental study while the arithmetic average of the scores of 50 prospective teachers in the control group was 2.74. Standard deviation value was calculated to be 0.37 in the experimental group, while it was found 0.42 in the control group. In addition, t value was found to be 1.03, and p significance level was 0.305. Since the result of the independent groups t-test conducted over these values was as follows: ($t(96)= 1.03$; $p>.05$), no statistically significant difference was found between the attitudes towards physics laboratory of the experimental group and control group for pre-measurement.

The arithmetic averages of the post-test scores obtained by the experimental group and control group prospective teachers in the Physics Laboratory Attitude Scale were compared through the independent groups t-test. Table 11 provides a comparison via independent groups t-test of the scores obtained by the experimental

Table 8. The Comparison of AT Pre-Test Scores of the Experimental Group and Control Group

Groups	N	$\overline{X}$	Sd	df	t	p
Experimental Group	48	7.06	3.14	96	-0.45	0.87
Control Group	50	7.34	2.91			

Table 9. The comparison of at post-test scores of the experimental group and control group

Groups	N	$\overline{X}$	sd	df	t	p
Experimental Group	48	17.66	3.10	96	3.75	0.000
Control Group	50	14.84	4.22			

Table 10. The comparison of PLAS pre-test scores of the experimental group and control group

Groups	N	$\overline{X}$	Sd	df	t	p
Experimental Group	48	2.83	0.37			

Table 11. The comparison of PLAS post-test scores of the experimental group and control group

Groups	N	$\overline{X}$	sd	df	t	p
Experimental Group	48	3.91	0.44	96	2.48	0.014

group and control group through the implementation of Physics Laboratory Attitude Scale for post-measurement purposes.

The examination of table 11 demonstrates that the arithmetic average of the scores of 48 prospective teachers in the experimental group was 3.91 after the experimental study while the arithmetic average of the scores of 50 prospective teachers in the control group was 3.59. Standard deviation value was calculated to be 0.44 in the experimental group, while it was found 0.48 in the control group. In addition, t value was found to be 2.48, and p significance level was 0.014. Since the result of the independent groups t-test conducted over these values was as follows: ($t(96)= 2.48$; $p<.05$), a statistically significant difference in favor of the experimental group was found between the attitudes towards physics laboratory of the experimental group and control group for post-measurement.

DISCUSSION

When the findings of pre-measurement regarding the reflection were analyzed, it was seen that prospective teachers in experimental and control groups have difficulty in defining the reflection. Due to the fact that prospective teachers lack adequate opinion in relation to the nature of the light, they are thought to fail in defining the reflection of light scientifically. The definition belonging to prospective teacher encoded as K–7, The phenomenon of light's hitting on a certain place and its return…", is a supportive finding. The learners generally benefited from the concrete examples they encounter in their daily lives while explaining the abstract concepts. Many studies in literature proved that prospective teachers lack adequate knowledge on the nature of light (Yıldırım Benli, 2010; Epik, Kalem, Kavcar & Çallıca 2002; Akdeniz, Yıldız & Yiğit, 2001; Palacios, Cazorla & Cervantes, 1989). It is claimed that these non-scientific pre-knowledge may lead to misconceptions in relation to geometrical optics (Yıldırım Benli, 2010; Akdeniz, Yıldız & Yiğit, 2001). The findings obtained in post-measurement indicate that most of the prospective teachers define reflection of light accurately. It is assumed that the activities strengthening pre-knowledge of prospective teachers play a major role in raising comprehension levels regarding the reflection (Luangrath & Pettersson, 2012; Bodner, 1986). Based on this fact, it is possible to say that the activities conducted during the stage of Engage strengthened the pre-knowledge of prospective teachers.

When findings obtained as a result of pre-measurement in relation to principles of reflection were analyzed, it was seen that prospective teachers in both experimental and control groups share similar non-scientific opinions. Non-scientific answers of prospective teachers in relation to principles of reflection included over-explanations, lacking explanations or incorrect explanations. Prospective teacher encoded as D-14 claimed that there are three principles of reflection during pre-measurement. Prospective teacher encoded as K-21 made an incomplete explanation which is as follows: "Reflection is the return of light after hitting on a surface" Misconceptions of prospective teachers regarding this subject correspond with the ones reviewed in literature (Yıldırım Benli, 2010; Andersson & Bach, 2005; Colin, Chauvet & Viennot, 2002; Saxena, 1991; Palacios, Cazorla & Cervantes, 1989). It is assumed that this failure stems from the fact that prospective teachers were not able to construct the reflection of light accurately, which is a rather simple concept, until undergraduate years. Many prospective teachers stated that the light move in accordance with the principles of reflection after the practice. Generally, prospective teachers defined the principles of reflection accurately. For example, prospective teacher encoded as D-14 expressed the principle of reflection accurately. On the other hand, some of the prospective teachers failed to express the second principle of reflection despite the activities. Prospective teacher encoded as K-21 expressed the first principle of reflection accurately whereas s/he failed in the second one. The most important reason as to the failure of expressing the second principle of reflection is thought to be the incapability of perceiving the plane movement of reflected light in three-dimensional environment.

When findings obtained as a result of pre-measurement regarding regular and diffuse reflection were analyzed, it was seen that prospective teachers from both experimental and control groups concentrate on low levels of comprehension. It was detected that prospective teachers made an incorrect drawing of regular and diffuse reflections or their drawing were incomplete. It was observed in the drawings of prospective teachers that elements of reflection were not thoroughly displayed. In addition, some of the prospective teachers stated that the light reflecting from a rough surface propagates not in a linear but in a wriggly way. The drawing of prospective teacher encoded as K-33 is an example of this kind(See Figure-1). Prospective teacher encoded as K-33 showed that during diffuse reflection, the light reflects in a different angle from its coming angle. Similar misconceptions were encountered in some of the prospective teachers during post-measurement as well. As a matter of fact, Saxena (1991) reported that although prospective teachers knew the principles of reflection, they had difficulty in including the event of light reflecting through equal angles to the normal in their answers. In addition, it was detected in some of the studies that learners from different educational levels have difficulty in distinguishing the behaviors of the light on different surfaces (Anıl & Küçüközer, 2010; Andersson & Bach, 2005). It is believed that prospective teachers have non-scientific opinions due mainly to the fact that they fail to transfer the new knowledge they construct to different problem situations. In the elaborate stage of 5E learning model, the learners transfer the knowledge they construct to different problem situations (Bakırcı & Çalık, 2013). After the instruction, prospective teachers from experimental group managed to associate newly acquired knowledge to different problem situations. In other words, they gave more accurate replies for regular and diffuse reflections. In this sense, it is possible to say that the activities in the stage of elaborate which were related to daily life strengthened the association skills of prospective teachers.

When the findings obtained from pre-measurement regarding field of vision on a plane mirror were analyzed, both experimental and control group prospective teachers concentrate on low levels of comprehension similarly. At the end of the study, it was revealed that prospective teachers from experimental group generally could not draw the image accurately. In addition, it was also detected that prospective teachers failed to explain the subject in relation to the reflection and principles of reflection. The answer given by the prospective teacher encoded as D-14 is a clear example of this kind (See Figure 2). However, nearly half of the prospective teachers from control group drawn accurately while most of them failed to make association with principles of reflection. Similar results were encountered in many studies of literature (Kocakülah & Demirci, 2010; Anıl & Küçüközer, 2010; Alptekin & Yılmaz, 2007; Saxena, 1991). This indicates that the knowledge constructed by prospective teachers constitute a weak structure independent from the employed methods or models. Learners try to construct the knowledge they newly get regardless of the scientific principles. The fact that prospective teachers from experimental and control groups make accurate drawings and not mentioning the principles of reflection in their explanations support this claim. Constructivist learning theory emphasizes the construction of knowledge in social terms (Çalık, 2013; Fer, 2009; Matthews, 2002). Based on this assumption, presentation of the ways to obtain new knowledge and questioning of scientific quality of new knowledge are of importance in the explain stage of 5E learning model.

When the findings obtained as a result of pre-measurement conducted in relation to image on a plane mirror and its characteristics were analyzed, it was understood that prospective teachers from experimental and control groups possess some non-scientific opinions. In general terms, there were non-scientific opinions regarding the image's being virtual or real, its position, and its being reverse or erect. It was found in many studies that prospective teachers have similar difficulties regarding the image on a plane mirror and its characteristics (Bakırcı, 2014; Yıldırım Benli, 2010; Anıl & Küçüközer, 2010; Andersson & Bach, 2005; Heywood, 2005; Chen, Lin & Lin, 2002; Epik, et.al., 2002; Palacios, Cazorla & Cervantes, 1989). Alptekin & Yılmaz (2007) stated that prospective teachers head towards these misconceptions since they cannot build association between concrete and abstract concepts. It is rather interesting that prospective teachers have misconceptions regarding the appearance of image on a plane mirror which is frequently experienced in daily life. This may be the result of their failure in not constructing these abstract concepts adequately during their previous learning processes. In the explore stage of 5E teaching model, there are experimental activities which enable learners to construct abstract concepts. Despite these activities, it was seen that prospective teachers could not construct the phenomenon of image on a plane mirror thoroughly.

When the results of pre-measurement in relation to academic achievements of prospective teachers were analyzed, it was seen that prospective teachers both from experimental and control group concentrate on incomprehension and miscomprehension levels. When the results of post-measurement were analyzed, it was noted that majority of prospective teachers from experimental group had achieved the levels of full comprehension and partial comprehension. On the other hand, it was seen that prospective teachers from control group had been on the levels of partial comprehension and partial comprehension with a certain misconception. Based on this fact, it was seen that there is an increase in the levels of comprehension of prospective teachers during post-measurement compared to pre-measurement. However, it was also detected that prospective teachers from experimental group were more successful than the prospective teachers from control group. Statistical analysis result regarding the academic achievements of prospective teachers supports this conclusion ($t(96)= 3.75$; $p<.05$). Therefore, it was proven that print laboratory materials based on 5E model of constructivist learning theory contributed more to the academic achievements of prospective teachers than the instruction based on traditional laboratory practices. In many studies made within the scope of geometrical optics teaching (Yıldırım Benli, 2010; Tekos & Solomonidou, 2009; Andersson & Bach, 2005; Hubber, 2005), it was detected that the instruction prepared for different contexts and based on 5E model contributed to academic achievements of learners more than traditional teaching practices.

It is acknowledged that the most permanent learning is the one learning by practicing. Constructivist learning theory emphasizes that learners have to be active role players during the process of constructing new knowledge (Matthews, 2002; Köseoğlu & Kavlak, 2001). Learners become active role players in the learning based on 5E learning model which indicates that learners may construct the knowledge and repair their misconceptions more easily. Also, teachers have to prepare learning environments in which their students experience different things during their lectures (Ayvacı & Bakırcı, 2012; Taşar, 2006; Özmen, 2004). However, learners are not obliged to take active roles during instruction based on traditional laboratory practices (Toplis & Allen, 2012; Trumper, 2003). During the instruction of experimental group, prospective teachers took active roles in constructing the new knowledge. Thus, it is thought that prospective teachers from experimental group constructed the subjects of reflection of light and image on a plane mirror better.

Physics Laboratory Attitude Scale was employed to determine the attitudes of experimental group and control group prospective teachers towards physics laboratory. Whether the groups were homogenous was determined through pre-measurement. The change in attitudes of prospective teachers towards physics laboratory was determined through post-measurement.

The results of pre-measurement independent group t-test ($t(49)= -12.43$; $p<.05$) show that groups were homogenous. However, the results of post-measurement independent groups t-test ($t(96)= 2.48$; $p<.05$) demonstrate that there is a significant difference in favor of the experimental group between the attitudes of experimental group and control group towards physics laboratory. Thus, it can be said that the attitudes towards physics laboratory of the experimental group in which teaching process was conducted through the printed laboratory materials developed based on the 5E model of constructivist learning theory contributed more than the attitudes towards physics laboratory of the control group in which teaching process was based on traditional practices. Constructivist learning theory suggests that learning environment and individual characteristics are effective in constructing new knowledge (Naylor & Keogh, 1999). Those who learn according to 5E model improve their research curiosities, motivation levels as well as attitudes (Bakırcı & Çalık, 2013; Taşer, 2006; Özmen, 2004). Açışlı and Turgut (2011) determined that the experimental leaflets developed based on the constructivist learning theory improved the attitudes towards physical laboratory of students more in comparison to traditional laboratory practices.

CONCLUSION

The teaching process conducted through the teaching materials developed based on the constructivist learning theory made a bigger contribution to the academic achievements of prospective teachers in comparison to traditional laboratory practices.

The teaching process conducted through the teaching materials developed based on the constructivist learning theory had a higher positive effect on the attitudes towards physical laboratory of prospective teachers in comparison to traditional laboratory practices.

The study found out some points in which prospective science and technology teachers had difficulty on “The Reflection of Light”, “Regular Reflection and Diffuse Reflection”, “Field of Vision in a Plane Mirror”, and “Image in a Plane Mirror”. Some examples are as follows:

- ✓ They may have difficulty in describing the incident of the reflection of light.
- ✓ They may give deficient or wrong answers in regard to the laws of reflection.
- ✓ They may have difficulty in expressing the elements of reflection in regular reflection and diffuse reflection through drawings.
- ✓ They may have difficulty in associating the subject of "Field of Vision in a Plane Mirror" with the incident of reflection and the laws of reflection.
- ✓ They may have misconceptions about virtual image and real image, the position of image, the reverse or regular nature of image, and the size of image in a plane mirror.

RECOMMENDATIONS

It was concluded that the use of the constructivist learning theory in laboratory courses had a positive contribution to the academic achievements and attitudes towards physics laboratory of prospective teachers. In this regard, it is thought that the conduct of Physics Laboratory courses in accordance with the constructivist learning theory would be beneficial.

The teaching materials developed based on the constructivist learning theory may be used completely, partially, or through updates in the teaching of relevant subjects.

The points in which prospective teachers have difficulty on the subjects of optics may be determined within the scope of the General Physics Laboratory III course, and laboratory practices may be implemented for eliminating those learning difficulties of the prospective teachers.

The subjects of optics may be covered through integration with different disciplines so that prospective teachers can associate the subjects they learn in lessons with the situations likely to be encountered in the dairy life.

REFERENCES

Abraham., M. R., Gryzyboeski, E. B., Renner, J. W. & Marek, A. E. (1992). Understanding and misunderstanding eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, 29, 105-120.

Açışlı, S. & Turgut, Ü. (2011). The examination of the influence of the materials generated in compliance with 5e learning model on physics laboratory applications. *International Online Journal of Educational Sciences*, 3(2), 532-593.

Akdeniz, A. R., Yıldız, İ. & Yiğit, N. (2001). 6th class students' misconceptions about light subject. *Çukurova University Faculty of Education Journal*, 2(20), 72-78.

Alptekin, S. & Yılmaz, A. (2007). The effects of the change in the optic curriculum, added into 9th grade classes on the students success. *Ahi Evran University Journal of Kirşehir Education Faculty*, 8(1), 157-165.

Andersson, B. & Bach, F. (2005). On designing and evaluating teaching sequences taking geometrical optics as an example. *Science Education,* 89(2), 196-218. DOI: 10.1002/sce.20044

Anıl, Ö. & Küçüközer, H. (2010). Identifying 9th grader students' previous knowledge and misconceptions about plane mirrors. *Journal of Turkish Science Education*, 7(3), 104-122.

Ayvacı, H. Ş. (2007). A *study toward teaching the nature of science based on different approaches for classroom teachers in gravity content.* Unpublished Phd. Thesis, Karadeniz Technical University, Institute of Graduate Studies in Science. Trabzon.

Ayvacı, Ş. H. (2013). Investigating the effectiveness of predict-observe-explain strategy on teaching photo electricity topic. *Journal of Baltic Science Education*, 12(5), 548-564. ISSN 1648–3898.

Ayvacı, H. Ş. & Bakırcı, H. (2012). Analysis of science and technology teachers views about science education process in terms of 5E model. *Journal of Turkish Science Education*, 9(2), 132-151.

Bahadır, H. (2007). *The effect of elementary science education based on scientific method process on science process skills, attitude, academic achievement and retention.* Hacettepe University, Master's Thesis, Graduate School of Social Sciences, Ankara.

Bakırcı, H. (2014). *The study on evaluation of designing, implementing, and investigating the effects of teaching material based on common knowledge construction model: Light and voice unit sample.* Unpublished Phd. Thesis, Karadeniz Technical University, Institute of Graduate Studies in Science, Trabzon.

Bakırcı, H. & Çalık, M. (2013). Effect of guide materials developed in adaptation and natural selection subject on remedying grade 8 students' alternative conceptions. *Education and Science*, 38(168), 215-229.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, 63(10), 873-878. DOI: 10.1021/ed063p873.

Brooks, J. G. & Brooks M. G. (1993). *In search of understanding: The case for constructivist classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.

Bybee, R. (1993). *An instructional model for science education. In developing biological literacy*. Colorado Spring, CO: Biological Sciences Curriculum Study.

Chen, C. C., Lin, H. S. & Lin M. L. (2002). Developing a two-tier diagnostic instrument to assess high school students' understanding: The formation of images by plane mirror. *Proceedings of the National Science Council, Part D*. 12 (3), 106-121.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics,* 50(1), 66-71. DOI: 10.1119/1.12989.

Colin, P., Chauvet, F. & Viennot, L. (2002). Reading images in optics: Students difficulties and teachers views. *International Journal of Science Education*, 24(3), 313-332, DOI:10.1080/09500690110078923.

Çalık, M. (2013). Effect of technology-embedded scientific inquiry on senior science student teachers' self-efficacy. *Eurasia Journal of Mathematics, Science & Technology Education*, 9(3), 223-232. DOI: 10.12973/eurasia.2013.931a.

Çepni, S. (2010). *Introduction to research and project studies.* Celepler Printing, 4th Edition, Trabzon.

Epik, Ö., Kalem, R., Kavcar, N. & Çallıca H. (2002). Investigation of the students views about the concepts of light, image formation, and image observation. *Dokuz Eylül University Buca Education Faculty Journal*, 14: 64-73.

Fer, S. (2009). Social constructivism and social constructivist curricula in Turkey for the needs of differences of young people: Overview in light of the PROMISE project. In T. Tajmel & S. Klaus (Eds.), Science education unlimited: Approaches to equal opportunity in learning science (pp. 179-199). Münster: Waxmann Verlag Co. Publisher.

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), 1447-1475, DOI: 10.1080/09500690500153741.

Hubber, P. (2005). Explorations of year 10 students' conceptual change during instruction. *Asia-Pacific Forum on Science Learning and Teaching,* 6(1), 1-27.

Kocakülah, A. & Demirci, N. (2010). Secondary school student's conceptual understanding of image and image formation by a plane mirror. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education,* 4(1), 141-162.

Köseoğlu F. & Kavlak, N. (2001). Constructivist approach in science teaching. *Gazi University Journal of Gazi Education Faculty*, 21(1), 139-148.

Luangrath, P. & Pettersson, S. (2012). Problems and possibilities with centering physics teaching on student discussions. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(3), 189-200. DOI: 10.12973/eurasia.2012.834a.

Matthews, M. R. (2002). Constructivism and science education: A further appraisal, *Journal of Science and Technology*, 11(2), 121-134. DOI:10.1023/A:1014661312550.

Naylor, S. & Keogh, B. (1999). Constructivism in classroom: Theory into practice. *Journal of Science Teacher Education,* 10(2). 93-106. DOI: 10.1023/A:1009419914289.

Nuhoğlu, H. & Yalçın, N. (2004). The development of attitude scale for physics laboratory and the assessment of pre-service teachers' attitudes towards physics laboratory. *Journal of Kırşehir Education Faculty*, 5(2), 317–327.

Özmen, H. (2004). Learning theories in science teaching and technology enhanced constructivist learning. *The Turkish Online Journal of Educational Technology*, 3(1), 100-111.

Palacios, F. J. P., Cazorla, F. N. & Cervantes, A. (1989). Misconceptions on geometric optics and their association with relevant educational variables. *International Journal of Science Education*, 11 (3), 273-286. DOI:10.1080/0950069890110304.

Saxena, A. B. (1991). The understanding of the properties of light by students in India. *International Journal of Science Education*, 13 (3), 283-289. DOI:10.1080/0950069910130306.

Taşar, M. S. (2006). Probing pre-service teachers understanding of scientific knowledge by using a vignette in conjunction with a paper and pencil test. *Eurasia Journal of of Mathematics, Science & Technology Education,* 2(1), 53-70.

Tekos, G. & Solomonidou, C. (2009). Constructivist learning and teaching of optics concepts using ict tools in Greek primary school: A pilot study. *Journal of Science Education and Technology*, 18(5), 415-428. DOI: 10.1007/s10956-009-9158-2.

Tharenou, P., Donohue, R. & Cooper, B. (2007). *Management research methods*, New York: Cambridge University Press.

Toplis, R. & Allen, M. (2012). I do and I understand?' Practical work and laboratory use in United Kingdom schools. *Eurasia Journal of Mathematics, Science & Technology Education*, 8 (1), 3-9. DOI: 10.12973/eurasia.2012.812a.

Trumper, R. (2003). The physics laboratory a historical overview and future perspectives. *Science & Education,* 12:645-670*.* DOI:10.1023/A:1025692409001.

Yeşilyurt, M. (2003). *A Constructivist Approach to Basic Physics Laboratory Applications.* Unpublished Phd. Thesis. Karadeniz Technical University. Institute of Graduate Studies in Science. Trabzon.

Yıldırım-Benli, A. (2010). *The effects of geometrical optics tasks based on inquiry-based instruction in cooperative learning environment*. Dokuz Eylül University, Master's Thesis, Institute of Graduate Studies in Science, Izmir.

◈◇◈

Annex-1. The Changes Made about the Content of the Teaching Material

Stages	The Changes Made in the Content of the Teaching Material						
	Pre-Template		Before Pilot Study		After Pilot Study / Before Main Study		After Main Study
	Content	Source and Change	Content	Source	Content	Source	Content
Engage	Narrative (Joke)	Instructors/ narrative (joke) replaced	Brainstorming	Researcher's notes/brainstorming replaced	Piece of story		Piece of story
Explore	Two experiments about the subject	Instructors / the number of experiments increased	Three experiments about the subject		Three experiments about the subject		Three experiments about the subject
Explain	Question-answer activity		Question-answer activity		Question-answer activity		Question-answer activity
Elaborate	Open-ended question leading to research		Open-ended question leading to research		Association question		Association question
Evaluate	Three open-ended questions	Instructors / questions changed	A total of three questions two of which are two-staged	Reflection paper and researcher's notes /The second question changed	A total of three questions two of which are two-staged	Reflection papers / questions changed completely	Three two-staged questions

Annex-2. General Changes Made in the Teaching Material through Teaching Processes

	Before Pilot Study	After Pilot Study / Before Pilot Study	After Main Study
General Changes	The prepared template was visually re-designed in accordance with the opinions of two instructors specialized in their fields.	Guiding pictures were added to the material, spelling mistakes in the material were corrected, and the material was improved visually in accordance with the opinions of instructors specialized in their fields and reflection papers.	The material was read by a linguist. The material was improved visually in accordance with the opinions of instructors.