

# Image and the Role of the Eye in Optics: University Students' Conceptual Understanding

# Editör

Prof.Dr. Fatih GÜRBÜZ





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"Bu kitapta yer alan bölümlerde kullanılan kaynakların, görüşlerin, bulguların, sonuçların, tablo, şekil, resim ve her türlü içeriğin sorumluluğu yazar veya yazarlarına ait olup ulusal ve uluslararası telif haklarına konu olabilecek mali ve hukuki sorumluluk da yazarlara aittir."

# INVESTIGATING OPTICIANRY STUDENTS' CONCEPTUAL UNDERSTANDING OF IMAGE FORMATION

# Erdoğan ÖZDEMİR<sup>1</sup>

#### 1. INTRODUCTION

Physics, being a fundamental branch of science, is directly related to many professions, including opticianry. Those who practice opticianry prepare and apply visual aids (eyeglass lenses, contact lenses, etc.) for patients according to doctor's prescriptions. Eyeglasses, in particular, are tools that support the vision of patients with refractive errors and eliminate the negative effects of these defects. To effectively carry out their profession while protecting public health, opticians must possess fundamental knowledge of light and optical concepts.

Generally, the study of physics involves various learning difficulties for students at almost every level. Research in the literature reports optics, a sub-branch of physics, as a difficult area of physics encountered by students (Özdemir, 2021; Nasser, El Khouzai, and Zahidi, 2021). Learning difficulties related to optical topics have been observed both in students at different educational levels (Uzoğlu et al, 2013) and in adults practicing opticianry (Özdemir, Çoramık and Ürek, 2020).

It is known that students particularly struggle to understand concepts in topics such as the nature of light, shadow formation, the movement of light in refractive and reflective

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materials, image formation, and light colors in optics (Özdemir and Kartal, 2024a).

The origins of learning difficulties related to image formation in optics date back to ancient times and are nurtured by alternative concepts that students still hold today. Ancient philosophers developed two fundamental views on how images are formed: the extramission theory (Euclid's Optics), which considers the eye as the source of light, and the intromission theory (Democritus), which argues that strips of atoms (eidola) travel from the object to the eye (Özdemir and Kartal, 2024b). Although these views have been proven invalid today, it has been observed that many students still maintain beliefs similar to these old theories. Furthermore, it has been determined that even adults believe that images are formed when rays emitted from the eye strike the object (Özdemir, Çoramık and Ürek, 2020). These common misconceptions become especially prominent in the context of image formation in the dark. Studies have indicated that students assume that an image can be formed even without the knowledge that light rays are emitted or reflected from an object (Uzoğlu et al, 2013). Students hold misconceptions that white objects are light sources and thus can be seen even in a dark room, while black objects cannot (Uzoğlu et al, 2013). Similarly, students hold beliefs that a black cat cannot be seen in the dark, only its eyes can. This belief resembles Damianus's statement regarding the glowing of nocturnal animals' eyes in the dark, cited as evidence for the extramission theory.

The accurate learning of the concept of vision, which is critically important in the practice of opticianry, during opticianry vocational training is of great significance for students' future professional competencies. Therefore, this research aimed to determine the existing conceptual understanding difficulties held by opticianry program students regarding image formation in the dark and to shed light on opticianry vocational training from this perspective.

#### 2. METHOD

In this study, the conceptual understanding levels of opticianry program students regarding image formation in optics were investigated. A two-stage test was used in the research. In the first stage, students marked a multiple-choice question, and in the second stage, they explained the reason for their answer. Qualitative and quantitative data collection tools were used together in this research. Details regarding the participants, the data collection tool, and data analysis are explained below.

# 2.1. Participants

The participants of the research consisted of first-year students enrolled in the opticianry program of a state university in the years 2023 and 2024. The data collection tool was administered to the participants at the end of the spring semesters of the 2022–2023 and 2023–2024 academic years. All students participating in the research had taken the Basic Physics and Geometric Optics courses in their first year. A total of 100 students participated in the study.

#### 2.2. Data Collection Tool

The data collection tool used in the research was developed by the researcher. In the creation of the data collection tool, an open-ended question and a concept cartoon used by Uzoğlu et al. (2013) to determine misconceptions related to light were utilized. In their study, Uzoğlu et al. (2013) included an open-ended question questioning whether a black and white piece of paper could be seen in a completely dark room, and a concept cartoon addressing whether a white cat (and the cat's eyes) could be seen in a dark room. The same concept cartoon also formed

the theoretical basis of an instructional tool developed by Özdemir and Kartal (2024b). These conceptual questions were also used by Özdemir, Çoramık, and Ürek (2020) to determine misconceptions about light and optics topics among opticians. Inspired by these open-ended questions and concept cartoons in the literature, a two-stage concept test was developed. In preparing the visuals for the questions in the test, black and white wooden materials were used as the background; square and triangular shaped wooden pieces were covered with aluminum foil and placed separately on the black and white backgrounds, and photographed. Thus, photos of a real situation, rather than drawings, were presented to the students in the concept test. The questions included in the concept test are shown in Figure 1.

1. Aşağıda, üzeri alüminyum folyo ile kaplı kare bir şekil bulunan beyaz renkte bir levhanın fotoğrafı ye almaktadır. Bu levha tamamen karanlık bir odaya bırakılmıştır. Bu odaya girdiğinizi kabul edelim. Bu levhanın ve üzerindeki kare şeklin görünümü ile ilgili aşağıdaki durumlardan hangisi gerçekleşir.



- a) Levhayı ve üzerindeki kare şekli göremem.
- b) Levhayı ve üzerindeki kare şekli görebilirim.
- c) Odaya girdiğimde hem levhayı hem de üzerindeki kare şekli göremem ama zaman geçtikçe her ikisini de görebilirim.
- d) Odaya girdiğimde hem levhayı hem de üzerindeki kare şekli göremem ama zaman geçtikçe levhanın üzerindeki kare şekli görebilirim.

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2. Aşağıda üzeri alüminyum folyo ile kaplı üçken bir şekil bulunan siyah renkte bir levhanın fotoğrafı ye almaktadır. Bu levha tamamen karanlık bir odaya bırakılmıştır. Bu odaya girdiğinizi kabul edelim. Bu levhanın ve üzerindeki üçgen şeklin görünümü ile ilgili aşağıdaki durumlardan hangisi gerceklesir.



- a) Levhayı ve üzerindeki üçgen şekli göremem.
- b) Levhayı ve üzerindeki üçgen şekli görebilirim.
- c) Odaya girdiğimde hem levhayı hem de üzerindeki üçgen şekli göremem ama zaman geçtikçe her ikisini de görebilirim.
- d) Odaya girdiğimde hem levhayı hem de üzerindeki üçgen şekli göremem ama zaman geçtikçe levhanın üzerindeki üçgen şekli görebilirim.

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Figure 1. Image Formation in Optics Concept Test

## 2.2.1. The first question of the concept test

Below is a photograph of a white plate with a square shape covered with aluminum foil on it. This plate has been left in a completely dark room. Let's assume you enter this room. Which of the following situations occurs regarding the appearance of this plate and the square shape on it?

- a) I cannot see the plate and the square shape on it.
- b) I can see the plate and the square shape on it.
- c) When I enter the room, I cannot see both the plate and the square shape on it, but I can see both as time passes.
- d) When I enter the room, I cannot see both the plate and the square shape on it, but I can see the square shape on the plate as time passes.

| Exp. | lain | your | rationa | le: | <br> | <br> |  |
|------|------|------|---------|-----|------|------|--|
|      |      |      |         |     |      |      |  |

# 2.2.2. The second question of the concept test

Below is a photograph of a black plate with a triangular shape covered with aluminum foil on it. This plate has been left in a completely dark room. Let's assume you enter this room. Which of the following situations occurs regarding the appearance of this plate and the triangular shape on it?

- a) I cannot see the plate and the triangular shape on it.
- b) I can see the plate and the triangular shape on it.
- c) When I enter the room, I cannot see both the plate and the triangular shape on it, but I can see both as time passes.
- d) When I enter the room, I cannot see both the plate and the triangular shape on it, but I can see the triangular shape on the plate as time passes.

| Explain your rationale: |  |  |
|-------------------------|--|--|
|-------------------------|--|--|

When answering the concept test, students first marked the option they thought was correct for each question, and then explained the rationale for their choice in the space provided below the question.

### 2.3. Data Analysis

Since the two-stage test required students both to mark a multiple-choice option and to write their justifications, the analysis process was conducted in two dimensions.

## 2.3.1. Quantitative data analysis

The responses given by students to the multiple-choice questions in the first stage of the Concept Test were transferred to the Microsoft Excel 2016 program. The percentage of students marking each option was calculated for each question. This analysis allowed for the determination of the students' overall achievement levels regarding conceptual understanding.

# 2.3.2. Qualitative data analysis

The open-ended justifications, which constituted the second stage of the concept test, were jointly examined by a physics expert and a physics education expert. The experts first read the student statements aloud in sequence and placed the student's statement into categories they jointly determined. After all student explanations were read and grouped into specific categories, they returned to the beginning, and all student views and categories were re-examined. At the end of this process, the percentage distributions of the created categories were formed.

Quantitative findings (options marked by students) and qualitative findings (open-ended explanations) were interpreted together to evaluate the students' levels of understanding of the concept of image formation in optics within a holistic framework.

#### 3. FINDINGS

This section presents the findings based on the analysis of student responses obtained from the concept test used in the research. First, the percentage distributions of the multiple-choice answers for each question are provided in tables. Then, the categories derived from the students' open-ended explanations and their corresponding percentage distributions are presented, also in table format, along with exemplary student opinions.

# 3.1. Responses and Distribution for the First Question of the Concept Test

The percentage distribution of multiple choice answers to the first question of the concept test is given in Table 1.

Table 1. Distribution of responses to the first question

| Option | Description  | Percentage |
|--------|--|------------|
| A      | I cannot see the plate and the square shape on it.   | 23         |
| В      | I can see the plate and the square shape on it.  | 4          |
| С      | When I enter the room, I cannot see both the plate and the square shape on it, but I can see both as time passes.                          | 50         |
| D      | When I enter the room, I cannot see both the plate and the square shape on it, but I can see the square shape on the plate as time passes. | 24         |

When Table 1 is examined, it is seen that half of the students (50%) thought that both the plate and the shape on it would become visible over time in a completely dark environment. This situation indicates the existence of a misconception among students that "dark adaptation compensates for the lack of light." Furthermore, 24% of the students stated that only the foil-covered shape would become visible over time; this points to another misconception, such as "reflective materials can emit light in the dark." The fact that Option A, the scientifically correct answer, was chosen by only 23%, indicates that students have difficulty learning the fundamental optical principles related to image formation.

The distribution of open-ended justifications for this question into categories is given in Table 2.

Table 2. Distribution of student justifications for the first question

| Category  | Percentage | Sample Student Opinion  |
|---|------------|---|
| In complete darkness, after a while, both the white and the shiny object become visible.      | 52         | S 11: When the room is dark, a little time is necessary for the eye's adaptation to darkness, but after the eye completes its adaptation, it starts to see the plate and the square shape.                                  |
| In complete darkness, the shiny object becomes visible.                                       | 19         | S 81: Since this plate was left in a completely dark room, I cannot see it when I first enter the room, but because the foil has a shiny structure and the eye gets accustomed to the environment, I see it as time passes. |
| In complete darkness,<br>neither the white object<br>nor the shiny object<br>becomes visible. | 21         | S 35: We cannot see anything in<br>an environment without any light<br>source because rays reflected<br>from objects fall onto the retina<br>and the image is seen. Nothing is<br>visible in a dark environment.            |

The qualitative findings in Table 2 strongly support the quantitative findings in Table 1. The most frequently observed category (52%) in Table 2 largely overlaps with the most frequent multiple-choice response (50%) and supports the belief that "everything becomes visible over time in complete darkness." The fact that 19% of the students thought the shiny object would become visible in the dark indicates that "reflective materials" are perceived as a "light source." The category containing the correct scientific explanation (21%) shows proportional parallelism with the correct option in the multiple-choice results (23%).

# **3.2. Responses** and Distribution for the Second Question of the Concept Test

The percentage distribution of multiple choice answers to the second question of the concept test is given in Table 3.

Table 3. Percentage distribution of responses to the second question

| Option | Description  | Percentage |
|--------|--|------------|
| A      | I cannot see the plate and the triangular shape on it.   | 19         |
| В      | I can see the plate and the triangular shape on it   | 9          |
| С      | When I enter the room, I cannot see both the plate and the triangular shape on it, but I can see both as time passes.                              | 13         |
| D      | When I enter the room, I cannot see both the plate and the triangular shape on it, but I can see the triangular shape on the plate as time passes. | 56         |

When Table 3 is examined, it is seen that a high proportion of students (56%), similar to the first question, thought that the foil-covered triangular shape would become visible over time. The main difference between the first question and the second question relates to the background of the aluminum foil-covered shape. While the background in the first question was white, the background in the second question was black. When the background was white, students stated that both the aluminumcovered shiny object and the white background would become visible over time, but when the background was black, they stated that only the aluminum-covered shiny object would become visible over time. This situation indicates the misconception that "shiny and light-colored objects can become visible over time in complete darkness." The correct response rate for this question (19%) is consistent with the correct response rate in the previous question (23%).

The distribution of student justifications for the second question into categories is presented in Table 4.

**Table 4. Distribution of student justifications for the second question** 

| Category   | Percentage | Sample Student Opinion   |
|--|------------|--|
| In complete darkness, after a while, both the black and the shiny object             | 6          | S 54: Our eye gets used to it and since the plate is aluminum, the triangle in the middle is also  |
| become visible.  |            | visible.   |
| In complete darkness, the shiny object becomes visible                               | 70         | S 32: When we enter a dark area, after the eye gets used to it, you cannot see the background because it is black, but you see the shape because it is covered with aluminum foil.                 |
| In complete darkness, neither the black object nor the shiny object becomes visible. | 17         | S 35: We cannot see anything in an environment without any light source. Because rays reflected from objects fall onto the retina and the image is seen. Nothing is visible in a dark environment. |

The qualitative findings show that the belief that "reflective materials will be visible in the dark" was explicitly expressed by 70% of the students in the second question. This rate is consistent with the high-percentage response (56%) given to the second question of the concept test and supports the misconception that foil emits light or "generates shimmer" in the dark. The category representing the correct scientific explanation (17%) is again at a low level. When both quantitative and qualitative findings are evaluated together, it is understood that a significant portion of the students: (i) perceives reflective materials and white objects as light sources, (ii) believes that the eye's adaptation to darkness eliminates the absence of light, and (iii) struggles to apply the knowledge that an image cannot be formed without light to different situations.

#### 4. CONCLUSION AND DISCUSSION

This research investigated the conceptual understanding status of opticianry program students regarding image formation in the dark. The findings showed that a significant portion of the students believed that an image could be formed over time even in a lightless environment. This situation points to the misconception that "the eye's dark adaptation compensates for the lack of light." This situation can be interpreted as students incorrectly transferring some knowledge about eye anatomy and eye physiology to the topic of image formation in optics. Specifically, interpreting the information that "visual sensitivity increases in low light" as the ability for an image to be formed in complete darkness is a clear indicator of this incorrect transfer. Furthermore, these results can be interpreted as showing that traces of extramission-based beliefs, dating back to antiquity, are still observed today (Özdemir and Kartal, 2024b). Additionally, students perceive aluminum foil and white objects as light sources, leading them to believe that "shiny or light-colored objects can be seen in complete darkness." This finding is consistent with the results of other studies conducted with students of different educational levels and ages (Özdemir, Çoramık and Ürek, 2020; Uzoğlu et al, 2013; Şen, 2003; Özdemir and Kartal, 2024c).

When the research results are evaluated as a whole, it can be said that traditional instruction is not sufficient for the effective teaching of the concept of image formation in optics physics education for the opticianry profession. It is recommended that concrete experiences, scenario-based discussions, and reflection activities (Anıl and Küçüközer, 2010) be further integrated into the instructional process so that opticianry students correctly understand the fundamental principles related to light and image formation.

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# INVESTIGATING OPTICIANRY STUDENTS' CONCEPTUAL UNDERSTANDING OF LIGHT COLORS

#### Sebahattin KARTAL<sup>1</sup>

#### 1. INTRODUCTION

Physics, as a fundamental science that studies mass, energy, and their interrelationships, largely underpins today's technological advancements. Therefore, physics education is given importance from pre-school to postgraduate levels. Optics, a sub-branch of physics, is a central field that studies light and its behavior in different media. Although optical topics are frequently encountered in daily life, research has shown that students have difficulty structuring these concepts meaningfully in their minds. This learning difficulty may stem from students combining their daily life experiences with incomplete optical knowledge learned in classes (Ronen and Eylon, 1993; Özdemir, 2021; Epik et al., 2002).

Many studies in the literature show that students generally have difficulty learning physics topics, and this leads to misconceptions. Research in the field of optics has revealed that students have difficulty defining the concept of an image, confusing image formation with other concepts such as vision, reflection, or shadow formation (Durukan and Paliç Şadoğlu, 2020; Kocakülah, 2006; Çökelez and Çiftçi Yaşar, 2015). These difficulties inherent in the problem of the image concept also

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affect the conceptual learning of the concept of vision itself (Çökelez and Çiftçi Yaşar, 2015; Şen, 2003).

The concept of color, which is included in the topics of optics, is one of the fundamental properties of light, and the process of perceiving the colors of objects requires understanding the mechanisms of selective absorption and reflection of light by objects. It is known that the sun and ordinary lamps generally emit white light, and objects are visible according to the colors of light they reflect or absorb. Mixing light colors and perceiving the colors of objects are complex optical topics that students find challenging. Studies in this area show that students experience difficulties related to the propagation of light and the phenomenon of vision (Galili and Hazan, 2000), making it necessary to examine topics such as the formation and perception of colors in depth. For example, understanding basic information such as the fact that yellow light can be formed from a combination of red and green light is critical for correctly interpreting the appearance of objects under different colored lights. To examine these complex relationships, demonstration experiments and tools inspired by Newton's camera obscura, such as the "dark box"—which isolates light from the external environment and is illuminated by remotely controlled LED light strips—have been developed (Özdemir and Kartal 2024a). Experiments conducted in such a setup aim to contribute to the teaching of the subject by revealing results that may surprise students, such as an object that appears yellow outside the box being observed as almost black under blue light. These perceptual difficulties regarding color indicate that students do not fully grasp the relationships between primary and secondary colors.

The aim of this study is to identify students' misconceptions and conceptual understanding difficulties regarding light colors. To this end, students were presented with a conceptual question about what color an object with two

intermediate colors, cyan and yellow, would appear to be under red and blue primary light, respectively. This aims to reveal students' scientific ideas and alternative conceptions about the nature of intermediate colors, their components, and how these objects are perceived under different light sources.

#### 2. METHOD

This study investigated the misconceptions about colors held by students in the optometry program. A two-stage test was used in the research. In the first stage, students answered a multiple-choice question, and in the second stage, they explained the reason for their answers. Both qualitative and quantitative data collection tools were used in this research. Details regarding the participants, data collection tools, and data analysis are explained below.

## 2.1. Participants

The data collection tool for the research was administered to first-year students in the optometry program at the end of 2023 and 2024. All participants were first-year students in the spring semesters of 2022-2023 and 2023-2024. These participants took Basic Physics and Geometric Optics courses during their studies. A total of 100 students participated in the research.

#### 2.2. Data Collection Tool

In order to determine students' misconceptions about light colors, a "Light Colors Concept Test" consisting of two different object images prepared in cyan and yellow intermediate colors was used in the study (Figure 1). These images were designed to reveal how students interpret basic optical principles such as color mixing, the components of light, and which color light an object reflects or absorbs. Each question in the test aims to

reveal not only which option the student considers correct, but also the **mental model on which this choice is based.** 

1. Resimdeki cisim, doğal ısık altında cyan renktedir. Bu cisim içerisinde kırmızı ısık olan ve dış ortamdan ışık açısından yalıtılmış bir odaya konuluyor. Bu odaya girdiğinizi kabul edelim. Cismin odadaki görünümü ile ilgili aşağıdaki durumlardan hangisi gerceklesir. a) Çyan görürüm. b) Yeşil görürüm c) Mavi görürüm. d) Kırmızı görürüm e) Siyah görürüm. Gerekcenizi acıklayınız: 2. Resimdeki limon, doğal ışık altında sarı renktedir. Bu cisim içerisinde mavi ışık olan ve dış ortamdan ışık açısından yahtılmış bir odaya konuluyor. Bu odaya girdiğinizi kabul edelim. Cismin odadaki görünümü ile ilgili aşağıdaki durumlardan hangisi gerçekleşir a) San görürüm. b) Yesil sommum. c) Mavi gorurum. d) Kırmızı görürüm. e) Siyah görürüm. Gerekçenizi açıklayınız:

Figure 1. Light Colors Concept Test

For each question, students first marked the option they thought was correct, and then justified how they arrived at this answer in writing in the space below the question. Thus, the test produces two-dimensional data: quantitative data (marked

options) and qualitative data (justifications written by the students themselves). This two-stage structure allows for the analysis not only of the accuracy of student responses but also of the cognitive process behind this accuracy or inaccuracy. In this respect, the test has a structure consistent with effective measurement tools suggested in the literature for identifying misconceptions.

## 2.3. Data Analysis

The data obtained from the research were analyzed using both quantitative and qualitative analysis techniques. Since the test, which was created in two stages, required students to both mark a multiple-choice option and write their justifications, the analysis process was also carried out in two dimensions.

# 2.4. Quantitative Data Analysis

In the first stage of the test, the students' answers to the multiple-choice questions were transferred to the Microsoft Excel 2016 office program environment. The frequency and percentage of marking the options for each question were calculated. This analysis enabled the determination of the students' general success levels regarding conceptual understanding and the quantitative presentation of misconceptions.

# 2.5. Qualitative Data Analysis

The open-ended justifications, which constituted the second stage of the test, were examined jointly by two independent researchers. Student statements were first read aloud by one researcher, and then placed into categories jointly determined by the two researchers in accordance with the meaning of the statements. After all student responses were read and grouped into specific categories, the process was repeated, and all student opinions were re-evaluated. At the end of this process, frequency and percentage distributions were calculated for each category created. Thus, the students' misconceptions,

levels of explanation, and ways of thinking were qualitatively revealed in depth.

Quantitative findings (options marked by students) and qualitative findings (open-ended answers) were interpreted together to evaluate the students' conceptual understanding levels in light and optics within a holistic framework. This approach aims to reveal both the students' tendencies towards correct and incorrect answers and the thinking processes behind these answers in a structural whole.

#### 3. FINDINGS

This section presents the findings based on the analysis of student responses obtained from the two-stage concept test used in the research. First, the percentage distributions of the multiple-choice answers for each question are given in tables. Then, the categories obtained from the students' open-ended answers and the percentage distributions related to these categories are also shown in table form.

Table 1. Percentage distribution of responses to the first question of the Light Colors Concept Test

| Option | Description | Percentage |
|--------|-------------|------------|
| A      | I see cyan  | 4          |
| В      | I see green | 5          |
| С      | I see blue  | 8          |
| D      | I see red   | 9          |
| E      | I see black | 71         |

When Table 1 is examined, it is seen that the conceptual approaches of the students regarding how a cyan-colored object will appear under red light differ significantly. The vast majority of students stated that the object would appear black. This situation indicates that some students believe that a component of light reflected by a cyan surface in a red light environment. However, a significant group of students thought the object could

appear in different colors such as blue, green, or red; this reveals that some students failed to correctly interpret the principles of light reflection and absorption, the components of cyan color, or the effect of ambient light. Furthermore, a small group who said "I see cyan" ignored fundamental optical principles regarding how a surface reflects light, assuming the object's color would remain constant regardless of the environment.

Table 2. Percentage distribution of student justifications for the first question of the Light Concept Test

| Category                        | Percentage | Sample Student Opinion          |
|---------------------------------|------------|---------------------------------|
| It appears black because        | 51         | Ö 16: Cyan is a mixture of      |
| there is no blue or green light |            | green and blue, and if there is |
| in the environment.             |            | red light in the room, it       |
|                                 |            | doesn't reflect it and appears  |
|                                 |            | black.                          |
| The object emits light of its   | 7          | Ö 84: I see the combined        |
| own color.                      |            | color of the object and the     |
|                                 |            | ambient light.                  |
| The object appears in the       | 4          | Ö 62: It takes on the color of  |
| color of the light.             |            | red light.                      |
| All the different colors of     | 4          | Ö 88: Blue + green + red =      |
| light combine to form black.    |            | black.                          |

The student justifications in Table 2 are illustrative of the response trends revealed in Table 1. A significant portion of students who answered "black" provided explanations based on the correct physical model, stating that cyan is composed of blue and green components and that these components are absent in a red light environment. In contrast, when examining the explanations of students who deviated from the correct answer in Table 1, explanations based on incorrect cognitive models are observed, such as "the object emits light in its own color," "the object takes on the color of the ambient light," or "colors combine to form black." This situation indicates that most incorrect answers stem from thinking in terms of pigment logic instead of light reflection, misinterpreting the nature of light colors, or considering the object as an internal light source.

Table 3. Percentage distribution of responses to the second question of the Light Colors Concept Test

| Option | Description  | Percentage |
|--------|--------------|------------|
| A      | I see yellow | 5          |
| В      | I see green  | 59         |
| С      | I see blue   | 7          |
| D      | I see red    | 2          |
| Е      | I see black  | 27         |

Table 3 shows that students' responses regarding how a yellow object would appear under blue light are quite scattered. A significant number of students stated that the object would appear green, indicating a thought process that confuses the mixing of light with the mixing of pigments. While a yellow surface can only reflect red and green light, the correct physical model is that the object would appear black due to the absence of these components in the environment; however, the lower percentage of students who chose this option shows that a large portion of the students cannot correctly apply the reflection-absorption principles. Furthermore, students who chose yellow or blue reflect common misconceptions about the relationship between the color of an object and ambient light, such as "the object takes on the color of the ambient light" or "the object retains its own color under all conditions."

Table 4. Percentage distribution of student justifications for the first and second parts of the Light Concept Test.

| Category                       | Percentage | Sample Student Opinion                  |
|--------------------------------|------------|---|
| The object emits light in its  | 47         | Ö 95: When blue light shines on         |
| own color. The object emits    |            | yellow, green appears and the object    |
| light in its own color.        |            | appears blue.                           |
| Since there is no red or green | 16         | Ö 19: Yellow is formed from a           |
| in the environment, it appears |            | mixture of the primary colors Red +     |
| black.                         |            | Green. Since there is no common         |
|                                |            | primary color under blue light, no      |
|                                |            | image is formed.                        |
| The object appears in the      | 3          | A lemon is yellow under natural         |
| color of the light             |            | light. Then, because it is placed in a  |
|                                |            | room with blue light and isolated       |
|                                |            | from the outside light, it takes on the |
|                                |            | color of the light in the room (blue).  |

The qualitative explanations in Table 4 reveal the thought patterns behind the diversity of responses observed in Table 3. Students who answered green, while knowing that yellow is a combination of red and green, incorrectly interpreted this information in relation to the behavior of light colors, using a pigment-based model that suggests "a new color will be formed by mixing colors." The explanations of students who answered black are more consistent with the components of light and the principles of reflection and absorption, correctly interpreting that the surface cannot reflect light because there are no red and green components in the environment. In contrast, students who said the object would appear blue or take on the color of the ambient light used a model that assumed the object acquired a color "property" rather than the light was reflected by the surface. These justifications show that most of the incorrect responses stemmed from an inability to distinguish between light and pigment mixing, misinterpreting surface reflection, and a tendency to view the color perception of an object as an active "color production" rather than a passive process.

#### 4. CONCLUSION AND DISCUSSION

The aim of this study was to determine the conceptual understanding levels and misconceptions of optometry students regarding the perception of light colors and the colors of objects. The findings support the literature indicating that optical topics make it difficult for students to conceptually understand them (Özdemir, Kartal, 2024 a, b,c). Indeed, studies conducted at different learning levels have also shown that students experience difficulties in understanding fundamental optical concepts such as image, reflection, and vision (Durukan, Paliç Şadoğlu, 2020; Kocakülah, 2006; Çökelez, Çiftçi Yaşar, 2015; Şen, 2003). These difficulties are not limited to geometric optics but also extend to

physical optics topics such as color perception, which was examined in this study (Özdemir, Kartal, 2024).

When the appearance of the cyan object under red light was examined, it was observed that the vast majority of students chose the correct answer, black. Qualitative reasoning revealed that more than half of these students, knowing the components of the color cyan, accurately explained that the object would appear black due to the absence of light to reflect in a red light environment (Özdemir, Kartal, 2024). This demonstrates that students were able to apply the basic principles of light reflection and absorption in this relatively simple scenario. However, a significant group of students exhibited erroneous beliefs, such as the object emitting light of its own color or taking on the color of the ambient light (Özdemir, Kartal, 2024). This misconception is similar to the problem commonly seen in optics, where the object is perceived as an active light source rather than a passive reflector (Epik et al., 2002; Goldberg, McDermott, 1987; Kocakülah, 2006). Similarly, some studies have shown that students associate the image with shapes or devices such as television/cinema screens, thinking of the object as a source emitting light into the environment (Özdemir, Kartal, 2024; Kocakülah, 2006).

Conceptual difficulties became even more pronounced when the appearance of a yellow object under blue light was questioned. The correct answer, black, was chosen by only a small number of students (Özdemir, Kartal, 2024). In contrast, a significant number of students incorrectly applied basic optical principles by stating that the object would appear green (Özdemir, Kartal, 2024). Qualitative analyses showed that although students knew the components of the color yellow, they attempted to combine this information in the blue light environment with the logic of pigment-based color mixing rather than light reflection (Özdemir, Kartal, 2024). This finding is consistent with students'

tendency to confuse the concept of color with other optical concepts such as visual phenomena, reflection, or shadow formation (Kocakülah, 2006; Kocakülah, Demirci, 2010; Cökelez, Ciftci Yasar, 2015; Durukan, Palic Sadoğlu, 2020). In particular, misconceptions that confuse image formation with illumination or shadow phenomena have been frequently identified in various studies from the primary school level onwards (Kocakülah, 2006; Kocakülah, Demirci, 2010; Cökelez, Ciftci Yasar, 2015). This confusion observed in color studies suggests a general deficiency in students' knowledge of the components of light, which they know theoretically, and their ability to combine this knowledge with the absorption and reflection mechanisms of objects through ray diagrams or analytical application skills. This situation aligns with findings indicating that students are inadequate in explaining the concept of light rays and diagrams, and that they struggle even to draw images and describe their properties in mirrors (Durukan, Palic Şadoğlu, 2020; Kocakülah, Şardağ, 2013; Çökelez, Çiftçi Yaşar, 2015).

In conclusion, while students' theoretical knowledge of the components of intermediate colors is somewhat strong, there are profound conceptual gaps in the accurate application of this knowledge to the reflection and absorption mechanisms under light sources. This demonstrates the persistence misconceptions arising from the misinterpretation of optical concepts, particularly the nature of light and image, through everyday experiences (e.g., pigment mixing), and the failure to fully internalize scientific knowledge. Therefore, it is understood that color perception topics in optics education should be supported by visual and applied learning environments that will clarify the distinction between light and pigment mixing in the minds of students.

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# INVESTIGATING OPTICIANRY STUDENTS' CONCEPTUAL UNDERSTANDING OF IMAGE FORMATION IN A PLANE MIRROR

# Erdoğan ÖZDEMİR<sup>1</sup>

#### 1. INTRODUCTION

Physics is a fundamental branch of science that is directly related to a wide range of professions, including opticianry. Opticians prepare and dispense optical aids, such as spectacles, for patients according to a doctor's prescription (Özdemir ve Kabak, 2018). Opticians must possess fundamental optics knowledge to perform their profession.

Optics, a sub-branch of physics, examines light and its behavior in different media. Difficulties students experience in learning optics topics have been investigated by many researchers (Anıl ve Küçüközer, 2010; Özdemir, 2021; Özdemir ve Kartal, 2024 a; 2024b).

Students frequently encounter plane mirrors, which is one of the topics in optics, in their daily lives (Çökelez ve Yaşar, 2015). Nevertheless, learning difficulties related to this topic are widespread (Kocakülah, 2006). One of the learning difficulties observed among students regarding plane mirrors is their belief that the image forms on the surface of the mirror. Furthermore, studies have determined that when students draw the image in a plane mirror, instead of drawing straight lines representing the rays coming from the source and reflecting off the mirror, and

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examining whether these rays reach the eye, they draw an image at a distance equal to the distance of the object from the mirror. This situation indicates that students lack the necessary knowledge to construct a "ray diagram" (Goldberg ve McDermotti 1987; Kocakülah, 2006). Anıl ve Küçüközer (2010), on the other hand, stated that high school students possess alternative concepts concerning the relationship between the observer's position and the image, the location of the image in a plane mirror, and the properties of the image.

One of the most important factors making the correct understanding of the image concept difficult in optics is the failure to correctly understand the relationship between the concepts of image formation, image observation, and image formation in the eye (Özdemir ve Çoramık, 2022). The literature consistently shows that students do not fully grasp the critical role of the observer's eye in both the formation and observation of the image (Ronen ve Eylon, 1993; Epik vd., 2002). The correct learning of the concept of vision in a plane mirror, which is critically important for the practice of the opticianry profession, holds great significance for students' future professional competencies.

This research aimed to determine the current conceptual understanding difficulties of opticianry program students regarding image formation in a plane mirror and to shed light on opticianry vocational education from this perspective.

#### 2. METHOD

In this study, the conceptual understanding levels of opticianry program students regarding image formation in a plane mirror were investigated. A two-stage conceptual question was used in the research. In the first stage of this question, students selected a multiple-choice answer, and in the second stage, they

explained the reason for their marked response. A mixed-methods approach, utilizing both qualitative and quantitative data collection tools, was adopted in this research. Details regarding the participants, the data collection tool, and data analysis are explained below.

## 2.1. Participants

The participants of the research consisted of first-year students enrolled in the opticianry program of a state university in 2023 and 2024. The data collection tool was administered to the participants at the end of the spring semesters of the 2022–2023 and 2023–2024 academic years. All students participating in the research had taken the Basic Physics and Geometrical Optics courses in their first year. A total of 100 students participated in the study.

#### 2.2. Data Collection Tool

The question shown in Figure 1, which was adapted by Eylon, Ronen, and Ganiel (1996) to determine students' misconceptions regarding image formation, was used as the data collection tool in this study.



Figure 1. Conceptual question on image formation in a plane mirror

Conceptual Question: Below there is a lamp, a plane mirror, and an observer. Does the image of the lamp in the figure form in the plane mirror? Can the observer see this image?

- a) It does not form and the observer cannot see it.
- b) It forms but the observer cannot see it.
- c) It forms and the observer sees it.

Explain your reason/justification.....

This question aimed to evaluate image formation in a plane mirror and the visibility of an image by an observer. The question in Figure 1 examined the image of a lamp in the mirror and whether this image could be seen by the observer.

# 2.3. Data Analysis

Since the conceptual question in Figure 1 was structured in two stages, requiring students both to mark a multiple-choice option and to write their justifications related to the option, the analysis process was conducted in two dimensions

# 2.3.1. Quantitative data analysis

The students' responses to the multiple-choice question in the first stage of the Concept Test were transferred to the Microsoft Excel 2016 program. The percentage of students selecting each option was calculated for every question. This analysis allowed for the determination of the students' general achievement levels regarding conceptual understanding.

# 2.3.2. Qualitative data analysis

The open-ended student justifications, which constituted the second stage of the conceptual question, were analyzed jointly by two researchers, one specializing in physics and the other in physics education. During the analysis process, the experts first evaluated all student statements by reading them aloud sequentially and placed each explanation into agreed-upon categories through consensus. After all explanations were categorized for the first time, the process was restarted; all student statements and the created categories were reviewed again. At the end of this process, the final categories were determined, and the percentages of the number of students corresponding to each category were calculated.

Furthermore, the drawings students used when answering the question were also subjected to a separate analysis process. Within this scope, the percentages of students who used drawings and those who did not were determined, and the drawings were examined in two main groups: correct and incorrect. Examples supporting the quantitative and qualitative findings were selected from the drawings and photographed for presentation in the report. Finally, the quantitative findings (the options marked by students) and the qualitative findings (open-ended explanations and drawings) were interpreted together using a holistic approach. Thus, students' understandings, misconceptions, and ways of thinking regarding the concept of image in a plane mirror were evaluated comprehensively and in depth.

#### 3. FINDINGS

This section presents the findings based on the analysis of student responses to the conceptual question used in the research. Firstly, the percentage distributions of the answers given to the multiple-choice question are presented in a table; subsequently, the categories derived from the students' open-ended explanations and the percentage distributions related to these categories are provided along with sample student opinions. Finally, the findings obtained from the drawings used by students in solving the question are explained, and example drawings are provided.

The percentage distribution of the students' answers to the conceptual question is shown in Table 1.

Table 1. Percentage distribution of answers given to the conceptual question

| Option | Description   | Percentage |
|--------|---|------------|
| A      | Image does not form and the observer cannot see it. | 21         |
| В      | Image forms but the observer cannot see it.         | 27         |
| С      | Image forms and the observer sees it.               | 52         |

When Table 1 is examined, it is seen that more than half of the students (52%) thought that the image formed in the plane mirror could be seen by the observer. This situation indicates that the alternative concept 'if an image forms, it must be visible' is widespread among a significant portion of the students. However, Option B, which is the scientifically correct answer, was marked by only 27%. This result shows that students have difficulty grasping the principle that reflected light must reach the observer, which distinguishes between image formation and the visibility of the image in plane mirrors. Furthermore, the fact that 21% of the students (Option A) thought that the image would not form at all reveals deficiencies in fundamental optics knowledge related to image formation in plane mirrors.

The categories derived from the students' open-ended explanations and the percentage distributions related to these categories are shown in Table 2.

Table 2. Percentage distribution of student justifications related to the conceptual question

| Category                        | Percentage | Sample Student Opinion        |
|---------------------------------|------------|-------------------------------|
| The image forms if the object   | 7          | S 27: Since it is outside the |
| is aligned with the mirror in a |            | mirror axis, the image of the |
| plane mirror.                   |            | lamp does not form, and the   |
|                                 |            | observer cannot see it.       |
| The image forms but the         | 13         | S 38: The light rays spread   |
| observer cannot see it in a     |            | at an angle on the mirror     |
| plane mirror.                   |            | that the observer cannot see. |
| The image forms and the         | 30         | S 62: Since the plane mirror  |
| observer sees it in a plane     |            | reflects the image, the image |
| mirror.                         |            | forms, and the observer also  |
|                                 |            | sees it.                      |

The qualitative findings in Table 2 significantly support the quantitative findings in Table 1. The category with the highest percentage, "image forms and the observer sees it" (30%), is consistent with Option C (52%), which was the most frequently marked option in Table 1. This situation indicates that a significant portion of the students evaluates the visibility of the image based on the logic that "if the image exists, it is visible," rather than the condition that the reflected ray must reach the observer. 13% of the students stated that the image would form but the observer would not be able to see it. This category overlaps with the lower, yet parallel, qualitative percentage for Option B (27%), which is the scientifically correct answer in Table 1.

In contrast, 21% of the students gave the answer "image does not form" in Table 1. Explanations supporting this situation are seen in Table 2 at a rate of 7%. These students relate image formation to the position of the object relative to the mirror's axis; consequently, they reflect the alternative concept that "the object must be on the mirror's axis (aligned with it) for the image to form". Generally, when Tables 1 and 2 are considered together, it is understood that students experience significant conceptual

difficulties in fundamental optics principles such as reflection, the rectilinear propagation of light, and the requirement for the ray to reach the observer, which determine image formation and image visibility in a plane mirror.

The findings indicate that two alternative ideas are particularly common among students: i) "The image can be seen even if the reflected light does not reach the observer." ii) "The object must be on the mirror's axis (aligned with it) for the image to form." Example student drawings are included in Figure 1.

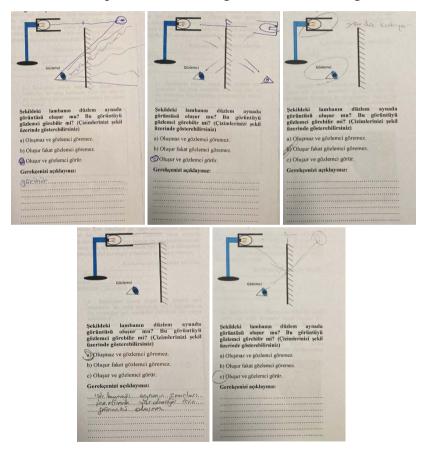


Figure 2. Example student drawings

Student drawings support these conceptual difficulties. 45% of the students did not make any drawing when answering

the question, meaning they did not use a ray diagram. Only two students from the 55% group who did draw made scientifically acceptable drawings. It is observed that the vast majority of students tend to draw a single ray instead of showing rays emanating from a point on the light source at different angles. This situation indicates that the principles of ray optics concerning the rectilinear propagation of light and the use of multiple rays have not been sufficiently internalized.

The drawings presented in Figure 2 clearly support the two main alternative concepts highlighted in the quantitative and qualitative findings of the research. In a significant portion of the drawings, students operate under the assumption that "the image can be seen if the observer looks in the direction where the lamp's image is located". This approach relates the visibility of the image to the observer's viewing direction rather than the principle that the reflected ray must reach the observer. Furthermore, some drawings show that students adopted the misguided belief that "the image does not form if the light source is higher relative to the mirror". This approach reflects the tendency to explain image formation based on the geometric position of the object relative to the mirror, rather than the fundamental principles of ray optics. This finding is also consistent with the idea identified in Table 2 that "the object must be on the mirror's axis (aligned with it) for the image to form".

# 4. CONCLUSION AND DISCUSSION

This research reveals that opticianry program students experience conceptual difficulties regarding image formation in a plane mirror and the conditions for an image to be visible by an observer. It was determined that more than half of the students participating in the study held the widespread alternative concept that if an image forms in a plane mirror, it must be visible by the

observer. However, the scientifically correct answer ("forms but the observer cannot see it") was marked by approximately onequarter of the students. This situation indicates that students evaluate the visibility of the image based on an intuitive logic that "if the image exists, it is visible," rather than the principle that the reflected ray must reach the observer.

The adoption of this alternative concept by more than half of the students points to the problem of a lack of full understanding of the fundamental relationship between image formation and image observation for an image to be visible, the reflected or refracted rays that form the image must reach the observer's eye. However, students fail to grasp the central role of the observer's eye in both the formation and observation of the image (Ronen ve Eylon, 1993; Epik vd., 2002). Additionally, a portion of the students thought that the image of the light source in the plane mirror would not form at all in the conceptual question. Qualitative analyses show that some students reflect an alternative concept linking image formation to the condition that the object must be on the mirror's axis (aligned with it).

The fact that nearly half of the students did not use a ray diagram when answering the question indicates that the principles of ray optics have not been sufficiently internalized. The literature states that students generally struggle with drawing and interpreting ray diagrams (Goldberg ve McDermott, 1987). Very few students who drew produced scientifically correct diagrams. The vast majority of students were observed to tend to draw a single ray instead of showing multiple rays. Incorrect drawing approaches support the students' tendency to associate the visibility of the image with the observer's viewing direction rather than the principle that the reflected ray must reach the eye.

Possession of fundamental optics knowledge is required for the practice of the opticianry profession. To this end, the use of instructional materials that provide concrete experiences proving the falsehood of students' alternative concepts may support conceptual change (Özdemir ve Kartal, 2024a). It is crucial to emphasize the role of vision and the process of image observation in optics education. For this purpose, it is recommended that a functional eye model explaining the scientific mechanism by which light reflects from an object and reaches the eye be used in the early stages of instruction. Furthermore, to improve students' ability to use ray diagrams correctly, optical simulations using multiple random rays (a beam of rays) emanating from the source, instead of just "special rays", can be used (Özdemir ve Çoramık, 2022). With these simulations, image drawings can be created to represent the entire field of view of an image, which can help students overcome these difficulties.

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# INVESTIGATING OPTICIANRY STUDENTS' CONCEPTUAL UNDERSTANDING OF IMAGE FORMATION IN CONVEX LENSES

### Sebahattin KARTAL<sup>1</sup>

#### 1. INTRODUCTION

Optics is one of the fundamental sub-branches of physics that studies light and its behavior in different media. One of the basic concepts within optics is the concept of image. Because physics forms the basis for technological advancements, schools place importance on teaching physics and optics. Although optics concepts are frequently encountered in daily life, it has been observed that students have difficulty structuring these concepts meaningfully in their minds. This situation may stem from students combining their daily life experiences with incomplete optical knowledge learned in classes (Ronen and Eylon, 1993; Epik et al., 2002).

Many studies in the literature show that students have difficulties in defining the concept of an image and explaining image formation (Durukan and Paliç-Şadoğlu, 2020; Çökelez and Çiftçi-Yaşar, 2015; Özdemir and Kartal, 2024 a,b,c). Students often confuse the concept of an image with other concepts such as the visual event (Durukan and Paliç-Şadoğlu, 2020; Çökelez and Çiftçi-Yaşar, 2015), reflection, or shadow formation (Kocakülah, 2006).

These conceptual difficulties are particularly evident when examining image formation in optical instruments such as

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lenses and mirrors. Research has shown that students struggle to perceive images formed in optical systems such as thin-edged lenses and concave mirrors, and to establish the relationship between the components of these systems (Goldberg and McDermott, 1987). It has even been observed that students who have taken an optics course are unable to fully succeed in any of the tasks related to thin-edged lenses (Goldberg and McDermott, 1987). It has been determined that students do not adequately understand the concept of a light ray when drawing diagrams related to image formation, and that they draw ray diagrams incorrectly or incompletely (Durukan and Aygün, 2014; Kocakülah and Şardağ, 2013; Kara, Kanlı and Yağbasan, 2003).

A significant portion of the conceptual difficulties regarding image formation stem from an inadequacy in understanding the observer's position and their role in the image formation process (Gürel-Kaltakçı, Eryılmaz, and McDermott, 2016). Students struggle to understand the role of the observer in the formation of an image in an optical system. It is believed that the root of these difficulties lies in the insufficient emphasis placed on the concept of image observation in the teaching of the subject (Epik et al., 2002). Students may think that the image may not be the same for observers in different positions (Galili, Goldberg, and Bendall, 1991), or they may believe that the image can only be seen when the observer is standing in their line of sight (Galili and Hazan, 2000; Galili, Goldberg, and Bendall, 1991). However, in optical systems, the observer themselves, along with their eyes, are a part of the system (Epik et al., 2002).

Given these challenges and misconceptions, it is crucial to thoroughly examine students' conceptual understanding in optics education and determine how they internalize their prior knowledge and experience in this area. In this context, the aim of this study is to reveal students' conceptual understandings and possible alternative ideas about image formation and the role of the observer in optics, through a conceptual question concerning how an image formed by a thin-edged lens is perceived and seen by two observers located at different positions.

### 2. METHOD

This study investigated the misconceptions of optometry students regarding image formation and perception of images in thin-edged lenses. A two-stage question was used in the research. In the first stage, students answered a multiple-choice question, and in the second stage, they explained the reason for their answers. Both qualitative and quantitative data collection tools were used in this research. Details regarding the participants, data collection tools, and data analysis are explained below.

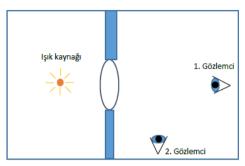
# 2.1. Participants

The data collection tool for the research was administered to first-year optometry students at the end of 2023 and 2024. All participants were first-year students in the spring semesters of 2022-2023 and 2023-2024. These participants took Basic Physics and Geometric Optics courses during their studies. A total of 100 students participated in the research.

# 2.2. Data Collection Tool

In this study, the question in Figure 1, designed by Ronen and Eylon (1993) to determine students' misconceptions about image formation, was used as the data collection tool.

# Aşağıdaki şekilde bir ışık kaynağı bir ince kenarlı merceğin merkezine yerleştirilmiştir.



Buna göre şekildeki gözlemcilerden hangisi veya hangileri ışık kaynağının mercekte oluşan görüntüsünü görebilir? (Not: Bir ince kenarlı merceğin merkezindeki bir cismin görüntüsü diğer tarafta mercekten eşit uzaklıkta oluştur. Çizimlerinizi şekil üzerinde gösterebilirsiniz.)

- a) Her iki gözlemci de görür.
- b) Her iki gözlemci de göremez.
- c) Yalnız 1. Gözlemci görür.
- d) Yalnız 2. Gözlemci görür.Gerekçenizi açıklayınız:

.....

Figure 1. Conceptual Question on Image Formation in a Thin Lens

In the question, students were asked to determine the position of the actual image formed on the other side of the lens and to explain which observer could see the image, considering that this image can only be seen if the rays forming the image reach the eye. When answering the test, students first marked the option they thought was correct, and then explained their reasons for this choice in the space provided below the question. Thus, the test has a two-stage structure that produces both quantitative

data (selection of options) and qualitative data (open-ended explanations).

# 2.3. Data Analysis

The data obtained from the research were analyzed using both quantitative and qualitative analysis techniques. Since the two-stage test required students to both mark a multiple-choice option and write their reasons, the analysis process was also conducted in two dimensions.

# 2.4. Quantitative Data Analysis

In the first stage of the test, the students' answers to the multiple-choice questions were transferred to Microsoft Excel 2016. For each question, the frequency and percentage of answer choices were calculated. This analysis allowed for the determination of students' overall achievement levels regarding conceptual understanding and the quantitative identification of misconceptions.

# 2.5. Qualitative Data Analysis

The open-ended explanations, which constitute the second stage of the test, were examined jointly by two independent researchers. Student statements were first read aloud by one researcher, then placed into categories jointly determined by both researchers according to the meaning of the statements. After all student explanations were read and grouped into specific categories, the process was repeated, and all student opinions were re-evaluated. At the end of this process, frequency and percentage distributions were calculated for each category created. Thus, the misconceptions, explanation levels, and thinking styles of the students were qualitatively revealed in depth. Quantitative findings (options marked by students) and qualitative findings (open-ended explanations) were interpreted together to evaluate students' conceptual understanding levels in

light and optics within a holistic framework. This approach aims to reveal both students' tendencies to give correct and incorrect answers, and the thought processes behind these answers, in a structurally coherent manner.

#### 3. FINDINGS

This section presents the findings based on the analysis of student responses to the two-stage conceptual question used in the research. First, the percentage distributions of the multiple-choice answers for each question are given in tables. Then, the categories obtained from the students' open-ended explanations and the percentage distributions related to these categories are also shown in table form.

Table 1. Percentage distribution of responses to the conceptual question

| Option | Description                      | Percentage |
|--------|----------------------------------|------------|
| A      | Both observers see it.           | 33         |
| В      | Neither observer can see it.     | 2          |
| С      | Only observer one can see it.    | 61         |
| D      | Only the second observer sees it | 4          |

When Table 1 is examined, it is seen that the vast majority of students preferred the correct answer, "Only observer I sees." This finding shows that a significant portion of the students understand that an image can only be perceived if the rays forming the image reach the observer's eye. However, the fact that one-third of the students thought that both observers could see the image reveals that the misconception frequently reported in the literature, "the image emits light like a light source," is also prominent among opticianry students. Two other options, seen at lower rates, indicate that some students tend to attribute image formation to a screen or make intuitive decisions without tracking light rays.

Table 2. Percentage distribution of student justifications for the concept question

| Category   | Percentage | Sample Student Opinion   |
|--|------------|--|
| The image emits light around it.   | 24         | Ö 59: The image (light) is collected and falls in the center. Therefore, both observers can see the light. |
| The image is formed by the light rays that make up the image reaching the eye. | 43         | Ö 21: A thin-edged lens collects light; only the observer opposite can see it                              |

When the student explanations given in Table 2 are examined, it is seen that the response trends in Table 1 are also qualitatively supported. Some students interpreted the image as a physical light source, stating that both observers could see the image; this situation shows that the misconception that "images emit light" is also reflected in the justifications. Another group of students correctly emphasized that the rays must intersect with the eye for the image to be perceived, and stated that the lens only directs rays in a specific direction towards the observer. Furthermore, the students' drawings related to the image in a thinedged lens were examined; it was found that 47% of the students did not draw at all, 9% made correct drawings, and the remaining 44% made a drawing, but it was incorrect. Below is a drawing by a student who stated that both observers would see the image, as mentioned in the concept question.

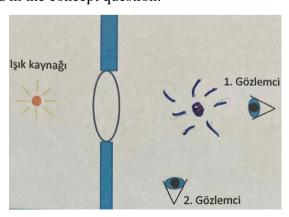


Figure 2. Example student drawing

In this drawing, the student drew the image of the light source on the other side of the lens and answered with the option "both observers see it". When the student's drawing and answer are evaluated together, it is understood that the student thinks that the observer can see the images within the field of view.

When both tables are evaluated together, it is understood that some of the students correctly understood the principles of image formation, but a significant group maintained fundamental optical misconceptions regarding the nature of the image and the mechanism of image perception by the eye. The students' explanations clearly show that the incorrect answers stemmed especially from perceiving the image as if it were a light source.

# 4. CONCLUSION AND DISCUSSION

The aim of this study is to reveal the conceptual understandings and possible alternative ideas of optometry program students about image formation in a thin-edged lens and the role of the observer in perceiving this image, through a two-stage conceptual question. The quantitative and qualitative findings show that students were partially successful in understanding the principles of image formation, but a significant portion of them persisted with fundamental optical misconceptions frequently encountered in the literature.

Although all students participating in the study had taken Basic Physics and Geometric Optics courses by the end of the academic year, conceptual difficulties were observed to continue. According to the quantitative analysis results, the vast majority of students (61%) chose the correct answer, "Only observer I sees." This finding supports the idea that a significant portion of the students understood that the rays forming the image must reach the observer's eye for the image to be perceived. In the qualitative analysis, 43% of the students also provided correct justifications

for the need for the rays forming the image to reach the eye for the image to be seen. This suggests that they have somewhat internalized the idea that the observer, along with their eyes, is part of the system in optical systems (Epik et al., 2002).

However, a significant portion of the students (33%) chose the incorrect option, "Both observers see," exhibiting a common misconception in optics. This misconception is also supported by qualitative data; 24% of students cited the erroneous idea that "the image emits light around it" as the justification. This clearly shows that, as stated in the literature, students tend to interpret the image as a physical light source (Galili, Goldberg, and Bendall, 1991). Due to this misconception, students may believe that the image is only visible when it is in the observer's line of sight, or they may think that the image may not be the same for observers in different positions (Galili and Hazan, 2000; Galili, Goldberg, and Bendall, 1991).

Previous studies in the literature have already reported that students experience difficulties in perceiving images formed in thin-edged lenses and in drawing ray diagrams (Durukan and Aygün, 2014; Kocakülah and Şardağ, 2013; Kara, Kanlı, and Yağbasan, 2003). It has even been observed that students who have taken an optics course are not entirely successful in such tasks (Goldberg and McDermott, 1987). The results of this study confirm that even opticianry students experience conceptual difficulties in tasks involving thin-edged lenses, especially when it comes to the observer's position and the image perception mechanism.

It is thought that the root of these conceptual difficulties lies in the insufficient emphasis placed on the concept of image observation in the teaching of the subject (Epik et al., 2002). Students continue to confuse the concept of an image with other concepts such as the act of seeing (Durukan and Paliç-Şadoğlu,

2020; Çökelez and Çiftçi-Yaşar, 2015), reflection, or shadow formation (Kocakülah, 2006).

In conclusion, in order to improve students' conceptual understanding in optics education, more focus should be placed on the nature of real images and the role of the observer in the image perception process. Teaching processes should aim to eliminate the misconception that students perceive the image as a passive light source by demonstrating, through detailed applications, how light rays radiate from the image to the eye and how these rays are refracted by the lens.

#### 5. RECOMMENDATIONS

This research has shown that optometry students experience significant difficulties in perceiving images formed in thin-edged lenses, regarding the nature of the image and the observer's position, and persist with common misconceptions such as "The image radiates light around it." At the root of these difficulties lies the insufficient emphasis placed on the concept of image observation in the teaching of the subject. Therefore, in order to improve conceptual understanding in optics education, the tendency of students to interpret the image as a physical light source should be eliminated

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# IMAGE AND THE ROLE OF THE EYE IN OPTICS: UNIVERSITY STUDENTS' CONCEPTUAL UNDERSTANDING



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