Examination of Prospective Science Teachers' Content Knowledge on Image in Plane Mirrors in Terms of Their Approaches to Error

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Doi: 10.19044/ejes.v10no2a41 https://doi.org/10.19044/ejes.v10no2a41

Submitted: 16 May 2022
Accepted: 22 July 2023
Published: 31 October 2023

Abstract

This paper focuses on examining prospective science teachers' content knowledge about image formation in plane mirrors in terms of approach to error. In accordance with this purpose, 15 questions about the conceptual understanding of the image in plane mirrors and a data collection tool containing correct or incorrect information in the answers for each question were prepared and applied to the teacher candidates. The phenomenology, which is a qualitative research design, was used in this study. The sample consisted of 36 prospective teachers who continued their education in 3rd and 1st grades at a university in Turkey. The findings obtained in the research were analyzed with the descriptive analysis method. In the study, it was seen that the percentage of the candidates who were able to identify the questions that presented correct or incorrect answers about the image in plane mirrors was at a moderate level. Among the participants who detected incorrect answers in the questions presented to the candidates, it was determined that the explanations written by a small number of participants regarding the solution to the questions were correct. Most of the participants have misconceptions such as "the image is formed on the mirror surface in a plane mirror", "the image of objects in mirrors only occurs when the observer looks towards the mirror and does not occur when he does not", and "the size and location of an object's image in plane mirrors are affected by the movement of the observer". In the study, it was determined that some participants had the misconception of "seeing the mirror as a light source", which was not encountered in the literature. From the findings, it was stated that the participants in the research group were not in an acceptable position in terms of the image in plane mirrors, including their development in subject knowledge and student understanding. At the end of the study, some suggestions were made to researchers interested in the subject.

Keywords: Plane mirrors, approach to error, student understandings, misconceptions, physics education

Introduction

Today, states are in a great race in technology and science, as in every field. In order to survive in this race, states must train individuals in their own countries to be well literate in science. The most essential elements in this process are students, teachers, and teacher training institutions. Training teachers who will build the future of society must be well-planned and executed in these institutions. Teachers are expected to be strategists who can prevent the challenges they face in education in the 21st century global society (Spadora et al., 2017). In this context, the fact that prospective teachers know what they may encounter while performing their profession, and know how to find a solution to the problems they encounter is closely related to their teaching qualifications. Van Driel et al. (1998) defined teacher competencies as an integrated phenomenon that includes teachers' knowledge and beliefs about curriculum, subject, etc. Studies on this have revealed that the mentioned phenomenon determines what the teacher will teach and in what way (Uluçınar Sağır, 2018). Subject content knowledge (SCK) is one of the most critical pieces of information that teachers should have for an efficient education (Alev & Karal, 2013). In addition to SCK, teachers should also have features that will contribute to students' formal learning of concepts. These features constitute the main element of pedagogical content knowledge (PCK), which is defined as the teacher's ability to teach the subject depending on the education, training environment, and the individual differences of the learners (Alev & Karal, 2013). In the literature, different PCK models have been proposed in studies on teacher competencies. Among these studies, the study of Park (2005) has found an important place in science teaching. In her study, Park suggested the hexagon PCK model by first adding the pentagon model and then adding teacher competence to the pentagon model. In the hexagon model, one of the components of PCK is student understandings in science.

According to Park (2005), teachers' misconceptions about students, learning difficulties, and development levels involve students understanding of science component. Student errors can also be considered in this component. Incorrect questions, answers, and misconceptions may be encountered in students' written or verbal expressions and sources. Therefore, teacher candidates and teachers should be able to identify the errors they encounter. This necessity was expressed in the literature by Uluçınar Sağır (2018), which states that "the teacher should sense students' verbal or non-verbal errors and misconceptions". According to Konyalıoğlu et al. (2010), the prospective teacher or teacher who can identify the error and explain the reasons correctly is able to interpret the related concept appropriately. Detection of information

such as misconceptions and student errors and the effective implementation of studies to eliminate them will contribute to the development of teacher candidates' PCK. According to Konyalıoğlu (2013), deep knowledge of the subject to be taught plays an essential role in shaping PCK. Konyalıoğlu further reported that, SCK with the desired quality increases students' success and education quality. In science subjects that students have difficulty in learning, the teacher's SCK is important. According to Konyalıoğlu et al. (2012), the ability to correctly identify and correctly explain the error can be used in determining the sufficiency of subject knowledge. In the same study, it was also emphasized that identifying the error correctly and expressing why it was wrong requires in-depth knowledge of the subject matter. Based on this information, it can be stated that the candidates, who can identify the wrong information about physics and reveal the reasons correctly, will be able to plan and implement the education process by knowing the reasons for the error when they are in the position of instructors in the future.

There are difficulties in teaching and learning concepts related to many subjects in physics because of its abstract nature. In order to overcome these difficulties, the choice of the teaching techniques, methods, and language to be used in teaching the concepts are also important. The scientific language and the language of daily life can sometimes differ. These differences appear as misconceptions in the education process. Daily life language, teachers, books, etc. are sources of misconceptions. As in most subjects in physics, the concepts related to the image in mirrors can be misused in daily life without realizing it. Some students may acquire university education with misconceptions and incomplete or incorrect information. For this reason, before the topics are given, what the students know and do not know should be determined. Planning the teaching process according to the results obtained will contribute to the efficiency and quality of education.

In the studies on the image in the mirrors (Anıl, 2010; Anıl & Küçüközer, 2010; Aydın et al., 2012; Ayvacı & Candaş, 2018; Blizak et al., 2009; Chen et al., 2002; Çökelez & Çiftçi Yaşar, 2015; Durukan & Paliç Şadoğlu, 2020; Feher & Rice, 1988; Fetherstonhaugh & Treagust, 1992; Galili & Hazan, 2000; Heywood, 2005; Kaltakçı Gürel et al., 2017; Kocakülah, 2006; Pompea et al., 2007; Şen, 2003; Taşlıdere & Eryılmaz, 2015; Wahyuni et al., 2019; Widiyatmoko & Shimizu, 2019). it has been determined that some of the primary, secondary and high school students, Computer and Instructional Technologies, Classroom Teaching, and Science and Physics teacher candidates have incomplete or incorrect information and misconceptions about the image in plane mirrors. Missing or incorrect information and misconceptions identified in the literature are listed below:

- The image of an object in a plane mirror is right in front of the observer.
- In a plane mirror, the image of the object is in front of/on the surface/inside/on the mirror.
- In a plane mirror, the image is inverted, big, small, and real.
- Real images are seen in the mirror, virtual images cannot be seen.
- The image size is always equal to the mirror size.
- If the dimensions of the plane mirror are increased, the image becomes larger.
- The distances of the object and its image from the plane mirror are at different values.
- Apple, black, and white pieces of paper can be seen in a dark environment.
- Light-colored objects can be seen in complete darkness as they emit light.
- Black-colored objects do not reflect light at all.
- If you want to use the mirror to see yourself in a dark room, the mirror should be illuminated with light rather than yourself.
- When the light hits the mirror, it stays on its surface.
- Expressing an image as a shadow in plane mirrors.
- If there is an obstacle in front of the rays coming out of the object, the image of a part or the whole of the object does not occur.
- For the image to be seen, the object must be directly in front of the mirror.
- If the object is in front of the mirror, its image is formed.
- A change in the observer's position affects whether the object is mirrored or not.
- Images that are not in the same region as the observer cannot be seen.
- When the observer moves, the image of the object moves in the opposite direction.
- The image in the mirror is directly opposite the point where the observer is.
- When the observer moves, the size and location of the image of the object in the plane mirror changes.
- The observer, who is in front of the plane mirror, sees more of himself when he moves away from the mirror.
- The image of the object moving away from the plane mirror becomes smaller.
- When we look in the mirror, an image is formed, otherwise there is no image in the mirror.
- As a person approaches or moves away from the plane mirror, they can see more of their own image in the mirror due to the increase in the field of view.

Importance of Research

In the literature, it is seen that there are misconceptions about the image in plane mirrors in every society and researches on this subject are still ongoing. Studies aim to detect incomplete or incorrect information and misconceptions and eliminate these misconceptions. The fact that there is no research covering the approach to error in the literature reveals the need to carry out this study. Considering that the study results will shed light on prospective science teachers who will give lectures on this subject in the future, thus the subject is worth investigating. Visual working memory serves as the foundation of cognitive processes (Amundsen et al., 2014). For these reasons, the knowledge of prospective teachers about images in plane mirrors and their approaches to solving questions with incorrect answers were examined in the study.

Purpose of the Research

The objective of this research was to examine prospective science teachers' image subject knowledge in plane mirrors according to their approach to error, and to determine the developmental status of subject knowledge and student understanding knowledge. Therefore, the research aimed to find answers to the following questions:

1. How are prospective science teachers continuing their education in 1st and 3rd grades to detect correct or incorrect information about the image in plane mirrors?
2. How do prospective science teachers approach the error in the image subject area in plane mirrors?

Method

This is a qualitative study. Data collection methods such as document analysis, interview, and observation are used in qualitative research. Qualitative research is a form of research that aims to identify events in their own environment realistically and inclusively (Yıldırım & Şimşek, 2021). According to Bülbül (2016), the qualitative research method is an approach that generally analyzes verbal data and aims to research and explore beyond generalization anxiety. In this context, the qualitative research approach was utilized to examine the knowledge of prospective science teachers about images in plane mirrors and students' understanding knowledge (misconceptions, proficiency levels, etc.).

This section gives explanations about the research model, data collection, study group, data analysis, validity and reliability.

Model of the Research

Based on the image in plane mirrors, this study aimed to determine the developmental status of students studying in 1st and 3rd grades of the Science Education program in the fall semester of 2021-2022 academic year. The study further aimed to identify the understanding of the students and their approaches to the errors related to the subject. In accordance with this purpose, the study was organized within the framework of the phenomenology pattern, which is one of the qualitative research methods. The phenomenology design is used in research to inquire deeply about participants thoughts based on their experiences with the subject or concepts, their perceptions, as well as the ways and methods of connecting concepts (Aydın Günbatar, 2019; Yıldırım & Şimşek, 2021). For this reason, the knowledge of the subject of images in plane mirrors was investigated with a phenomenological design in terms of the prospective teachers' approaches to error.

Study Group of the Research

The research group of the study, which was carried out with the qualitative research method, was determined with easily accessible sampling. This is one of the sampling methods suitable for the purpose. In the study group, 18 students from 3rd grade (F=16, M=2) and 18 students from 1st grade (F=12, M=6) were included in the Science Teaching Program of the Faculty of Education. Among the participants, 3rd grade students took the course related to the research topic in their 2nd grade. First grade students took the relevant course in high school. The study group was formed from 1st and 3rd grade students in order to examine the development of the knowledge of the image subject in plane mirrors of prospective teachers in 3rd grade. The demographic characteristics of the individuals in the research group were determined in this context, as seen in Table 1. The names of the participants were not included in the study, considering the ethical principles. As a result, each participant was given a code as $C1_1$, $C1_2$, - $C1_{18}$ for 1st grade students and $C3_1$, $C3_2$, - $C3_{18}$ for 3rd grade students.

Table 1. Demographic Characteristics of Participants

High School	**1st Grade**		**3rd Grade**		**Total**			
	Female	**Male**	**Female**	**Male**	**Female**		**Male**	
	N	**n**	**n**	**N**	**n**	**%**	**n**	**%**
Anatolian High School	9	6	11	2	20	55	8	22
Science High School	2	-	-	-	2	6	-	-
Imam Hatip High School	1	-	1	-	2	6	-	-
Vocational High School	-	-	3	-	3	8	-	-
Commerce High School	-	-	1	-	1	3	-	-
Total	12	6	16	2	28	78	8	22

According to Table 1, it was revealed that 77% of the participants graduated from Anatolian high schools. This group had the highest rate in terms of the schools graduated. As for the gender of the participants, 78% of the participants were female and 22% were male.

Data Collection Tool and Process

The researcher prepared a two-stage data collection tool for conceptual understanding. The data collection tool included 15 open-ended questions and correct and incorrect answers for these questions (Appendix 1. data collection tool). Teacher candidates were asked to examine the answers given to the questions about the conceptual understanding of 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, participants were told to write their own answers for the explanations they deem wrong.

Analysis of Data

First, the numbers and percentages of the participants who distinguished the correct or wrong answers from the candidates' answers to the questions from the data obtained in the study were determined and tabulated. Second, the explanations of the candidates who could not and did not detect the erroneous explanations were grouped into the determined categories and codes. Data were analyzed with descriptive analysis. Descriptive analysis brings the data to a state that readers can comprehend and use whenever they want (Bayar & Zengin, 2020). After each question was analyzed, the findings were presented in tables. Samples selected from the answers given by the participants in the tables were given separately for all categories and codings. In Table 2, the categories and codes used in the analysis phase were given.

Table 2. Categories and Codes

Categories	Codes	Examining Codes*
No Response		
Inability to Detect the Wrong	No Description	
	Description Incorrect	
	Description Partially Correct	
	Description Correct	
Detecting the Wrong	No Description	
	Description Incorrect	
	Description Partially Correct	
	Description Correct	

*The review is defined below.

Categories

1. No response: No opinion is expressed.
2. Inability to Detect the Wrong: It is the situation in which the given answer is evaluated as correct.
3. Detecting the Wrong: It is the situation of detecting that the given answer is wrong.

Codes and Review

The explanations written by the participants as answers to the questions were handled under four different coding. These are the codes:

1. No Description: It is the coding without any explanation.
2. Description Incorrect: It is the coding where the explanation is seen as completely wrong.
3. Description Partially Correct: It is the situation where the explanation is not seen as completely correct. Incomplete explanations or explanations where some are correct and some are incorrect are evaluated under this coding. In addition, the answers written by the candidates are scientifically correct, but the explanations that are not fully related to the answer of the given question are included in this coding.
4. Description Correct: It is the coding in which the explanations are considered completely correct.

Validity Reliability

In order to ensure the reliability and validity of the study, the knowledge of a sufficient number of faculty members who are experts in the field of physics education has been consulted. Tables prepared separately for each question were given their final shape within the framework of expert opinions. To calculate the reliability of the study, the formula [Reliability = consensus / (disagreement + consensus) X 100], which was put forward by Miles and Huberman (1994), was used. Saban (2009) emphasized in his study that research reliability would be ensured when the consensus between the expert and the researcher was 90% or more. The study determined that the consensus between the experts and the researcher was 94% on average. The levels developed by the researcher were used to interpret the percentages of the candidates whose explanations were accepted/acceptable, (correct and partially correct) based on the error based on the research findings. Also, it was used to evaluate the development levels of the candidates in terms of subject knowledge. These levels include the following: very high (100 - 80%), high (80 - 60%), medium (60 - 40%), low (40 - 20%), and very low (20 - 0%).

Ethical Procedures

This research was carried out with the "Ethics Committee Permission" dated 13/10/2021 and numbered E-30640013-108.01-37445 of the Social Sciences Ethics Committee and the Amasya University Science Ethics Committee.

Findings

In this section, the findings related to the sub-problems of the research obtained from the data collection tools are given. The answers to questions 4, 6, 9, 12, and 14 presented to the prospective teachers in the data collection tool in Appendix 1 were correctly constructed, and the answers to the other questions were arranged with incorrect definitions or citing misconceptions in the literature.

1. How are prospective science teachers continuing their education in 1st and 3rd grades to distinguish between true and false information about the image in plane mirrors?

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 3.

Table 3. Number and Percentages of Participants Who Determined that the Answers were Correct or Wrong

Number and Percentages of Prospective Teachers Identifying the Correct Answers				
Question	**1st Grade**		**3rd Grade**	
	n	**%**	**N**	**%**
4	9	50	2	11
6	3	17	3	17
9	11	61	13	72
12	13	72	12	67
14	12	67	17	94
Number and Percentages of Prospective Teachers Identifying Wrong Answers				
Question	**1st Grade**		**3rd Grade**	
	n	**%**	**N**	**%**
1	9	50	15	83
2	18	100	16	89
3	9	50	11	61
5	4	22	1	6
7	16	89	16	89
8	9	50	10	56
10	4	22	3	17
11	2	11	2	11
13	5	28	7	39
15	8	44	7	39

According to Table 3, the number and percentage of the first-grade teacher candidates who determined that the answers to the questions given to the participants were correct were the highest (72%), and the answer for the twelfth question indicates that "the image of an object in a plane mirror is flat compared to the object". The answer with the highest number and percentage of the participants in 3rd grade was 94%. However, the answer for the 14th question denotes that "When the observer approaches the plane mirror with the speed v, his image approaches the mirror with the speed v, and when the observer moves away from the plane mirror with the speed v, the image also has the speed v and moves away from the mirror". The answer given for the 6th question, where the number and percentage of the 1st grade participants who identified the correct explanations was the smallest (17%), denotes that "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". The smallest number and percentage of prospective teachers in 3rd grade (11%) is the answer given for the 4th question, which states that "When the object is brought from point A to point B, which is closer to the plane mirror, the image of the object approaches the mirror, and the size of the image of the object in the mirror does not change". The 2nd question, however, identified the number and percentage of the first-grade candidates who found that the solutions of the questions presented to them about the image in plane mirrors were wrong (100%). Conversely, the number and percentage of the 3rd grade candidates were the highest (89%). The answer given for the 11th question showed that the number and percentage of the 1st grade prospective teachers who detected erroneous explanations were the smallest (11%). The frequency and percentages of the 3rd grade candidates are the smallest (6%), based on the 5th question.

2. How do prospective science teachers approach the error in the image subject area in plane mirrors?

The findings in Table 4 were obtained by examining the statement and answers given by the students to the 1st question. Nonethelesss, the solution was incorrect about the image in plane mirrors.

Table 4. Categories, Codes, Participants, and Sample Answers for Question 1

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response				
	No Description*	$C1_{12}$, $C1_{15}$		
Inability to Detect the Wrong	Description Incorrect	$C1_2$, $C1_4$, $C1_5$, $C1_8$, $C1_{11}$, $C1_{16}$, $C1_{18}$	$C3_3$, $C3_6$	*"A little image is formed by the light of the mirror."* $C1_{16}$, *"In the dark, a white object brings light to our eyes, and thus we see the image"* .$C3_3$
	Description Partially Correct**			
	Description Correct*		$C3_4$	
	No Description**			
	Description Incorrect	$C1_3$, $C1_{13}$, $C1_{14}$	$C3_{11}$	*"Because black does not reflect any color, so white is seen as black."* $C1_3$, *"Because the color white is exploited by the color black."* $C3_{11}$
Detecting the Wrong	Description Partially Correct	$C1_1$, $C1_{17}$	$C3_2$, $C3_{12}$, $C3_{13}$, $C3_{16}$, $C3_{18}$	*"Since there is no light, light cannot reflect on the object and no image is formed."* $C1_1$, *"Nothing is visible in a dark environment."* $C3_{13}$
	Description Correct	$C1_6$, $C1_7$, $C1_9$, $C1_{10}$	$C3_1$, $C3_5$, $C3_7$, $C3_8$, $C3_9$, $C3_{10}$, $C3_{14}$, $C3_{15}$, $C3_{17}$	*"An image does not form. There must be an illuminated environment for it to occur."* $C1_9$*," No image is formed because there is no light."* $C3_{15}$

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

As seen in Table 4, the number of participants who determined that the answer to the 1st question was wrong and their explanations were correct was 9 (nine) in 3rd grade and 4 in 1st grade. The number of participants whose explanations were partially correct was 5 in 3rd grade and 2 in 1st grade. Subsequently, the percentages of the participants whose explanations were acceptable were 33% (thirty-three percent) for 1st grade and 78% for 3rd grade.

The findings in Table 5 were obtained by examining the explanations and answers given by the students to the second question. However, the solution was incorrect about the image in plane mirrors.

Table 5. Categories, Codes, Participants, and Sample Answers for Question 2

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response				
	No Description**			
	Description Incorrect*		$C3_3$	*"When the reflected ray comes into the eye, we see the light and form the image."* $C3_3$
Inability to Detect the Wrong	Description Partially Correct**			
	Description Correct*		$C3_2$	"*The observer must look at the object to see it, but if she/he does not have to see, the object will still appear in the mirror."* $C3_2$
	No Description*	$C1_{12}$, $C1_{14}$		
	Description Incorrect	$C1_2$, $C1_4$, $C1_{11}$, $C1_{13}$,		*"It occurs in the refraction of a black object in a bright environment."* $C1_4$
	Description Partially Correct	$C1_7$, $C1_8$, $C1_9$, $C1_{16}$, $C1_{17}$, $C1_{18}$	$C3_{10}$, $C3_{13}$, $C3_{14}$, $C3_{15}$, $C3_{16}$, $C3_{17}$, $C3_{18}$	*"In a bright environment, the object is seen even if it is black."* $C1_{18}$, *"The image is formed. Because of the light in the environment, it is reflected on the mirror."* $C3_{17}$
Detecting the Wrong	Description Correct	$C1_1$, $C1_3$, $C1_5$, $C1_6$, $C1_{10}$, $C1_{15}$,	$C3_1$, $C3_4$, $C5_5$, $C3_6$, $C3_7$, $C3_8$, $C3_9$, $C3_{11}$, $C3_{12}$	*"In a bright environment, the color does not affect the formation of the image."* $C1_{15}$,*"Since the environment is bright, the image of the black object in the plane mirror is formed."* $C3_{12}$

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

According to Table 5, the number of participants who determined that the answer to the 2nd question was wrong and their explanations were correct was 9 (nine) in 3rd grade and 6 in 1st grade. Subsequently, the number of participants whose explanations were partially correct was 7 (seven) in 3rd grade and 6 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 67% (sixty-seven percent) for 1st grade and 89% for 3rd grade.

The findings in Table 6 were obtained by examining the explanations and answers given by the students to the 3rd question. Nevertheless, the solution was incorrect about the image in plane mirrors.

Table 6. Categories, Codes, Participants, and Sample Answers for Question 3

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response				
	No Description*	$C1_8$, $C1_{15}$		
Inability to Detect the Wrong	Description Incorrect	$C1_3$, $C1_7$, $C1_{10}$, $C1_{12}$, $C1_{14}$	$C3_1$, $C3_9$, $C3_{12}$	*"The point of view and the position of the observer are important."* $C1_{12}$, *"It comes to our eyes with the refraction of light by looking in the mirror."* $C3_9$
	Description Partially Correct	$C1_9$, $C1_{18}$	$C3_3$, $C3_{13}$, $C3_{16}$	*"If she/he doesn't look in the mirror she/he can't see if an image will form."* $C1_9$, *"If she/he does not use other material (camera, mirror ...) to observe whether the image is formed, she/he cannot see whether it is reflected or not."* $C3_{16}$
	Description Correct*		$C3_2$	*"The observer has to look at the object to see it, but still the object is seen in the mirror."* $C3_2$
Detecting the Wrong	No Description**			
	Description Incorrect	$C1_4$, $C1_{17}$		*"The mirror must see the image."* $C1_{17}$
	Description Partially Correct	$C1_{11}$, $C1_{13}$	$C3_7$	*"She/he doesn't need to look. Because the light is refracted, all sorts of images will appear."* $C1_{13}$, *"An image of your own body is also formed."* $C3_7$
	Description Correct	$C1_1$, $C1_2$, $C1_5$, $C1_6$, $C1_{16}$	$C3_4$, $C5_5$, $C3_6$, $C3_8$, $C3_{10}$, $C3_{11}$, $C3_{14}$, $C3_{15}$, $C3_{17}$, $C3_{18}$	*"It is enough for the ray reflected from the object to fall on the mirror to form the image."* $C1_1$, *"The image is formed even if we don't see it."* $C3_6$

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

As seen in Table 6, the number of participants who determined that the answer to the 3rd question was wrong and their explanations were correct was 10 (ten) in 3rd grade and 5 in 1st grade. Also, the number of participants whose explanations are partially correct is 1 (one) in 3rd grade and 2 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 39% (thirty-nine percent) for 1st grade and 61% for 3rd grade.

The findings in Table 7 were obtained by examining the explanations and answers given by the students to the 5th question. Nonetheless, the solution was incorrect about the image in plane mirrors.

Table 7. Categories, Codes, Participants, and Sample Answers for Question 5

		Participants		
Categories	**Codes**	**1st Grade**	**3rd Grade**	**Sample answers**
No Response		$C1_8$		
	No Description*	$C1_{15}$		
Inability to Detect the Wrong	Description Incorrect	$C1_1$, $C1_3$, $C1_5$, $C1_6$, $C1_7$, $C1_{10}$, $C1_{11}$, $C1_{12}$, $C1_{13}$, $C1_{14}$, $C1_{17}$, $C1_{18}$	$C3_1$, $C3_2$, $C3_3$, $C3_4$, $C5_5$, $C3_6$, $C3_7$, $C3_8$, $C3_{10}$, $C3_{11}$, $C3_{12}$, $C3_{13}$, $C3_{14}$, $C3_{15}$, $C3_{16}$, $C3_{17}$, $C3_{18}$	*"There is no image where there is an obstacle."* $C1_{12}$, *"The obstacle forms an obstacle to the reflected part of the object and closes some of it."* $C3_8$
	Description Partially Correct**			
	Description Correct**			
	No Description**			
Detecting the Wrong	Description Incorrect*	$C1_2$, $C1_4$, $C1_9$, $C1_{16}$,		*"Depends on where the observer is. If it's on the right side of the object, it's fully visible."* $C1_2$
	Description Partially Correct*		$C3_9$	*"Opaque objects are opaque. Therefore, the image is not formed."* $C3_9$
	Description Correct**			

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

According to Table 7, the participant who determined that the answer to the 5th question was wrong and whose explanations were correct could not be determined. The number of participants whose explanations were partially correct was zero in 1st grade and 1 in 3rd grade. Also, the percentages of prospective teachers who made an acceptable statement were 0% (zero percent) for 1st grade and 6% for 3rd grade.

The findings in Table 8 were obtained by examining the explanations and answers given by the students to the 7th question. However, the solution was incorrect about the image in plane mirrors.

Table 8. Categories, Codes, Participants, and Sample Answers for Question 7

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response		$C1_8$		
Inability to Detect the Wrong	No Description**			
	Description Incorrect	$C1_{10}$	$C5_5$, $C3_{11}$	*"As the mirror gets bigger, the focal point changes. Therefore, the size of the image also increases."* $C1_{10}$, *"The larger the mirror, the larger the pupil."* $C3_{11}$
	Description Partially Correct**			
	Description Correct**			
Detecting the Wrong	No Description**			
	Description Incorrect	$C1_1$, $C1_{14}$, $C1_{17}$	$C3_1$, $C3_2$, $C3_6$, $C3_7$, $C3_9$, $C3_{14}$, $C3_{17}$	*"It shrinks."* $C1_{14}$, *"Since the student's place does not change, there is no change in her/his image."* $C3_{17}$
	Description Partially Correct	$C1_2$, $C1_3$, $C1_5$, $C1_6$, $C1_7$, $C1_{12}$ $C1_{15}$, $C1_{16}$	$C3_4$	*"It does not change. Because the distance of the mirror is effective, not the size."* $C1_3$, *"The size of the mirror does not affect the image. The distance of the pupil affects the image size."* $C3_4$
	Description Correct	$C1_4$, $C1_9$, $C1_{11}$, $C1_{13}$, $C1_{18}$	$C3_3$, $C3_8$, $C3_{10}$, $C3_{12}$, $C3_{13}$, $C3_{15}$, $C3_{16}$, $C3_{18}$	*"Increasing the size of the plane mirror does not affect the size of the image."* $C1_{18}$, *"The size of the plane mirror image of the pupil does not change."* $C3_{15}$

**: There are no participants in both grades for this coding group.

As seen from Table 8, the number of participants who determined that the answer to the 7th question was wrong and whose explanations were accepted as correct was 8 (eight) in 3rd grade and 5 in 1st grade. Subsequently, the number of participants whose explanations were partially correct was 1 (one) in 3rd grade and 8 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 72% (seventy-two percent) for 1st grade and 50% for 3rd grade.

Findings in Table 9 were obtained by examining the explanations and answers given by the students to the 8th question. However, the solution is incorrect about the image in plane mirrors.

Table 9. Categories, Codes, Participants, and Sample Answers for Question 8

Categories	**Codes**	**Participants**		**Sample answers**
		1st Grade	**3rd Grade**	
No Response				
Inability to Detect the Wrong	No Description**			
	Description Incorrect	$C1_1$, $C1_3$, $C1_4$, $C1_6$, $C1_8$, $C1_{10}$, $C1_{12}$, $C1_{14}$, $C1_{17}$	$C3_2$, $C3_3$, $C3_4$, $C3_8$, $C3_{13}$, $C3_{14}$, $C3_{18}$	*"As objects A and C do not look into the mirror, their images do not form."* $C1_8$, *"Plane mirrors do not see objects."* $C3_{18}$
	Description Partially Correct*		$C3_9$	*"If we are directly opposite the plane mirror, we only see the image of B. A and C are not in line with the mirror."* $C3_9$
	Description Correct**			
Detecting the Wrong	No Description**			
	Description Incorrect	$C1_7$, $C1_{13}$, $C1_{16}$	$C3_6$, $C3_{12}$, $C3_{17}$	*"Depends on how you look in the mirror."* $C1_{13}$, *"The plane changes depending on where you're looking at the mirror."* $C3_{12}$
	Description Partially Correct	$C1_2$, $C1_{15}$	$C3_5$	*"All of them are viewed from different angles."* $C1_{15}$, *"They all form images. But depending on the eye that sees."* $C3_5$
	Description Correct	$C1_5$, $C1_9$, $C1_{11}$, $C1_{18}$	$C3_1$, $C3_7$, $C3_{10}$, $C3_{11}$, $C3_{15}$, $C3_{16}$	*"The image of all is formed."* $C1_{11}$ *"The objects are not visible when viewed from the angle of the B object. However, if we look from the points where A and C are located, we see the image of the objects"* $C3_{16}$

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

As seen in Table 9, the number of participants who identified the erroneous explanation given in the answer to the 8th question and whose explanations were correct was 6 (six) in 3rd grade and 4 in 1st grade. Subsequently, the number of participants whose explanations are partially correct is 1 (one) in 3rd grade and 2 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 33% (thirty-three percent) for 1st grade and 39% for 3rd grade.

Findings in Table 10 were obtained by examining the explanations and answers given by the students to the 10th question. Nevertheless, the solution is incorrect about the image in plane mirrors.

Table 10. Categories, Codes, Participants, and Sample Answers for Question 10

Categories	**Codes**	**Participants**		**Sample answers**
		1st Grade	**3rd Grade**	
No Response		$C1_7$, $C1_8$		
Inability to Detect the Wrong	No Description	$C1_2$, $C1_5$, $C1_{14}$	$C3_7$, $C3_{10}$, $C3_{12}$, $C3_{14}$	
	Description Incorrect	$C1_3$, $C1_4$, $C1_6$, $C1_{10}$, $C1_{11}$, $C1_{13}$, $C1_{16}$, $C1_{17}$	$C3_2$, $C3_3$, $C3_4$, $C5_5$, $C3_6$, $C3_8$, $C3_{13}$, $C3_{15}$, $C3_{17}$, $C3_{18}$	*"The image of an object in a plane mirror is upside down and on the surface of the mirror."* $C1_{11}$, *"Since the object is visible to the naked eye, the image is formed on the surface of the mirror."* $C3_{15}$
Detecting the Wrong	Description Partially Correct	$C1_{12}$	$C3_9$	*"On the surface of the mirror, a flat image is formed."* $C1_{12}$, *"It appears in the mirror."* $C3_9$
	Description Correct**			
	No Description**			
	Description Incorrect**			
	Description Partially Correct	$C1_9$	$C3_{11}$, $C3_{16}$	*"The image of the object in the plane mirror depends on the distance of the object from the mirror."* $C1_9$, *"For example, if the object is 5 steps ahead, its reflection in the plane mirror will be 5 steps away."* $C3_{16}$
	Description Correct	$C1_1$, $C1_{15}$, $C1_{18}$	$C3_1$	*"It occurs behind the mirror."* $C1_{15}$, *"In a plane mirror, the image of the object occurs behind the mirror."* $C3_1$

**: There are no participants in both grades for this coding group.

As seen in Table 10, the number of participants who identified the erroneous explanation given in answer to the 10th question and whose explanations were correct was 1 (one) in 3rd grade and 3 in 1st grade. Subsequently, the number of participants whose explanations are partially correct is 2 (two) in 3rd grade and 1 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 22% (twenty-two percent) for 1st grade and 17% for 3rd grade.

Findings in Table 11 were obtained by examining the explanations and answers given by the students to the 11th question. However, the solution is incorrect about the image in plane mirrors.

Table 11. Categories, Codes, Participants, and Sample Answers for Question 11

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response		$C1_8$		
Inability to Detect the Wrong	No Description	$C1_{12}$, $C1_{14}$, $C1_{15}$,	$C5_5$, $C3_7$, $C3_{10}$, $C3_{14}$	
	Description Incorrect	$C1_2$, $C1_3$, $C1_5$, $C1_6$, $C1_7$, $C1_9$, $C1_{10}$, $C1_{11}$, $C1_{13}$, $C1_{16}$, $C1_{17}$	$C3_1$, $C3_2$, $C3_3$, $C3_4$, $C3_6$, $C3_9$, $C3_{11}$, $C3_{13}$, $C3_{15}$, $C3_{16}$, $C3_{17}$	*"The observer increases as long as she/he looks from a certain point."* $C1_2$, *"Like the real observer, the mirror reflects what it sees."* $C3_4$
	Description Partially Correct	$C1_4$	$C3_8$	*"As the object gets closer to the mirror, the angle of impact of the rays reflected from the object to the mirror changes."* $C1_4$, *"When we get closer to the mirror, we see our face closer, clearer, more distinct, but as we move away, it becomes blurred."* $C3_8$
Detecting the Wrong	Description Correct**			
	No Description**			
	Description Incorrect**			
	Description Partially Correct**			
	Description Correct	$C1_1$, $C1_{18}$	$C3_{12}$, $C3_{18}$	*"The size of the image does not depend on the distance of the object from the mirror. The image size does not change".* $C1_1$, *"The size of the image formed in a plane mirror is the same as the size of the object "* $C3_{12}$

**: There are no participants in both grades for this coding group.

As seen in Table 11, the number of participants who knew that the answer to question 11 was incorrect and whose explanations were correct was 2 in 1st and 3rd grades. Also, the percentage of prospective teachers who made acceptable statements is 11% in 1st and 3rd grades.

Findings in Table 12 were obtained by examining the explanations and answers given by the students to the 13th question. Nonetheless, the solution is incorrect about the image in plane mirrors.

Table 12. Categories, Codes, Participants, and Sample Answers for Question 13

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response		$C1_8$		
Inability to Detect the Wrong	No Description**			
	Description Incorrect	$C1_1$, $C1_4$, $C1_6$, $C1_9$, $C1_{10}$, $C1_{11}$, $C1_{13}$, $C1_{16}$, $C1_{18}$	$C3_1$, $C3_6$, $C3_9$, $C3_{10}$, $C3_{12}$, $C3_{13}$, $C3_{14}$, $C3_{16}$, $C3_{17}$	*"It changes because the observer's perspective changes."* $C1_4$, *"When we look at the pen, it is on the right side of the pen."* $C3_{14}$
	Description Partially Correct	$C1_7$, $C1_{12}$, $C1_{15}$	$C3_{11}$	*"The image size does not change. As there is a change of location, the location of the image changes."* $C1_7$, *"The pen and its image are on the right with respect to the observer at position A, while it is on the left with respect to the observer at position B."* $C3_{11}$
	Description Correct*		$C3_4$	*"The location and image of the pen is fixed. When the observer moves, his own image moves too."* $C3_4$
Detecting the Wrong	No Description**			
	Description Incorrect*	$C1_2$, $C1_3$, $C1_{14}$		*"The image is independent because the distance of the male does not change."* $C1_3$
	Description Partially Correct	$C1_5$	$C3_5$, $C3_7$, $C3_{18}$	*"The plane mirror image does not change. It changes depending on where the observer is looking."* $C1_5$, *"Her/his image does not move. The position where the observer sees the pen changes."* $C3_7$
	Description Correct	$C1_{17}$	$C3_2$, $C3_3$, $C3_8$, $C3_{15}$	*"The image of the object in the mirror does not change. The observer's point of view may change."* $C1_{17}$, *"The image does not move because the position of the mirror and pen does not change."* $C3_{15}$

**: There are no participants in both grades for this coding group, *: For this coding group, there are participant(s) in one grade but not in the other grade.

According to Table 12, the number of participants who identified the erroneous explanation given in answer to the 13th question and whose explanations were correct was 4 (four) in 3rd grade and 1 in 1st grade. Subsequently, the number of participants whose explanations were partially correct was 3 (three) in 3rd grade and 1 in 1st grade. The percentages of prospective teachers who made an acceptable statement were 11% (eleven percent) for 1st grade and 39% for 3rd grade.

Findings in Table 13 were obtained by examining the explanations and answers given by the students to the 15th question. However, the solution is incorrect about the image in plane mirrors.

Table 13. Categories, Codes, Participants, and Sample Answers for Question 15

Categories	Codes	Participants		Sample answers
		1st Grade	3rd Grade	
No Response		$C1_8$		
Inability to Detect the Wrong	No Description	$C1_{15}$	$C3_{14}$	
	Description Incorrect	$C1_5$, $C1_{10}$, $C1_{11}$, $C1_{12}$, $C1_{14}$, $C1_{16}$, $C1_{17}$	$C3_4$, $C3_7$, $C3_8$, $C3_{10}$, $C3_{11}$, $C3_{13}$, $C3_{15}C3_{18}$	*"The greater the distance, the smaller the image."* $C1_{10}$, *"As you move away from the mirror, the size of your pen in the mirror also changes."* $C3_{13}$
	Description Partially Correct	$C1_9$	$C3_9$	*"As the observer gets farther away, the pen seems to shrink in size. Because of the eye focus."* $C1_9$, *"As she/he gets further away, the distance increases, and she/he sees smaller."* $C3_9$
	Description Correct**			
	No Description**			
Detecting the Wrong	Description Incorrect	$C1_2$, $C1_4$, $C1_6$,	$C3_2$, $C3_3$, $C3_{16}$, $C3_{17}$	*"The location of the object does not change."* $C1_4$, *"The farther you get from the light source, the larger the object becomes in the mirror."* $C3_{16}$
	Description Partially Correct	$C1_3$, $C1_7$	$C5_5$	*"The pen doesn't change in size. The pen gets bigger if it gets closer, it gets smaller if it gets farther away. It's not dependent on the observer."* $C1_3$, *"The observer is getting farther away, the distance is increasing, so the pen looks small."* $C5_5$
	Description Correct	$C1_1$, $C1_{13}$, $C1_{18}$	$C3_1$, $C3_6$, $C3_{12}$	*"It doesn't change. The image the observer sees shrinks."* $C1_1$, *"The size of the image does not change, the observer sees smaller."* $C3_6$

**: There are no participants in both grades for this coding group.

As seen in Table 13, the number of participants who identified the erroneous explanation given in answer to the 15th question and whose explanations were correct was 3 in 3rd and 1st grades. The number of participants whose explanations were partially correct was 1 (one) in the 3rd grade and 2 in the 1st grade. The percentages of prospective teachers who made an acceptable statement were 22% (twenty-two percent) for 3rd grade and 28% for 1st grade.

Discussion and Conclusion

Under this heading, in light of the findings given in Table 3 by the researcher, the prospective teachers' ability to distinguish between true and false information was evaluated for each grade. Subsequently, the findings obtained from the explanations given by the prospective teachers to the questions with incorrect answers (Table 4-14) were interpreted separately for each question solution, and the misconceptions, wrong or missing information of the candidates were revealed and compared with the literature results. In addition, the opinions of prospective teachers on the subject of images in plane mirrors and the need to improve in terms of understanding the student were also included.

Although the percentage of the candidates who determined that the explanations given with correct answers to the questions varied depending on the question (Table 3, p.6) on average, it was 53% for 1st grade students who took this course in 2nd grade at the university. On the other hand, those studied in 3rd grade was 52%. Looking at these values, the candidates in both grades have a moderate level of distinguishing the correct information about the image in the plane mirrors presented to them. Candidates' ability to distinguish erroneous explanations given to them also varies depending on the question. The percentage of students in 1st grade that detected false information is 47% on average and 49% in 3rd grade. The percentage of prospective teachers that are able to distinguish false information is moderate for both grades. In general, prospective teachers' ability to distinguish false information is slightly lower than their ability to distinguish correct information. The level of distinguishing between correct and incorrect information as a percentage of prospective teachers in 3rd grade is almost at the same level as the students in 1st grade. Based on this result, the information obtained by 3rd grade students through distance education does not increase their knowledge in distinguishing between true and false information. However, the number of candidates who detected the erroneous explanation given to them and also gave a correct or partially correct explanation for the 1st, 2nd, 3rd, 8th, and 13th questions was higher in 3rd grade than in 1st grade. This is an indicator of the development of the candidates in 3rd grade for these questions, even if their subject knowledge is at an average level.

Furthermore, it was determined that the participants who thought the answer to the 1st question was correct (Table 4, p.7), and whose explanation was wrong, had the misconception that "objects in front of a mirror in unlit environments have a mirror image". It can be stated that some candidates in this category also have misconceptions such as "thinking of the mirror as a light source", "an image occurs in the mirror with or without light in the environment", and "using the concepts of image and shadow interchangeably". These misconceptions of prospective teachers are similar to the misconceptions found in the relevant literature (Ayvacı & Candaş, 2018; Chen et al., 2002; Feher & Rice, 1988; Fetherstonhaugh & Treagust, 1992; Şen, 2003; Taşlıdere & Eryılmaz, 2015). Therefore, it was concluded that the participants who detected the error in answer to this question, but whose explanation was wrong, had the unacceptable wrong information about the subject. In addition to the wrong information, it can be said that some candidates in this coding have the misconception that "black objects do not reflect light". This misconception was also emphasized in the studies of Pompea et al. (2007). According to the findings in Table 4, the percentages of the participants' acceptable explanations for the question that was answered incorrectly were 33% (thirty-three percent) for 1st grade and 78% for 3rd grade. In the light of these findings, the percentage of 1st grade prospective teachers who learned that an object cannot be seen in a dark environment and that an image cannot be formed in the mirror without light is low, while the percentage of 3rd grade teacher candidates is high.

The candidates whose explanations were wrong by determining that the answer to the second question was wrong (Table 5, p. 8) confuse the concepts of reflection and refraction. Candidates whose explanations were partially correct were able to identify that the answer to this question was incorrect. Thus, it has been understood that they know that light is necessary for an object to be seen, but they do not fully understand the formation of the image, and they have incomplete information on this subject. According to the findings in Table 5, the percentage of prospective teachers' acceptable explanations for solving erroneous questions was 67% (sixty-seven percent) for 1st grade and 89% for 3rd grade. In the light of these findings, the percentage of 1st grade students who learned that a black object would appear in the mirror in a bright environment and that black objects do not absorb all of the light falling on them, but reflect a small part of it, was at a high level, while the percentage of prospective teachers in 3rd grade was very high.

Based on the findings obtained in Table 6 (p. 9), the following conclusions were drawn. Candidates who cannot detect that the answer to question 3 is wrong and whose explanations are wrong have the misconception that "the image of an object in a bright environment only occurs when the observer looks into the mirror but does not form when he does not". This

misconception was also revealed in the studies of Anıl and Küçüközer (2010), Çökelez and Çiftçi Yaşar (2015), and Galili and Hazan (2000). In addition, it can be emphasized that the participants in this category and coding confuse vision with image formation. Candidates in this category whose explanations are partially correct may suggest that they do not fully understand the question and lack information. An opinion can be put forward that the candidates who discover that the answer given for this question is wrong, but whose explanations are wrong, confuse the concepts and cannot fully understand what is being asked. According to the findings in Table 6, the percentage of the participants' acceptable explanations for the solution of the question whose answers were given incorrectly was 39% for 1st grade and 61% for 3rd grade. Hence, the percentage of 1st grade students, who internalized that when the rays reflected from an object illuminated by light fall on a mirror surface, an image will be formed in that mirror, is low while the percentage of 3rd grade teacher candidates is high.

Candidates who cannot determine that the answer to question 5 is incorrect and whose explanations are wrong have the misconception that "when an obstacle is placed between the mirror and an object, part or all of the object's image is not formed". This misconception is compatible with the results of the literature (Anıl & Küçüközer, 2010; Galili & Hazan, 2000; Kaltakçı Gürel et al., 2017). Furthermore, the candidates who determined that the answer to the question was wrong (Table 7, p.10), but whose explanations were wrong, confused the image's formation with the image's appearance. These candidates have the misconception that "the image of objects is formed when looking in the mirror, otherwise the image does not form". According to the findings in Table 6, the percentage of participants' acceptable explanations for incorrect question solving is 0% (zero percent) for 1st grade and 6% for 3rd grade. The percentage of teacher candidates in the study group is very low. Based on findings in Table 8 (p.10), the candidates who cannot detect that the answer to question 7 is wrong and whose explanations are wrong do not know that the focal point of the plane mirror is infinite. The candidates in this coding group have the misconception that "when the dimensions of the plane mirror change, the size of the image also changes". These candidates also confuse plane mirrors with spherical mirrors. The mentioned misconception is also similar to the misconceptions given in the literature (Anıl & Küçüközer, 2010; Kaltakçı Gürel et al., 2017). It was determined that the candidates who detected the error in the solution of this problem and whose explanations were wrong had the misconception of "when the size of the plane mirror is increased, the size of the image decreases", which is not encountered in the literature. According to the findings obtained from Table 8, the percentage of acceptable explanations for erroneous question solving by prospective teachers is 72% (seventy-two percent) for 1st grade and 50% for 3rd grade.

Also, the percentage of acceptable explanations for erroneous question solving by prospective teachers is 72% (seventy-two percent) for 1st grade and 50% for 3rd grade.

Accordingly, it can be emphasized that candidates who cannot detect that the answer to question 8 is incorrect (Table 9, p.11), and whose explanations are wrong at the same time, have the misconception that "the image of an object that is not directly in front of the mirror does not form". This misconception is also present in the literature (Blizak et al., 2009; Chen et al., 2002). Thus, it can be stated that the candidates who detect the error given as an answer to this question and whose explanations are wrong have wrong information. According to the findings obtained from Table 9, the percentage of acceptable explanations for erroneous question solving by prospective teachers is 33% (thirty-three percent) for 1st grade and 39% for 3rd grade. In the light of these findings, the percentage of first-grade prospective teachers, who learned that the image of an object not directly in front of the mirror will be formed, is low while the percentage of third-grade prospective teachers is medium.

Considering the findings outlined in Table 10 (p.12), the candidates who could not determine that the explanation given as the solution to the 10th question were incorrect, and whose explanations were wrong, had the misconception of "in a plane mirror, the image is on the mirror's surface". This misconception has been reported in the literature in different ways (Blizak et al., 2009; Chen et al., 2002; Durukan & Paliç Şadoğlu, 2020; Heywood, 2005; Kocakülah, 2006; Pompea et al., 2007; Şen, 2003). Therefore, it can be stated that some of the candidates in this coding group have misconceptions that the image is inverted and real. Candidates in this category with partially correct explanations have the above-mentioned alternative concepts about the image location in a plane mirror. The percentage of acceptable explanations for erroneous question solving by prospective teachers is 22% (twenty-two percent) for 1st grade and 17% for 3rd grade. Thus, the percentage of the participants in 1st grade who know the information that "the image of an object is behind the mirror in the plane mirror" is low, and the percentage of the participants in 3rd grade is deficient. Anıl and Küçüközer (2010) opined that the misconceptions of the candidates regarding this question can be corrected with an activity involving a glass plate and two identical candles.

Based on the findings in Table 11 (p.13), participants who could not identify the wrong explanation given for the solution of the 11th question, and whose explanations were also wrong, had the misconception that "the size of an object's image in a plane mirror varies depending on the object's distance from the mirror". This misconception was also revealed in the studies of Blizak et al. (2009). The percentage of acceptable explanations for erroneous question solving by prospective teachers is 11% for 1st and 3rd grades. As a

result, the percentage of 1st and 3rd grade candidates who comprehend the information that "the size of the image in a plane mirror is independent of the distance of the object from the mirror and the size of the image is equal to the size of the object no matter how far the object is" is very low. However, the reason for the misconception in solving this problem of many candidates is because they confuse the actual size of the image with the image size perceived by the observer. This misconception can be eliminated by sharing the knowledge that no matter how far an object moves away from us, the actual size of the object does not change even though the perceived/apparent size of the object decreases.

From the findings presented in Table 12 (p.13), it was concluded that the candidates who could not determine that the answer to the 13th question was wrong, and whose explanations were wrong, had the misconception that "the image location of the object in the plane mirror changes according to the position of the observer". This misconception has also been revealed in the literature (Anıl & Küçüközer, 2010; Blizak et al., 2009; Chen et al., 2002; Heywood, 2005). The percentage of acceptable explanations for erroneous question solving by prospective teachers is 11% (eleven percent) for 1st grade and 39% for 3rd grade. Subsequently, the percentage of the participants in 1st grade who learned the information that "The position of the image of the object in the plane mirror does not depend on the location and point of view of the observer" is deficient, while the percentage of the participants in 3rd grade is at a low level.

Based on the findings in Table 13 (p.14), the participants who could not detect the wrong explanation given in the answer to question 15, and whose explanations were also wrong, thought that "the farther away an object is from us, the smaller we perceive the object". In addition, the candidates substitute the perceived/apparent size of the image for the actual size of the image. In line with this idea, the misconception which states that “if the observer moves away from the mirror, the dimensions of the image of the object get smaller” occurs amongst the participants in this category and coding. This misconception is consistent with the results of the literature (Anıl, 2010; Aydın et al., 2012; Chen et al., 2002; Heywood, 2005; Kaltakçı Gürel et al., 2017; Taşlıdere & Eryılmaz, 2015). A lack of information was detected amongst the candidates who determined that the answer to this question was wrong, but whose explanations were wrong. Thus, it can be said that these candidates do not fully understand the question or do not know the answer to the subject. The percentage of acceptable explanations for erroneous question solving by prospective teachers is 28% (twenty-eight percent) for 1st grade and 22% for 3rd grade. Hence, the percentage of 1st and 3rd grade candidates who learned the conceptual knowledge that "the size of an object's image in a plane mirror is not affected by the observer's looking at the mirror from a near or far point"

is low. According to Anıl and Küçüközer (2010), the misconceptions experienced by the candidates here can be corrected with an activity involving a glass plate and two identical candles. Subsequently, prospective science teachers have alternative concepts, wrong or incomplete information about the image in plane mirrors seen in the literature. It can be stated that the participants are not in an acceptable situation regarding their development in the field knowledge of the image in plane mirrors and their understanding of the students. Therefore, candidates should re-examine their subject knowledge. It is possible for the candidates to turn their own learning mistakes into profit when they become teachers or when they consider the mistakes they make due to wrong learning and lack of knowledge. According to Konyalıoğlu et al. (2010), using activities related to students' mistakes in the education of teacher candidates can help the latter to see the reasons for mistakes and to plan lessons while taking these into account. Candidates must be aware of students' mistakes and misunderstandings in the process of becoming teachers. Teachers should take precautions to ensure that students can distinguish between right and wrong. Being able to detect errors and reveal the causes of errors is related to learning. Individuals should be able to recognize mistakes with learned knowledge. It is further emphasized by Konyalıoğlu et al. (2010) that when something is right or wrong, it is essential to determine the cause of the error.

When teachers' PCK develops, it will be easier for students to learn concepts at a meta cognitive level. This depends on the adequacy of the teacher's SCK, which cannot be separated from her/his PCK. Nevertheless, giving wrong information or correct information while teaching the subjects allow the student to think about their experiences (Akpınar & Akdoğan, 2010). For this reason, error-based activities can be carried out to eliminate students' misconceptions about the image subject knowledge in plane mirrors at all levels of education. The activities' contribution to the students' learning can be examined. Similar studies can be done for different subjects related to physics. The effects of this can be investigated by including error-based activities in teaching. Research can be conducted regarding the approaches of students or teacher candidates who use concrete tools related to the subject and the changes in their knowledge levels. Prospective teachers' learning difficulties, motivations, and interests can be revealed through bilateral meetings with prospective teachers. Along with error-based activities, research can be conducted to determine which teaching strategies and methods can be used by prospective teachers to eliminate students' errors. The contribution of error-based activities to prospective teachers' assessment and evaluation can also be examined.

Limitations of the Study

This study is limited to 36 science teacher candidates continuing their education at a state university and their answers to these questions. It is also limited to 15 questions prepared by the researcher based on the professional knowledge and experience of the image in plane mirrors and the conceptual understanding from the relevant literature. In this context, similar results can be found in studies with sample groups in different environments, and different results can be obtained according to the perspectives and interpretation of the researchers.

Human Studies: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This research was carried out with the "Ethics Committee Permission" dated 13/10/2021 and numbered E-30640013-108.01-37445 of the Social Sciences Ethics Committee of Amasya University Science Ethics Committee.

Funding Statement: The authors did not obtain any funding for this research.

Data Availability: All the data are included in the content of the paper.

Conflict of Interest: The authors reported no conflict of interest.

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Appendix 1. Data Collection Tool

In the data collection tool, there are 15 open-ended questions, as well as correct and incorrect answers for these questions. Teacher candidates were asked to examine the answers given to the questions about the conceptual understanding of 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, the participants were told to write their own answers for the explanations they deem wrong.

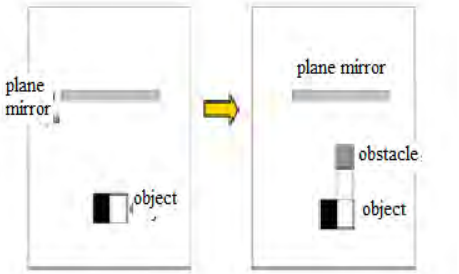
(*Answer key*: 1 F, 2 F, 3 F, 4 T, 5 F, 6 T, 7 F, 8 F, 9 T, 10 F, 11 F, 12 T, 13 F, 14 T, 15 F)

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. (.....)
Description:
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. (.....)
Description:
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, p.174)

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. (.....)
Description:
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. (.....)
Description:

5. There is an obstacle between the object in a bright environment and the plane mirror as seen 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, p.109)



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. (.....)

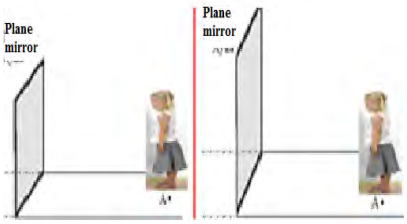
Description:

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. (.....)

Description:

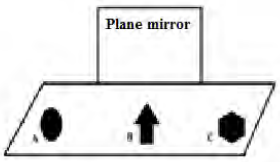
7. How does the size of the image formed in the mirror of a student standing in front of the plane mirror change when the size of the plane mirror is increased? (Excerpt image: Anıl & Küçüközer, 2010, p.116)



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

Description:

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. (.....)

Description:

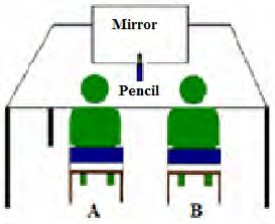
9. What can be said about the virtual or real image of an object formed in a plane mirror?

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

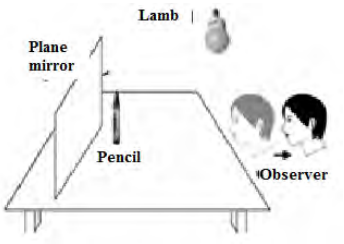
Description:

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

Answer: The image of the object in the plane mirror is formed on the surface of the mirror. (.....)
Description:
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. (.....)
Description:
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. (.....)
Description:
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, p.162)



Answer: When the observer changes position, the image of the object in the plane mirror also changes place. (.....)
Description:
14. What can be said about the speed of the observer's image on the plane mirror when the observer moves with speed 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. (.....)
Description:
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 et al., 2002, p.119)



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

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.Ethical procedures. This research was carried out with the "Ethics Committee Permission" dated 13/10/2021 and numbered E-30640013-108.01-37445 of the Social Sciences Ethics Committee of Amasya University Science Ethics Committee.
This article does not contain any studies with animals performed by any of the authors.
The data was not taken from any electronic medium. The data has not been shared in any environment. The data is not available online.

There is no conflict of interest with any author, institution, or organizati