Macrothink Institute™

Journal of Educational Issues
ISSN 2377-2263
2022, Vol. 8, No. 1

The Effect of Subject Matter Knowledge Education on Pre-Service Science Teacher's Approach to Errors

Salih Değirmenci (Corresponding author)

Faculty of Education, Amasya University, PK: 05100, Amasya, Turkey

E-mail: salih.degirmenci@amasya.edu.tr

Received: April 27, 2022 Accepted: May 25, 2022 Published: June 8, 2022

doi:10.5296/jei.v8i1.19805 URL: https://doi.org/10.5296/jei.v8i1.19805

Abstract

The aim of this research is to examine the effect of subject matter knowledge education (SMKE) on the pre-service science teachers' approach to error about plane mirrors. This study was conducted using developmental research and phenomenology designs, which are qualitative research methods. In the study, the data were analyzed with the descriptive research method. As a result of the research, it was observed that the rate of detecting the correct or incorrect statements given by the teacher candidates increased after the SMKE. It has been revealed that many candidates, who identified the wrong solutions directed to them after the SMKE, were able to make correct statements. These show that although it is dependent on the question, SMKE contributes to the conceptual development of many candidates and their learning at a metacognitive level. Some teacher candidates participating in the research has misconceptions. These are the misconceptions given in the literature such as "the location and size of an object's image in plane mirrors are affected by the movement of the observer", "if there is an obstacle in front of an object, some or all of the object does not appear in the mirror", "when we look at the plane mirror, the image of the object is formed, when we do not look, the image of the object does not form", and "the size of the image depends on the distance of the object from the mirror". In addition, it was revealed that a few candidates had a misconception, which was not seen in the literature, as "if the mirror size increases, the image becomes smaller".

Keywords: Plane mirrors, Subject matter knowledge education, Approach to error, Misconceptions, Physics education

1. Introduction

Education is the process of indirectly or directly helping young people and children to gain the necessary understanding, knowledge and skills to take part in social life, and to develop their personalities outside and inside the school (Türk Dil Kurumu Sözlükleri, 2019). Those who

will contribute to the execution of this process as desired are the family, the immediate environment and the teachers. In this context, considering that they will be teachers in the future, it is important that pre-service teachers have the necessary knowledge and skills. Pre-service teachers' knowing what they may encounter and being aware of how to cope with the problems they encounter are related to their teacher knowledge. Teacher knowledge is an integrated phenomenon that includes teachers' beliefs and knowledge about the subject, curriculum, etc. (Van Driel, Verloop, & De Vos, 1998). Subject matter knowledge (SMK) is one of the main components of this phenomenon. SMK comes first at the beginning of the knowledge that teachers should have in order to carry out education in accordance with the purpose (Alev & Karal, 2013). Teachers should have certain qualifications in addition to SMK. These features constitute the main element of pedagogical content knowledge (PCK), which is defined as the teacher's ability to teach the subject according to the environment and the individual differences of the students (Alev & Karal, 2013).

There are studies in the literature suggesting PCK models related to teacher knowledge. Among these studies, the study of Park (2005) has an important place in science teaching. Park (2005) suggested the hexagon PCK model in his study. In this model, one of the components of PCK is student understandings in science. This component is the component for teachers to understand students' misconceptions, learning difficulties, development levels, etc. (Park, 2005). Among these, knowledge of student errors should also be considered. Incorrect questions, answers and misconceptions may be encountered in students' verbal or written statements and textbooks. Therefore, teacher candidates and teachers should be able to identify the errors they encounter. A teacher or pre-service teacher who can identify the mistake and explain the reasons correctly means that he/she knows the related concept correctly (Konyalıoğlu, Aksu, Şenel, & Tortumlu, 2010). According to what Konyalıoğlu (2013) reported from the literature in his study, the desired level of SMK increases the standard of education and the success of students.

A teacher is someone who helps students learn. Teachers who do not have sufficient subject matter knowledge create a great obstacle to the success of students. A teacher with a lack of subject matter knowledge will not be able to help students learn the subjects adequately by giving evasive answers to the questions of the students by not dwelling on the subjects that he does not consider himself sufficient (Karal, 2003). The specified teachers create misconceptions in students or provide a basis for them to continue their education with incomplete and wrong learning. Such a situation is not a desirable situation in the education and education process. In order not to encounter such undesirable situations in education, the subject matter knowledge education (SMKE) given to teacher candidates during the education process is very important. SMKE has an important place in teacher education. A good planning of this educational process will be beneficial in teacher candidates' education. Before starting the education process, it should be determined what pre-service teachers know as right and wrong, what concepts they use incorrectly and why, and what their missing information is. Depending on the evaluation made later, pre-service teachers should be given subject knowledge education. After the education, self-evaluation should be done by checking whether the education provided is useful or not, and deficiencies, if any, should be corrected for the new

education process.

Students have alternative concepts about the image in mirrors, as in many other subjects in physics. In the studies on the image in the mirrors; it has been determined that students studying at all levels of education, and especially teacher candidates studying in education faculties, have wrong or incomplete information and misconceptions about the image in plane mirrors. Incorrect or missing information and alternative concepts identified in the literature were given in Table 1.

Table 1. Alternative concepts encountered in the literature related to image in a plane mirror

No.	Alternative Concepts	Literature
1	Light colored objects can be seen in the dark. People see in the dark.	Ayvacı & Candaş (2018); Fetherstonhaugh & Treagust (1992); Şen (2003); Taşlıdere & Eryılmaz (2015); Uzunoğlu, Yıldız, Demir, & Büyükkasap (2013)
2	Black objects do not reflect light, so an image of the object is not formed in a plane mirror.	Aydın (2017); Aydın & Öztekin (2018); Pompea, Dokter, Walker, & Sparks (2007)
3	When looking at the mirror, an image is formed, and when not looking, the image is not formed.	Anıl & Küçüközer (2010); Çökelez & Çiftçi Yaşar (2017); Galili & Hazan (2000)
4	If there is an obstacle in front of an object, some or all of the object does not appear in the mirror.	Anıl & Küçüközer (2010); Galili & Hazan (2000); Kaltakçı Gürel, Eryılmaz, & McDermott (2017)
5	The larger the mirror, the larger the image.	Anıl & Küçüközer (2010); Kaltakçı Gürel, Eryılmaz & McDermott (2017); Pınarkaya (2017)
6	The image of an object is formed/can be seen when the object is within the limits of the mirror.	Chen, H. S. Lin, & M. L. Lin (2002); Kaltakçı Gürel, Eryılmaz, & McDermott (2017); Taşlıdere & Eryılmaz (2015)
7	The image is on/in/in front of/above the plane mirror.	Blizak, Chafiqi, & Kendil (2009); Chen, H. S. Lin, & M. L. Lin (2002); Durukan & Paliç Şadoğlu (2020); Favale & Bondani (2013); Heywood (2005); Kocakülah (2006); Kocakülah & Demirci (2010); Pompea, Dokter, Walker, & Sparks (2007); Şen (2003); Taşlıdere & Eryılmaz (2015)
8	The size of the image depends on whether the object is near or far from the mirror. The image gets smaller as the object moves away from the plane mirror.	Anıl (2010); Kaltakçı Gürel, Eryılmaz, & McDermott (2017); Pınarkaya (2017); Şen (2003)

9	When the observer changes position, the location and size of the image of the object changes.	Ahçı (2012); Anıl (2010); Anıl & Küçüközer (2010); Aydın (2017); Aydın & Öztekin (2018); Aydın, Ural Keleş, & Haşıloğlu (2012); Blizak, Chafiqi, & Kendil (2009); Chen, H. S. Lin, & M. L. Lin (2002); Favale & Bondani (2013); Heywood (2005); Öztekin (2018); Taşlıdere (2013); Taşlıdere & Eryılmaz (2015)
10	The image is real/smaller/larger/inverted.	Anıl (2010); Kocakülah (2006)
11	The location and size of the image formed in the mirror of an object illuminated by light depends on the position of the illuminator.	Aydın, Ural Keleş, & Haşıloğlu (2012); Chen, H. S. Lin, & M. L. Lin (2002); Taşlıdere & Eryılmaz (2015)
12	Using the concept of shadow instead of the concept of image.	Anıl (2010); Anıl & Küçüközer (2010); Chen, H. S. Lin, & M. L. Lin (2002); Feher & Rice (1988); Kocakülah (2006); Kocakülah & Demirci (2010)

1.1 Importance of Research

In the literature on the research subject, it is seen that misconceptions exist in every society and studies on this subject continue. The researches were carried out with the aim of detecting wrong or incomplete information and misconceptions and eliminating these misconceptions. The fact that there is no research in the literature that includes the approach to error about the research subject shows that it is necessary to carry out this study. SMKE has an important place in the education of teachers. For this reason, the SMKE given to teacher candidates should be investigated at every stage of the education process. In addition, it can be emphasized how necessary it is to study the subject, considering that the results of the research will guide the educators. Correctly detecting and explaining errors can be seen as an indicator of meaningful learning in education. Considering the stated reasons, in the study, the effect of SMKE on the approach to error of pre-service science teachers was investigated in the subject.

1.2 Purpose of the Research

This research was planned to determine the effect of SMKE on the error approach of pre-service science teachers, the developmental status of subject knowledge and student understanding of image in plane mirrors. In line with the determined purpose, it was desired to find answers to the following questions.

(1) What is the effect of SMKE's Science Teaching Program on the discrimination of true or false information by pre-service teachers studying in the 2nd grade regarding the image in plane mirrors?

(2) What is the effect of SMKE on the development of pre-service science teachers in terms of approach to error on image in plane mirrors?

2. Method

In qualitative research, data collection methods such as observation, document analysis and interview are used. In qualitative research, events are determined as in their own environment and in an inclusive way (Yıldırım & Şimşek, 2021). In this context, qualitative research method was used to determine the pre-service science teachers' ability to distinguish between true and false information, the effect of SMKE on pre-service teachers' approach to error, and the developments in student comprehension.

Under this heading, information about the research model, data collection, study group, data analysis and validity and reliability are given.

2.1 Model of the Research

The aim of this research is to determine the status of distinguishing between right and wrong, their approach to error, and the development of student comprehension knowledge of pre-service science teachers who received image subject knowledge in plane mirrors in the 2nd grade of Science Education in the fall semester of the 2021-2022 academic year. The developmental research design is used to examine the changes and developments of thoughts, emotions, behaviors, etc., at different times in people's lives (Şahin Çakır, 2019). The phenomenology design is used in research to inquire deeply about what the participants think about the subject or concepts as a result of their experiences, their perceptions, the ways and methods of establishing relationships between concepts (Aydın Günbatar, 2019). Therefore, study; the effects of SMKE on pre-service teachers' approaches to error were carried out with a developmental research design and a phenomenology design to determine the pre-service teachers' ability to distinguish between true and false information, and the developments in student comprehension.

2.2 Study Group of the Research

The study group of the research was determined by purposive sampling, which is one of the non-random sampling methods. Purposeful sampling allows for the determination and in-depth examination of information-rich situations depending on the purpose of the research (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2021). In the study group, there are 25 students (F = 22, M = 3) who continue their education in 2nd grade of the Faculty of Education Science Teaching Program. Subject matter knowledge education related to the research subject is given in the 3rd semester (2nd grade-fall semester) in the Science Teaching Program. The demographic characteristics of the students in the research group determined in this context were given in Table 2. In the study, the names of the participants were not included in accordance with ethical principles. For this reason, the participants were given codes in the form of $G2_1$, $G2_2$, $G2_{25}$.

Table 2. Demographic characteristics of the participants

Graduated High school	Female		Male		Total	
	n	%	n	%	n	%
Anatolian High School	18	72	-	-	18	72
Science High School	2	8	-	-	2	8
Imam Hatip High School	1	4	2	8	3	12
Vocational High School	1	4	-	-	1	4
Other (College)	-	-	1	4	1	4
Total	22	88	3	12	25	100

In the study group, 88% of the participants were female and 12% were male. 72% of the participants graduated from Anatolian high schools.

2.3 Data Collection Tool and Process

The researcher conducted a literature review on the subject, and a data collection tool was prepared in a way that would ensure content validity. In the data collection tool, there are 15 open-ended questions for conceptual understanding and correct and incorrect answers for these questions. A sufficient number of expert opinions were taken for the data collection tool and a pilot application was made with two pre-service teachers to ensure the clarity of the questions and solutions. The data collection tool was given its final shape, taking into account the feedback and expert opinions at the end of the pilot application (Appendix A. data collection tool). The answers to questions 4, 6, 9, 12, and 14 presented to the teacher candidates in Appendix 1 were arranged correctly, and the answers to the other questions were constructed with incorrect definitions or citing misconceptions in the literature. Teacher candidates were asked to examine the answers given to the questions about the conceptual understanding prepared about the image in plane mirrors in the data collection tool. When the examination process was over, the participants were first asked to write the letter D in parentheses (…) if the answers were correct, and the letter Y if they were incorrect. Then, it was especially emphasized that the participants should write their own answers for the statements they deem as right or wrong.

2.4 Analysis of Data

First of all, the numbers and percentages of the participants who distinguished the correct or incorrect answers from the answers given by the candidates to the questions in the study were determined and tabulated. After that, the statement of the participants who detected and could not detect erroneous statements were classified according to the determined themes and codes. Descriptive analysis technique was used in the analysis of the data. In the descriptive analysis technique, the data were organized to answer the research problem, supported by quotations,

and were presented in a way that readers can understand. In this analysis technique, the data is described and interpreted according to the conceptual framework (Aydın, 2019). In this context, after each question was analyzed, the findings were presented in tables. Samples selected from the answers were given by the participants were also presented in tables for all themes and codes. In Table 3, the themes and codes used in the analysis phase were given.

Table 3. Themes and codes

Themes	Codes	Examining Codes*
No Response		
Detecting the Error	No Statement	
	Statement Incorrect	
	Statement Partially Correct	
	Statement Correct	
Failure to Detect Error	No Statement	
	Statement Incorrect	
	Statement Partially Correct	
	Statement Correct	

Note. * The review is defined below:

Themes

- No response: No opinion is given.
- Detecting the error: It is the situation of detecting that the given answer is wrong.
- Failure to detect the error: It is the situation in which the wrong answer given is evaluated as correct.

Codes and Review

The statements written by the participants as answers to the questions were handled under four different encodings. These encodings are given below.

- No statement: It is the coding with No Statement written.
- Statement is wrong: It is the coding where the statement is taken as completely wrong.
- Statement partially correct: A situation where the statement is not considered completely correct. Incomplete statements and statements where some of them are correct and some of them are incorrect were evaluated under this coding. In addition, the

answers written by the candidates are scientifically correct, but the statements that are not fully related to the answer of the given question are included in this coding.

- Statement is correct: It is the coding in which the statement made is considered to be completely correct.

2.5 Validity and Reliability

Validity in qualitative research means that the researcher deals with the researched phenomenon as it is and as impartially as possible (Kirk and Miller, 1986 as cited in Yıldırım & Şimşek, 2021). For this reason, direct quotations were included in order to ensure the validity of the research, the facts were handled in an impartial way and conclusions were drawn from them. The data obtained in the research were classified according to themes and codes and tabulated. In order to ensure the reliability of the process, an expert in the field of physics education was requested to separate the data according to themes and codes. The tables prepared for each question were given their final form according to the expert opinion. The formula [Reliability = Consensus/(Disagreement + Consensus) × 100] was used to calculate the reliability of the study (Miles & Huberman, 1994). Research reliability is achieved when the consensus between the expert and the researcher is 90% or more (Saban, 2009). As a result of the evaluation, it was seen that the agreement between the coders was 95%.

3. Findings

In this section, the findings obtained from the data collection tools and related to the sub-problems of the research are given.

(1) What is the effect of SMKE's Science Teaching Program on the discrimination of true or false information by pre-service teachers studying in the 2nd grade regarding the image in plane mirrors?

Before and after the SMKE, the participants' ability to distinguish between true and false information was analyzed. The number (n) and percentages (%) of the participants who identified the questions with correct answers regarding the image subject area in plane mirrors, and the number (n) and percentages of the participants who identified the questions with incorrect answers were shown in Table 4.

Table 4. Number and percentages of participants who determined that the answers were correct or incorrect

Number and Percentage of Participants Identifying the Correct Answers						
Question	Before the SMKE		After the SMKE		Difference	
	n	%	n	%	n	%
4	9	36	16	64	7	28
6	8	32	12	48	4	16
9	15	60	22	88	7	28
12	17	68	23	92	6	24
14	20	80	22	88	2	8
Number and Percentage of Participants Identifying Incorrect Answers						
Question	Before the SMKE		After the SMKE		Difference	
	n	%	n	%	n	%
1	14	56	19	76	5	20
2	18	72	22	88	4	16
3	9	36	12	48	3	12
5	3	12	5	20	2	8
7	21	84	23	92	2	8
8	13	52	19	76	6	24
10	7	28	15	60	8	32
11	10	40	14	56	4	16
13	10	40	15	60	5	20
15	13	52	19	76	6	24

As can be seen from Table 4, the answer given for the fourteenth question is the highest (80%) number and percentage of participants who determined that the answers to the questions given to them before the SMKE were correct. The answer given for this question is arranged as "when the observer approaches the plane mirror with speed v, his image approaches the mirror with speed v, and when the observer moves away from the plane mirror with speed v, his image also moves away from the mirror with speed v". It is the answer given for the sixth question, in which the number and percentage of the participants who identified the correct statements given to them before the SMKE was the smallest (32%). This answer is as follows: "As the student moves away from the plane mirror, the size of the self-image that the student sees in the

mirror does not change". After the SMKE, it is the answer given for the twelfth question in which the number and percentage of participants who determined that the answers to the questions given to them were correct (92%) were the highest. This answer is "the image of an object formed in a plane mirror is flat with respect to the object". After the SMKE, the number and percentage of teacher candidates who determined that the answers to the questions given to them were correct was the lowest (48%) was the answer given for the sixth question.

As can be seen from Table 4, the answer given for the 7th question has the highest number and percentage (84%) of the participants who found that the answers to the questions presented to them before the SMKE were wrong about the image in plane mirrors. This answer was designed as "the size of the student's image formed in the plane mirror increases when the size of the mirror increases". It is the answer given for the 5th question, in which the number and percentage of the participants who detected the erroneous statements given to them before the SMKE was the smallest (12%). This answer is structured as "when an obstacle is placed between the object and the plane mirror, some of the object's image is formed while the other part is not". After the SMKE, it is the answer prepared for the 7th question, in which the number and percentage of participants who determined that the answers to the questions given to them were wrong (92%) were the highest. After the SMKE, it is the answer constructed for the 5th question, in which the number and percentage of teacher candidates who found that the answers to the questions given to them were wrong (20%) were the smallest.

In Table 4, it is seen that there has been an increase in the number and percentage of participants who identified the questions that were given correct or incorrect answers after the SMKE. While the average percentage of participants who determined that the answers to the questions given to them were correct, was 55% before the SMKE, it was 76% after the SMKE. While the percentage of participants who determined that the answers to the questions given to them were wrong, was 47% before the SMKE, it was 65% after the SMKE.

(2) What is the effect of SMKE on the development of pre-service science teachers in terms of approach to error on image in plane mirrors?

The findings in Table 5 were obtained by examining the statements given by the students before and after the SMKE for the wrong solution of the first question about the image in plane mirrors as "the image of a white colored object occurs in a plane mirror in a dark environment".

Table 5. Themes, codes, number of participants, difference and sample answers for question 1

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		2		-2	-8	
Detecting the Error	No Statement	1		-1	-4	
	Statement Incorrect	2		-2	-8	"The shadow does not fall in the dark." $G2_{25}$
	Statement Partially Correct	3	1	-2	-8	"The image of a white colored object in a plane mirror does not occur." $G2_{13}$, "White colored objects cannot be seen in dark environments." $G2_3$
	Statement Correct	9	18	+9	+36	"Light is needed for the object to form an image in a plane mirror. Since there is no light, there is no reflection and therefore no image is formed." $G2_6$, "The image of the object does not form in the dark environment. Because light is needed for the formation of the image." $G2_6$
Failure to Detect Error	No Statement	3	1	-2	-8	
	Statement Incorrect	5	4	-1	-4	"The image is formed because the object is light in color." $G2_9$, "As white colored objects reflect light, an image is formed in a plane mirror." $G2_{16}$
	Statement Partially Correct		1	+1	+4	"The formation of the image is not dependent on the observer." $G2_1$
	Statement Correct					
	Total	25	25			

After the SMKE, the number of participants who identified the wrong statement given in the answer to the 1st question and whose statement were correct increased (+36%). After the SMKE, the number of participants who detected the error and did not respond, did not make any statement, whose statement was wrong and whose statement was partially correct decreased. At the end of the SMKE, 40% of the participants had a mental transformation related to the formation of an image in the plane mirror in the dark environment.

The findings in Table 6 were obtained by examining the statements given by the students before and after the SMKE for the wrong solution of the second question about the image in plane mirrors, as "the image of a black object in a plane mirror does not occur in a bright environment".

Table 6. Themes, codes, number of participants, difference and sample answers for question 2

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		2		-2	-8	
Detecting the Error	No Statement	2		-2	-8	
	Statement Incorrect	2	1	-1	-4	"Because there is light, the object reflects off the mirror." $G2_{20}$, "The object can transmit the rays it receives from light to our eyes." $G2_{12}$
	Statement Partially Correct	4	1	-3	-12	"The object can be seen if there is light." $G2_4$, "The image occurs, why not?" $G2_1$
	Statement Correct	11	20	+9	+36	"Because the environment is bright, the image of the object is formed in a plane mirror." $G2_2$, "No matter what color the object is in a bright environment, the image of the object is formed." $G2_{22}$
Failure to Detect Error	No Statement	1	1	0		
	Statement Incorrect	2	1	-1	-4	"A black object is not reflected in the mirror and does not form in the image." $G2_{21}$, "A black object in a bright environment creates a shadow-like image." $G2_8$
	Statement Partially Correct		1	+1	+4	"There's light around." $G2_{10}$
	Statement Correct	1		-1	-4	"Because the environment is bright, the image of the black body is formed in the plane mirror." $G2_{13}$
	Total	25	25			

After the SMKE, the number of participants who detected the wrong statement given in the answer to the second question and whose statement were correct increased (+36%). After the SMKE, the number of participants who detected the error and did not respond, did not make any statement, had a wrong statement or made a partially correct statement decreased. At the end of the SMKE, the opinion of 36% of the participants about the formation of the image of a black object in a plane mirror in a bright environment has changed.

The answer to the 3rd question about the image in plane mirrors is designed as "the observer must look towards the plane mirror in order to form an image of an object, because in the plane mirror, the image of the object is formed only when the rays reflected from the plane mirror come into the eye of the observer". The findings in Table 7 were obtained by examining the statement given by the students before and after the SMKE to this constructed answer.

Table 7. Themes, codes, number of participants, difference and sample answers for question 3

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response						
Detecting the Error	No Statement	1		-1	-4	
	Statement Incorrect	3	2	-1	-4	"When we stand on the side of the mirror, we see the object from the opposite side." $G2_{14}$, "The image is not visible in the plane mirror." $G2_2$
	Statement Partially Correct	1	2	+1	+4	"The observer does not need to look at the plane mirror. It is sufficient to be in front of the mirror." $G2_{13}$, "The observer can see the image even if she/he is not in front of the mirror." $G2_{16}$
	Statement Correct	4	8	+4	+16	"An observer is not necessary for the formation of an image of an object. We have to look to see the image." $G2_1$, "An image is formed. However, when the observer does not look into the mirror, she/he cannot see the image formed in the mirror because the rays do not come into her/his eye."$G2_{15}$
Failure to Detect Error	No Statement	7	7	0		
	Statement Incorrect	6	5	-1	-4	"The rays reflect directly on the plane mirror." $G2_{18}$, "The image of objects entering the field of view of the plane mirror is visible." $G2_6$
	Statement Partially Correct	3	2	-1	-4	"Rays reflected in a plane mirror can be observed." $G2_5$, "She/he should look in the mirror, because the object is visible with the rays coming to the plane mirror." $G2_3$
	Statement Correct					
	Total	25	25			

After the SMKE, the number of participants who identified the erroneous statement given in the answer to the 3rd question and whose statement were correct and partially correct increased (+16% and +4%). After the SMKE, the number of participants who detected the error, did not explain, and whose statement was incorrect, decreased. At the end of the SMKE, the number of participants who had the perception that "even if the observer does not look at the mirror, the image of the object is formed in the plane mirror" increased by 20%.

The answer to the 5th question about the image in plane mirrors was designed as "when an obstacle is placed between the object and the plane mirror, some of the object's image is formed while the other part is not". The findings in Table 8 were obtained by examining the statement given by the students before and after the SMKE to this constructed answer.

Table 8. Themes, codes, number of participants, difference and sample answers for question 5

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		2		-2	-8	
Detecting the Error	No Statement					
	Statement Incorrect	3	2	-1	-4	"No image occurs." $G2_{11}$, "Where the image of the object does not form, the image of the obstacle is formed." $G2_8$
	Statement Partially Correct					
	Statement Correct		3	+3	+12	"The image of the whole object and the obstacle is formed on the plane mirror." $G2_{15}$
Failure to Detect Error	No Statement	4	4	0		
	Statement Incorrect	16	13	-3	-12	"An obstacle prevents the image from forming." $G2_4$, "As the obstacle is placed in front of the object, its image is formed in half." $G2_3$
	Statement Partially Correct		3	+3	+12	"The image of the opaque object is formed." $G2_4$
	Statement Correct					
	Total	25	25			

After the SMKE, the number of participants who identified the wrong statement given in the answer to the 5th question and whose statement were correct increased slightly (+12%). After the SMKE, the number of participants who detected the error and did not respond, and whose statement was incorrect, decreased. At the end of the SMKE, 12% of the participants had a positive development in their point of view regarding the image of objects with an opaque object in front of them in the plane mirror.

The answer to the 7th question about the image in plane mirrors was prepared as "the size of the student's image formed in the plane mirror increases when the size of the mirror increases". The findings in Table 9 were obtained by examining the statement given by the students before and after SMKE for the wrong solution prepared.

Table 9. Themes, codes, number of participants, difference and sample answers for question 7

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response						
Detecting the Error	No Statement	3	1	-2	-8	
	Statement Incorrect	4	2	-2	-8	"The size of the image does not change because the distance of the student from the mirror is the same." $G2_{22}$, "The larger the mirror, the smaller the image size." $G2_5$
	Statement Partially Correct	3		-3	-12	"The size of the image does not change. Because the distance between it and the mirror is the same." $G2_2$
	Statement Correct	12	20	+8	+32	"The size of the mirror does not change the size of the image. The size of the image is related to the size of the student." $G2_7$, "The size of the mirror does not affect the size of the image." $G2_7$
Failure to Detect Error	No Statement	2		-2	-8	
	Statement Incorrect	1	2	+1	+4	"As the image will be scattered in the mirror, the image will grow depending on the width of the mirror." $G2_3$, "The larger the mirror, the greater the image." $G2_{21}$
	Statement Partially Correct					
	Statement Correct					
	Total	25	25			

After the SMKE, the number of participants who identified the wrong statement given in the answer to the 7th question and whose statement were correct increased (+32%). After the SMKE, the number of participants who detected the error and did not make any statement, whose statement was wrong and partially correct, decreased. It was found that the number of candidates who internalized that the size of the plane mirror did not affect the size of the image at the end of the SMKE changed by 36%.

The answer to the 8th question was designed as "the image of B object is formed in the plane mirror, but the images of A and C objects do not form". The findings in Table 10 were obtained by examining the statement given by the students before and after SMKE for the erroneous solution constructed.

Table 10. Themes, Codes, Number of Participants, Difference and Sample Answers for Question 8

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		2		-2	-8	
Detecting the Error	No Statement	3		-3	-12	
	Statement Incorrect	3	2	-1	-4	"It changes depending on where we look at it." $G2_{19}$, "Part of the image of object A is visible. The image of B is not." $G2_5$
	Statement Partially Correct	4		-4	-16	"The mirror can create an image by enclosing the entire environment. Images of A and C can also be viewed." $G2_6$, "It changes depending on the point the observer is looking at. The reflected rays form the image of all of them." $G2_9$
	Statement Correct	5	17	+12	+48	"The image of A, B, and C is formed. But to see it, we need to look at it from different angles." $G2_{16}$, "Images of A, B, and C are formed. However, depending on the position of the observer, she/he can see the images or not. $G2_{15}$
Failure to Detect Error	No Statement	3		-3	-12	
	Statement Incorrect	6	6	0		"The length of the plane mirror is not enough for A and C." $G2_{18}$, "As there is no ray reaching the mirror from other objects, only B's image is formed." $G2_{24}$
	Statement Partially Correct	1		-1	-4	"May be images of A and C are forming. But they might be visible when viewed from different angles." $G2_4$
	Statement Correct					
	Total	25	25			

After SMKE, the number of participants who identified the wrong statement given in the answer to question 8 and whose statement were correct increased (+48%). After the SMKE, the number of participants who detected the error and did not respond, who did not explain at the same time, whose statement was wrong, and who made a partially correct statement decreased.

The answer to the 10th question about the image in plane mirrors was formed as "the image of the object in the plane mirror is formed on the surface of the mirror". The findings in Table 11 were obtained by examining the statement given by the students before and after the SMKE for the wrongly created solution.

Table 11. Themes, codes, number of participants, difference and sample answers for question 10

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		1		-1		
Detecting the Error	No Statement	1	1	0		
	Statement Incorrect	2		-2		"As the image is reflected on the surface, it does not occur on the surface." $G2_{25}$
	Statement Partially Correct	1	1	0		"The image does not form on the mirror's surface." $G2_{13}$, "In a plane mirror, the image is virtual." $G2_{15}$
	Statement Correct	4	11	+7	+28	"The image of the object is formed behind the mirror." $G2_{10}$, "In a plane mirror, the image is virtual and occurs behind the mirror." $G2_{20}$
Failure to Detect Error	No Statement	7	3	-4		
	Statement Incorrect	8	8	0		"The object and the image are aligned." $G2_{17}$, "In a plane mirror, the image is real and occurs on the surface of the mirror."$G2_3$
	Statement Partially Correct					
	Statement Correct		1	+1		"The image appears behind the mirror." $G2_1$
	Total	25	25			

After the SMKE, the number of participants who identified the wrong statement given in the answer to the 10th question and whose statement were correct increased (+28). After the SMKE, the number of participants who detected the error and did not respond, and whose statement was incorrect, decreased.

The answer to the 11th question about the image in plane mirrors is designed as "the size of the image of the object in the plane mirror changes depending on the distance of the object from the mirror, the object approaches the plane mirror, the size of the image increases, and when the object moves away from the mirror, the size of the image decreases". The findings in Table 12 were obtained by examining the statement given by the students before and after the SMKE for the erroneous solution constructed.

Table 12. Themes, Codes, Number of Participants, Difference and Sample Answers for Question 11

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response			1	+1	+4	
Detecting the Error	No Statement	2	1	-1	-4	
	Statement Incorrect	3		-3	-12	"The closer the object is to the plane mirror, the smaller the image size, and the farther the object is, the greater the image size." $G2_{11}$
	Statement Partially Correct					
	Statement Correct	7	13	+6	+24	"The dimensions of the image and the object are always the same in a plane mirror." $G2_1$, "The size of the image does not depend on the position of the object. The size of the image does not change." $G2_6$
Failure to Detect Error	No Statement	4	3	-1	-4	
	Statement Incorrect	9	6	-3	-12	"Because the size of the image depends on the distance of the object from the mirror." $G2_{21}$, "The size of the image of the object in the plane mirror increases as the object approaches the mirror and decreases when it moves away." $G2_3$
	Statement Partially Correct		1	+1	+4	"The image of the object is symmetrical in a plane mirror." $G2_5$
	Statement Correct					
	Total	25	25			

After the SMKE, the number of participants who identified the erroneous statement given in the answer to the 11th question and whose statement were correct increased (+24%). After the SMKE, the number of participants who detected the error, did not explain, and whose statement was incorrect, decreased.

The answer to the 13th question about the image in plane mirrors is arranged as "when the observer changes position, the image of the object in the plane mirror also changes place". The findings in Table 13 were obtained by examining the statement given by the students before and after SMKE for the wrongly arranged solution.

Table 13. Themes, codes, number of participants, difference and sample answers for question 13

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response		1		-1	-4	
Detecting the Error	No Statement	2		-2	-8	
	Statement Incorrect					
	Statement Partially Correct	1	1	0		"After all, the ray that comes into the eye of the observer is the same, the pen stays in the same place." $G2_1$, "Because the pen doesn't move" $G2_2$
	Statement Correct	7	14	**+7**	+28	"Because the position of the pen does not change, neither does the position of the image." $G2_5$, "Even if the observer changes position, the location of the image does not change because the position of the object remains the same." $G2_5$
Failure to Detect Error	No Statement	6	4	-2	-8	
	Statement Incorrect	7	5	-2	-8	"When the observer moves, she/he sees the object as displaced."$G2_{24}$, "The location of the image changes." $G2_6$
	Statement Partially Correct	1		-1	-4	"When the observer's position changes, so does the perspective." $G2_8$
	Statement Correct		1	+1	+4	"When the object moves, the image changes location." $G2_3$
	Total	25	25			

After the SMKE, the number of participants who identified the erroneous statement given in the answer to the 13th question and whose statement were correct increased (+28%). After the SMKE, the number of participants who detected the error and did not respond and did not make any statement decreased.

The answer to the 15th question about the image in plane mirrors is given as "when the observer moves away from the plane mirror, the size of the image of the pen in the plane mirror decreases". The findings in Table 14 were obtained by examining the statement given by the students before and after SMKE for the erroneous solution given.

Table 14. Themes, codes, number of participants, difference and sample answers for question 15

Themes	Codes	Before the SMKE	After the SMKE	Difference		Sample answers
		n	n	n	%	
No Response						
Detecting the Error	No Statement	4		-4	-16	
	Statement Incorrect	5	2	-3	-12	"The size of the image doesn't change unless we move the bulb or the pen." $G2_3$, "The size of the image does not change because the object stays in the same place." $G2_5$
	Statement Partially Correct	1		-1	-4	"The size of the image does not change. The position of the observer changes. Not the location of the pen." $G2_{18}$
	Statement Correct	5	17	+12	+48	"The size of the image in a plane mirror is not affected by the change of position of the observer. The size of the image is related to the size of the object." $G2_{17}$, "The size of the image does not change when the position of the observer changes." $G2_{25}$
Failure to Detect Error	No Statement	2	1	-1	-4	
	Statement Incorrect	7	5	-2	-8	"The image gets smaller if we move away from the mirror." $G2_{15}$, "The farther the observer is from the plane mirror, the smaller the object's image size." $G2_9$
	Statement Partially Correct					
	Statement Correct	1		-1	-4	"The size of the image doesn't change. Our perspective changes." $G2_4$
	Total	25	25			

After the SMKE, the number of participants who detected the wrong statement given in the answer to the 15th question and whose statement were correct increased (+48%). After the SMKE, the number of participants who detected the error and did not make any statement, whose statement was wrong and partially correct, decreased.

4. Discussion and Conclusion

Based on the research findings, it can be emphasized that the SMKE given on the subject of image in plane mirrors contributes to distinguishing true or false information of some participants. The SMKE was effective in changing the perceptions of many candidates who did not express any opinion about the wrong answers to the questions, whose opinions were right or wrong, but did not make any statement and whose statement were wrong. In this

section, the conclusions drawn from the pre-service teachers' approaches to errors for each question about the image in plane mirrors after the SMKE will be compared with the literature.

SMKE was effective on 40% of the participants at the point of assimilation that objects cannot be seen in a dark environment and that their images cannot be formed in a plane mirror. This is a positive reflection of the education given. However, SMKE did not have an effect on some participants. Some teacher candidates in the research group have the perception that objects can be seen in the dark. When this misconception is called a dark environment in daily life, the concept that occurs in people's minds is a room in which no lighting tool is used inside, but the light rays coming from outside are tried to be cut relatively. The person in such an environment thinks that he can see objects as a result of eye harmony. In order to eliminate or prevent this misconception, the concept of complete darkness can be used instead of darkness. Some participants think that because light colored objects reflect light, an image of the object will be formed in the plane mirror. These candidates, on the other hand, did not understand what they read or did not consider the concept of a dark environment. This led them to misinterpret the question. According to the situation before the SMKE, the misconceptions of some candidates regarding the first question were corrected. However, at the end of the given SMKE (Table 5), there is a misconception among several candidates that "images of objects are formed in a plane mirror in a dark environment". These misconceptions are similar to the misconceptions given in the literature (Ayvacı & Candaş, 2018; Fetherstonhaugh & Treagust, 1992; Şen, 2003; Taşlıdere & Eryılmaz, 2015; Uzunoğlu, Yıldız, Demir, & Büyükkasap, 2013). Some participants perceive the shadow of the object as an image formed on a plane mirror. This misunderstanding is also expressed in the study results of Anıl (2010), Anıl and Küçüközer (2010), Chen, H. S. Lin, and M. L. Lin (2002), Feher and Rice (1988), Kocakülah (2006), and Kocakülah and Demirci (2010) has been done. The stated misconception is also compatible with the misconception expressed in the literature (Aydın, Ural Keleş, & Haşıloğlu, 2012; Chen, H. S. Lin, & M. L. Lin, 2002; Taşlıdere & Eryılmaz, 2015) as "the location and size of the image of an illuminated object in the plane mirror changes depending on the position of the illuminator". Individuals who have this misconception think of the shadow of the object as an image formed in a plane mirror. This misconception can be corrected by showing students or teacher candidates an activity in which the image and shadow are created together.

In the solution of the wrongly constructed question 2, the number of participants who were able to correctly identify the error and make a correct statement after SMKE increased (Table 6). SMKE was effective on 36% of the participants in terms of comprehending those black colored objects reflect a small part of the light falling on them in a bright environment and that their images will be formed in the plane mirror with this light reflected from the object. This is a positive reflection of the education provided. Many candidates showed a positive development conceptually. However, in a very small number of candidates, the misconceptions such as "black objects do not reflect light at all" and "perceiving the image as a shadow in mirrors" could not be eliminated. A few participants have the perception of "the

reflection of the object from the mirror instead of the reflection of light rays from the mirror", which is thought to be due to their lack of knowledge. Similar results were found in the studies of Aydın (2017), Aydın and Öztekin (2018), and Pompea, Dokter, Walker, and Sparks (2007). The misconception that "black objects do not reflect light at all" formed in students can be eliminated by emphasizing that the object cannot be seen when the object does not reflect the light rays falling on it at all. It should be emphasized that the rays coming from the object must come to the lens of the eye in order for the phenomenon of vision to occur.

At the end of the SMKE, 20% of the participants changed their previous thoughts and learned that the image of an object would be formed in the plane mirror, even if the observer did not look into the mirror. The SMKE given on these candidates has been influential. On most of the candidates, SMKE did not make any positive contribution. It was concluded that many of the participants in the study group had the misconception that "when looking in a plane mirror, objects appear in the mirror, if not, there is no image", which does not change much before and after the SMKE (Table 7). This misconception was also emphasized in the research results of Anıl and Küçüközer (2010), Çökelez and Çiftçi Yaşar (2017), and Galili and Hazan (2000). The source of this misconception is the confusion of vision and image formation. In order to eliminate this wrong learning, it should be stated that the image occurs when the rays reflected from the object hit the mirror. In order for the image to be seen, it should be emphasized that the rays reflecting from the object and hitting the mirror must be reflected and these rays must pass through the eye lens and fall on the retina.

SMKE did not provide a positive transformation in the direction that even if there is an obstacle in front of the objects on about half of the participants, their image will be formed in the plane mirror. In the research, it was concluded that many participants have the misconception that "when we put an opaque object between the flat mirror and the object, the image of the object does not form in whole or in part". This result is compatible with the results of the literature (Anıl & Küçüközer, 2010; Galili & Hazan, 2000; Kaltakçı Gürel, Eryılmaz, & McDermott, 2017). SMKE (Table 8) did not have much effect in correcting the misunderstanding mentioned. This misconception can be eliminated by practice or by emphasizing that the image is not formed only by the rays reflecting from the object and coming towards the obstacle, but by the reflection of the rays striking different points of the mirror.

When the findings obtained from the statement of the participants for the 7th question (Table 9) are evaluated, it can be emphasized that SMKE contributed to the meaningful learning of some participants. However, although their number is small, some participants have a misconception that "when the dimensions of the plane mirror are increased, the image of the object in the mirror becomes larger". The mentioned misconception was also detected in the study results of Anıl and Küçüközer (2010), Kaltakçı Gürel, Eryılmaz, and McDermott (2017), and Pınarkaya (2017). The study also revealed the misconception that "when the dimensions of the plane mirror are increased, the image of the objects in the mirror becomes smaller", which was not encountered in the literature. In the research, there is a misconception that some candidates know that the size of the image will not change when the

dimensions of the mirror are increased, but that the image size will change when the distance of the observer changes in these candidates.

After the SMKE, the number of participants who realized that the images of objects that are not directly in front of the plane mirror will be formed in the mirror has increased significantly (Table 10). This shows that SMKE provided a positive conceptual transformation on about half of the candidates. Some candidates have the misconception that "the image of an object that is not directly opposite the plane mirror does not form". This alternative concept is similar to the results given in the literature (Chen, H. S. Lin, & M. L. Lin, 2002; Kaltakçı Gürel, Eryılmaz, & McDermott, 2017; Taşlıdere & Eryılmaz, 2015). This alternative concept can be corrected by practicing and showing students or teacher candidates the images of objects that are in front of the mirror but not directly in front of it.

At the end of the SMKE, the number of candidates who realized that the image of an object in the plane mirror was behind the mirror increased by 28%. This shows that SMKE is effective on the candidates mentioned. In the light of the findings in Table 11 in this study, it was concluded that the misconception of "the image is on the surface of the mirror" remained in some candidates after SMKE. This misconception is also given in the research results of Blizak, Chafiqi, and Kendil (2009), Chen, H. S. Lin, and M. L. Lin (2002), Durukan and Paliç Şadoğlu (2020), Favale and Bondani (2013), Heywood (2005), Kocakülah (2006), Kocakülah and Demirci (2010), Pompea, Dokter, Walker, and Sparks (2007), Şen (2003), and Taşlıdere and Eryılmaz (2015). Some of the participants also have the misconception that "the image formed in the plane mirror is real". This misconception is also given in the research results of Anıl (2010), and Kocakülah (2006). Alternative concepts stated in participants or students can be corrected with an activity with a glass plate and two identical candles, suggested by Anıl and Küçüközer (2010).

The number of participants who realized that the size of the image of an object in the plane mirror at the end of the SMKE is related to the size of the object and not dependent on the position of the object increased by 24%. This shows that SMKE has a positive reflection on the candidates mentioned. From the findings in Table 12, it can be concluded that SMKE has a positive effect on the candidates' approach to mistakes. However, it can be emphasized that some of the candidates could not correct the misconceptions of "the size of the image in a plane mirror depends on the distance of the object from the mirror" with SMKE. These mislearnings are also similar to the study results of some researchers (Anıl, 2010; Kaltakçı Gürel, Eryılmaz, & McDermott, 2017; Pınarkaya, 2017; Şen, 2003). The source of this alternative concept is the perception of distant objects smaller than their actual size. This misconception that occurs in individuals can be corrected by stating that the actual size of the object and the perceived or observed size are different concepts.

At the end of the SMKE, the number of candidates who internalized the knowledge that the location of the image of an object in the plane mirror would not be affected by the change in the position of the observer increased by 28%. This shows that SMKE is effective. From the findings obtained for the solution of the thirteenth question (Table 13) it was concluded that some participants had the misconception that "when the observer's location changes, the

position of the object's image in the mirror changes". This result is consistent with the research results emphasized by most researchers in the literature (Ahçı, 2012; Anıl, 2010; Anıl & Küçüközer, 2010; Aydın, 2017; Aydın & Öztekin, 2018; Aydın, Ural Keleş, & Haşıloğlu, 2012; Blizak, Chafiqi, & Kendil, 2009; Chen, H. S. Lin, & M. L. Lin, 2002; Favale & Bondani, 2013; Heywood, 2005; Öztekin, 2018, Taşlıdere, 2013; Taşlıdere & Eryılmaz, 2015). The occurrence of this misconception in students or teacher candidates can be prevented by an activity with a glass plate and two identical candles, suggested by Anıl and Küçüközer (2010).

At the end of the SMKE, the number of candidates who grasped the knowledge that the image size of an object in the plane mirror would not be affected by the change in the position of the observer increased by 48%. This shows that SMKE has an important place and influence in the education process. From the findings in Table 14, it can be stated that SMKE created a conceptual change in some participants and contributed to their ability to identify the mistake and provide a correct statement. Some participants in the research group have the misconception that "when the observer moves away from the mirror, the size of the image formed in the mirror decreases". The mentioned misconception was also emphasized in the literature (Ahçı, 2012; Anıl, 2010; Anıl & Küçüközer, 2010; Aydın, 2017; Aydın & Öztekin, 2018; Aydın, Ural Keleş, & Haşıloğlu, 2012; Blizak, Chafiqi, & Kendil, 2009; Chen, H. S. Lin, & M. L. Lin, 2002; Favale & Bondani, 2013; Heywood, 2005; Öztekin, 2018, Taşlıdere, 2013; Taşlıdere & Eryılmaz, 2015) in the study results of researchers interested in this subject. Such misconceptions that occur in students or teacher candidates can be eliminated by organizing an activity with a glass plate and two identical candles, which Anıl and Küçüközer (2010) suggest in their work.

At the end of this study, it was determined that the number of participants who correctly identified the errors and gave correct statement increased after the SMKE. This shows that although it is dependent on the question, SMKE contributes to the conceptual development of many candidates and their learning at a metacognitive level. However, the fact that some of the participants have misconceptions in the literature on the subject of the research is worrisome considering that they will be teaching in the future. The misconceptions of teacher candidates should be minimized as much as possible, and if possible, they should be completely eliminated. For this reason, while teaching the concepts to the participants, false information should be given in addition to the correct information, and the reasons for the wrong should be presented in a clear and understandable way.

In the literature, it has been stated that there are alternative concepts related to the subject in students and teacher candidates studying at various levels and levels in different countries. The reasons why the misconceptions in primary, secondary and high school students are also present in science teacher candidates in the study group should be questioned and solutions should be determined. It will be beneficial to educate and bring to humanity pre-service teachers who are free from misconceptions, can recognize true and false information, and can question the possible reasons for mistakes. In this context, it can be emphasized that the planning process of the SMKE given to prospective science teachers should be done well and the education time allocated to science courses should be increased.

In this study, it was assumed that the information written by the participants in the data collection tools was written accurately and honestly. This research was limited to 25 teacher candidates studying in the 2nd grade of the Science Teaching Program in the 2021-2022 academic year. The research was limited to 15 questions and a data collection tool with correct or incorrect answers. The researcher arranged the approaches to error of teacher candidates who received subject knowledge education according to themes and coding according to their own perspective. Similar results can be found in studies to be conducted in different environments, using different tools and methods and with different numbers or sample groups, and different results can be obtained depending on the perspectives and interpretation of the researchers.

References

Ahçı, M. (2012). *Üniversite öğrencilerinin ışık ve optik konuları ile ilgili kavramsal anlamaları* (Yüksel Lisans Tezi, Balıkesir Üniversitesi Fen Bilimleri Enstitüsü). Retrieved from https://dspace.balikesir.edu.tr/xmlui/handle/20.500.12462/2345?locale-attribute=en

Alev, N., & Karal, I. S. (2013). Fizik öğretmenlerinin elektrik ve manyetizma konularına ilişkin pedagojik alan bilgilerinin belirlenmesi. *Mersin Üniversitesi Eğitim Fakültesi Dergisi, 9*(2), 88-108. https://dergipark.org.tr/tr/pub/mersinefd/issue/17383/181572

Anıl, Ö. (2010). *Öğrenme sarmalına göre tasarımlanan 5E öğretim modeli uygulamaları ile 9. sınıf öğrencilerinin aynalar konusundaki kavramsal değişimlerinin incelenmesi* (Doktora Tezi. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü). Retrieved from https://dspace.balikesir.edu.tr/xmlui/handle/20.500.12462/337

Anıl, Ö., & Küçüközer, H. (2010). Ortaöğretim 9. sınıf öğrencilerinin düzlem ayna konusunda sahip oldukları ön bilgi ve kavram yanılgılarının belirlenmesi. *Türk Fen Eğitim Dergisi, 7*(3), 104-122. Retrieved from https://www.tused.org/index.php/tused/article/download/525/452

Aydın Günbatar, S. (2019). Fenomenolojik araştırma (Olgu bilim) yöntemi. In H. Özmen & O. Karamustafaoğlu (Eds.), *Eğitimde araştırma yöntemleri içinde* (pp. 293-316). Ankara: Pegem Akademi Yayınevi. https://doi.org/10.14527/9786052417867.14

Aydın, S. (2017). Eliminating the misconceptions about image formation in plane mirrors by conceptual change texts. *International Journal of Social Sciences and Education Research, 3*(4), 1394-1403. https://doi.org/10.24289/ijsser.320030

Aydın, S., & Öztekin, S. (2018). Üç aşamalı tanı testi ile fen lisesi öğrencilerinin geometrik optik konusundaki zihinsel modellerinin belirlenmesi. *Uluslararası Eğitim Bilim ve Teknoloji Dergisi, 4*(3), 155-172. Retrieved from https://dergipark.org.tr/tr/pub/uebt/issue/41983/505821

Aydın, S., Ural Keleş, Z., & Haşıloğlu, M. A. (2012). Establishment for misconceptions that science teacher candidates have about geometric optics. *The Online Journal of New Horizons in Education, 2*(3), 7-15. Retrieved from https://www.idealonline.com.tr/IdealOnline/lookAtPublications/paperDetail.xhtml?uId=59005&

Ayvacı, H. Ş., & Candaş, B. (2018). Students' understandings on light reflection from different educational level. *Journal of Computer and Education Research, 6* (11), 1-32. https://doi.org/10.18009/jcer.309748

Blizak, D., Chafiqi, F., & Kendil, D. (2009). Students misconceptions about light in Algeria. *Education and Training in Optics and Photonics* (p. EMA5). Optical Society of America. https://doi.org/10.1364/ETOP.2009.EMA5

Bülbül, M. Ş. (2016). *Nitel araştırmaların doğası*. Retrieved from https://www.academia.edu/22643956/NİTEL_ARAŞTIRMALARIN_DOĞASI

Büyüköztürk, Ş., Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2021). *Bilimsel araştırma yöntemleri* (31st ed.). Ankara: Pegem Akademi Yayınevi. Retrieved from https://www.academia.edu/40428382/Bilimsel_Ara%C5%9Ft%C4%B1rma_Y%C3%B6ntemleri_Tan%C4%B1t%C4%B1m_Metni_

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 a plane mirror. *Proc. Natl. Sci. Counc. ROC(D), 12*(2), 106-121. Retrieved from https://www.researchgate.net/publication/237236334_Developing_a_two-tier_diagnostic_instrument_to_assess_high_school_students'_understanding_The_formation_of_image_by_plane_mirror

Çökelez, A., & Çiftçi Yaşar, S. (2015). 6. sınıf öğrencilerinin 'görüntü kavramı' ile ilgili kavramsal öğrenmelerinin incelenmesi. *Turkish Studies, 10*(14), 159-180. https://doi.org/10.7827/TurkishStudies.8703

Demirci, N., & Ahçı, M. (2016). Işık ve optik konuları ile ilgili üniversite öğrencilerinin kavramsal anlama düzeyleri. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 10*(1), 142-181. https://doi.org/10.17522/nefefmed.39726

Durukan, Ü. G., & Paliç Şadoğlu, G. (2020). Fen bilgisi öğretmen adaylarının aynalarda görüntü konusuna ilişkin kavramsal anlamaları ve zihinsel modelleri. *Trakya Eğitim Dergisi, 10*(2), 330-346. https://doi.org/10.24315/tred.522213

Favale, F., & Bondani, M. (2013). Misconceptions about optics: An effect of misleading explanations? *Education and Training in Optics and Photonics* (p. EThI4). Optical Society of America. https://doi.org/10.1117/12.2070520

Feher, E., & Rice, K. (1988). Shadows and anti-images: Children's conceptions of light and vision. II. *Science Education, 72*(5), 637-649. https://doi.org/10.1002/sce.3730720509

Fetherstonhaugh, T., & Treagust, D. F. (1992). Students' understanding of light and its properties: Teaching to engender conceptual change. *Science Education, 76*(6), 653-672. https://doi.org/10.1002/sce.3730760606

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: Interpretation, structure and analysis. *International Journal of Science Education, 22*(1), 57-88. https://doi.org/10.1080/095006900290000

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. Retrieved from https://www.tandfonline.com/doi/full/10.1080/09500690500153741?casa_token=dKdcOgwIwG8AAAAA%3AMOeL46Si8y77uM6ya7ebdn9FQc2dvF4HuWAzHEKVq4-J_1G_iWMrTjm5QzHiKyFF8x4eidvS1PcV

Kaltakçı Gürel, D., Eryılmaz, A., & McDermott, L. C. (2017*)*. Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *Research in Science & Technological Education, 35*(2), 238-260. Retrieved from https://www.tandfonline.com/doi/full/10.1080/02635143.2017.1310094?casa_token=F3pLGaK_aosAAAAA%3AFsMSAefATpr5E1cjguP3mMZ0pUD_vT_KK-XdvMw3m_rQiyiYgje30u2L4k1URbVA0eE0mQ0Vmg-9

Karal, I. S. (2003). *Fizik öğretmeni adaylarının konu alan bilgi düzeylerinin belirlenmesi* (Yüksek Lisans Tezi, Karadeniz Teknik Üniversitesi Fen Bilimleri Enstitüsü). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Kocakülah, A. (2006). İlköğretim 5. sınıf öğrencilerinin görüntü kavramı ve düzlem aynalarda görüntü oluşumu ile ilgili kavramsal anlamaları. *Gazi Üniversitesi Kırşehir Eğitim Fakültesi, 7*(1), 157-171. Retrieved from https://dspace.balikesir.edu.tr/xmlui/bitstream/handle/20.500.12462/5084/aysel-kocakulah.pdf?sequence=1&isAllowed=y

Kocakülah, A., & Demirci, N. (2010). Ortaöğretim öğrencilerinin görüntü ve düzlem aynalarda görüntü oluşumu ile ilgili kavramsal anlamaları. Necatibey *Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 4*(1), 141-162. Retrieved from https://dergipark.org.tr/tr/download/article-file/39800

Konyalıoğlu, A. C. (2013). Matematik öğretmen adaylarının geometri alan bilgilerinin hata yaklaşımı ile incelenmesi. *Kâzım Karabekir Eğitim Fakültesi Dergisi, 27*, 45-62. Retrieved from https://dergipark.org.tr/tr/pub/ataunikkefd/issue/2786/37414

Konyalıoğlu, A. C., Aksu, Z., Şenel, E. Ö., & Tortumlu, N. (2010). *Matematik öğretmen adaylarının matematik soru çözümlerinde yapılan hataların nedenlerini sorgulama becerilerinin incelenmesi*. Uluslararası Öğretmen Yetiştirme Politikaları ve Sorunları Sempozyumu II. Hacettepe Üniversitesi, Mayıs 2010, Ankara. Retrieved from http://www.bakukongre.hacettepe.edu.tr/bildiri_kitabi.html

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded source book* (2nd ed.). Thousand Oaks: Sage Publications. Retrieved from https://books.google.com.tr/books?id=U4lU_-wJ5QEC&printsec=frontcover&hl=tr#v=onepage&q&f=false

Öztekin, S. (2018). *Fen bilimleri öğretmen adaylarının üç aşamalı tanı testi ile geometrik optik konusundaki zihinsel modellerinin belirlenmesi*. Ağrı İbrahim Çeçen Üniversitesi Fen Bilimleri Enstitüsü. Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=wrZLhXNCePmuEN7ghjYNaQ&no=EYrp2lkw_PqMkv0O6I0OCg

Park, S. (2005). *A study of pck of science teachers for gifted secondary students going through the national board certification process* (PhD Dissertation, Athens, Georgia).

Retrieved from https://getd.libs.uga.edu/pdfs/park_soonhye_200508_phd.pdf

Pınarkaya, Y. (2017). *"Aynalarda yansıma ve ışığın soğrulması" ünitesinde animasyon destekli kavram karikatürleri uygulamalarının öğrencilerin akademik başarılarına, kavram yanılgılarına ve tutumlarına etkisi* (Yüksek Lisans Tezi, Ordu Üniversitesi Fen Bilimleri Enstitüsü). Retrieved from http://earsiv.odu.edu.tr:8080/xmlui/handle/11489/718

Pompea, S. M., Dokter, E. F., Walker, C. E., & Sparks, R. T. (2007). Using misconceptions research in the design of optics. *Instructional Materials and Teacher Professional Development Programs*. ETOP. https://doi.org/10.1364/ETOP.2007.EMC2

Saban, A. (2009). Öğretmen adaylarının öğrenci kavramına ilişkin sahip oldukları zihinsel imgeler. *Türk Eğitim Bilimleri Dergisi, 7*(2), 281-326. Retrieved from https://dergipark.org.tr/tr/pub/tebd/issue/26107/275061

Şahin Çakır, Ç. (2019) Gelişimsel araştırma yöntemi. In H. Özmen & O. Karamustafaoğlu (Eds.), *Eğitimde araştırma yöntemleri içinde* (pp. 343-366). Ankara: Pegem Akademi Yayınevi. https://doi.org/10.14527/9786052417867.16

Şen, A. İ. (2003). İlköğretim öğrencilerinin ışık, görme ve aynalar konusundaki kavram yanılgılarının ve öğrenme zorluklarının incelenmesi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 25*, 176-185. Retrieved from https://dergipark.org.tr/tr/pub/hunefd/issue/7813/102582

Taşlıdere, E. (2013). Kavram karikatürleri ile zenginleştirilmiş çalışma yapraklarının öğrencilerin geometrik optik konusundaki kavramsal anlamalarına etkisi. *Eğitim ve Bilim, 38*(167), 144-160. Retrieved from http://egitimvebilim.ted.org.tr/index.php/EB/article/view/1549

Taşlıdere, E., & Eryılmaz, A. (2015). Öğretmen adaylarının geometrik optik konusundaki kavram yanılgılarının üç-aşamalı kavram yanılgısı testi ile değerlendirilmesi. *Bartın Üniversitesi Eğitim Fakültesi Dergisi, 4*(1), 269-289. Retrieved from https://dergipark.org.tr/tr/pub/buefad/issue/3816/51267

Türk Dil Kurumu Sözlükleri. (2019). *Eğitim*. Retrieved from https://sozluk.gov.tr

Uzunoğlu, M., Yıldız, A., Demir, Y., & Büyükkasap, E. (2013). Fen bilgisi öğretmen adaylarının ışıkla ilgili kavram yanılgılarının belirlenmesinde kavram karikatürlerinin ve açık uçlu soruların etkililiklerinin karşılaştırılması. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 14*(1), 367-388. Retrieved from https://dergipark.org.tr/tr/download/article-file/1490674

Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695. https://doi.org/10.1002/(SICI)1098-2736(199808)35:6%3C673::AID-TEA5%3E3.0.CO;2-J

Yıldırım, A., & Şimşek, H. (2021). *Sosyal bilimlerde nitel araştırma yöntemleri* (12th ed.). Ankara: Seçkin Yayınevi. Retrieved from https://www.seckin.com.tr/kitap/n/824235992/k/title/title/Nitel+Arastirma+Yontemleri

Appendix A

Data Collection Tool

In the data collection tool, there are 15 open-ended questions and correct and incorrect answers for these questions. Teacher candidates were asked to examine the answers given to the questions about the conceptual understanding prepared about the image in plane mirrors in the data collection tool.

After the examination process was completed, the participants were first asked to write the letter T in parentheses (…) if the answers were correct for them, and the letter F if they were incorrect. After that, it was especially emphasized that the participants should write their own answers for the statements they deem as right or wrong.

(*Answer key*: 1 F, 2 F, 3 F, 4 T, 5 F, 6 T, 7 F, 8 F, 9 T, 10 F, 11 F, 12 T, 13 F, 14 T, 15 F)

Questions and Answers

1. In a dark room, there is a white object in front of the plane mirror. What can be said about whether this object will appear in a plane mirror or not?

Answer: In a dark environment, a plane mirror image of a white object is formed. (...)

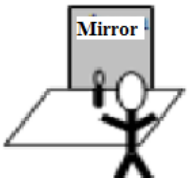
Your statement:

2. There is a black object in front of the plane mirror in a bright (illuminated) environment. What can be said about whether this object will appear in a plane mirror or not?

Answer: In a bright environment, the image of the black object in the plane mirror does not occur. (...)

Your statement:

3. What can be said about whether it is necessary for the observer to look towards the plane mirror in order for an object in front of the plane mirror to form an image in the plane mirror in a bright environment? (Cited image: Demirci & Ahçı, 2016)



Answer: In order for an object to appear, the observer must look towards the plane mirror. Because the image of the object in the plane mirror is formed only when the rays reflected from the plane mirror come to the eye of the observer. (...)

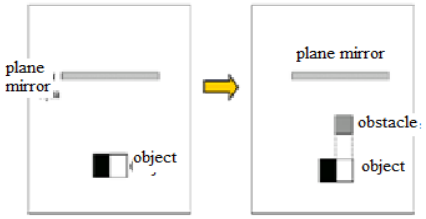
Your statement:

4. When an object in a bright environment is brought from point A to point B, which is closer to the plane mirror, what can be said about the location and size of the newly formed image of the object in the plane mirror?

Answer: When the object is brought from point A to point B, the image of the object in the plane mirror approaches the mirror, and the size of the object's image in the plane mirror does not change. (...)

Your statement:

5. There is an obstacle between the object in a bright environment and the plane mirror as in the figure. What can be said about the mirror image of the object when it is placed (an opaque object)? (Excerpt image: Anıl & Küçüközer, 2010)



Answer: When an obstacle is placed between the object and the plane mirror, some part of the object is imaged, while the other part does not. (...)

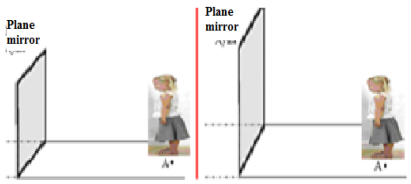
Your statement:

6. How does the size of the self-image seen by a student standing in front of a plane mirror change as the student moves away from the mirror?

Answer: As the student moves away from the plane mirror, the size of the student's own image in the mirror does not change. (...)

Your statement:

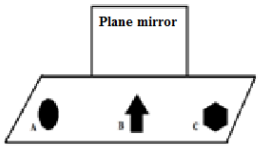
7. How does the size of the image formed in the mirror of a student standing in front of the plane mirror change when the size of the plane mirror is increased? (Excerpt image: Anıl & Küçüközer, 2010)



Answer: The size of the student's image formed in the plane mirror increases when the size of the mirror increases. (...)

Your statement:

8. Which of the objects A, B, and C in the figure form a plane mirror image?



Answer: The image of B object is formed in the plane mirror; the images of A and C objects are not formed. (...)

Your statement:

9. What can be said about the virtual or real image of an object formed in a plane mirror?

Answer: The image of the object in the plane mirror is virtual. (...)

Your statement:

10. What can be said about the location of an object's image formed in a plane mirror?

Answer: The image of the object in the plane mirror is formed on the surface of the mirror. (...)

Your statement:

11. What can be said when the size of the image formed in the plane mirror of an object is compared with the size of the object?

Answer: The size of the image formed in the plane mirror of the object varies depending on the distance of the object from the mirror. As the object gets closer to the plane mirror, the size of the image increases, and as the object moves away from the mirror, the size of the image decreases. (...)

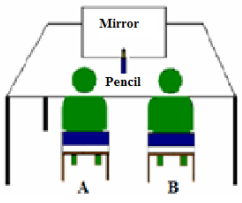
Your statement:

12. What can be said about the inverted or flat image of an object formed in a plane mirror?

Answer: The image of the object formed in the plane mirror is flat with respect to the object. (...)

Your statement:

13. What can be said for the observer about the location of the pencil's image in the plane mirror when the observer moves from position A to position B? (Excerpt image: Aydın & Öztekin, 2018)



Answer: When the observer changes position, the image of the object in the plane mirror also changes place. (...)

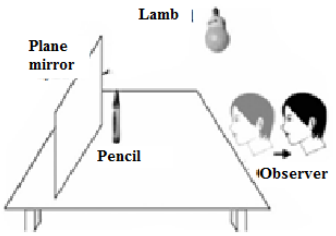
Your statement:

14. What can be said about the speed of the observer's image on the plane mirror when the observer moves with velocity v in a direction perpendicular to the plane mirror?

Answer: When the observer approaches the plane mirror with speed v, the image of the observer in the plane mirror also approaches the mirror with speed v. If the observer moves away from the plane mirror with the speed v, his/her image also moves away from the plane mirror with the speed v. (…)

Your statement:

15. In a bright environment, an observer looks at the image of the pen formed in the plane mirror, as seen in the figure. What can be said about the size of the image of the pen in the plane mirror when the observer moves away from the mirror? (Image quoted from Chen, H. S. Lin & M. L. Lin, 2002)



Answer: When the observer moves away from the plane mirror, the size of the pen's image on the plane mirror decreases. (...)

Your statement: