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A Content Analysis of Physics Textbooks as a Probable Source of Misconceptions in Geometric Optics*

Geometrik Optikte Muhtemel Kavram Yanılgılarının Kaynağı Olarak Fizik Ders Kitaplarının İçerik Analizi

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ABSTRACT: Studies on students' conceptions and reasoning in geometric optics have revealed that students have scientifically incorrect knowledge or lack of understanding in basic optical phenomena. For this reason, as well as the identification of these conceptions or reasoning, the factors or sources that may cause the construction of them should be determined. In the literature, textbooks are considered as one of the main sources of students' unscientific or lacking conceptions. In introductory optics, students may not recognize the role of the observer's eye in the formation and the observation of an image. In this study, nine commonly used physics textbooks around the world and the physics textbook advised by Ministry of National Education in Turkey analyzed in terms of the use of observer's eye and critiqued as a potential source of students' unscientific or lack of conception in optics. Document analysis method is used in order to analyze the ten textbooks. It is found that the role of the observer's eye is ignored or not specifically emphasized in the image formation or observation process in the textbooks. It is suggested that textbooks should be reviewed by experts and the role of observers' eye should be considered especially at the introductory optics for students' better understanding of the optical phenomena.

Keywords: physics education**,** physics textbook, geometric optics, observer's eye

ÖZ: Geometrik optikte öğrencilerin kavrama ve muhakemelerini konu alan çalışmalar, öğrencilerin temel geometrik optik olaylarda bilimsel olarak yanlış bilgilere ya da eksik anlamalara sahip olduklarını ortaya çıkarmıştır. Bu nedenle, tüm bu kavrama ve muhakemelerin yanı sıra bu yanlış ya da eksik anlama ve muhakemelere sebep olan faktörlerin de tespit edilmesi büyük önem taşımaktadır. Alan yazınında ders kitapları öğrencilerin bu yanlış kavrama ve muhakemelerine neden olan temel sebeplerden biri olarak görülmektedir. Optiğe giriş derslerinde öğrenciler gözlemcinin gözünün görüntü oluşumu ve gözlenmesindeki öneminin yeterince farkına varamamaktadırlar. Bu çalışmada dünya genelinde yaygın olarak kullanılan dokuz fizik ders kitabı ile Milli Eğitim Bakanlığı tarafından Türkiye'deki liselerde okutulmak üzere tavsiye edilen fizik ders kitabı gözlemcinin gözünün bu kitaplarda kullanımı ve optikte öğrencilerin hatalı ya da eksik kavramlarının muhtemel nedeni olma açısından irdelenmiştir. Toplam on ders kitabının analizinde doküman analizi metodu kullanılmıştır. Çalışma sonucunda incelenen ders kitaplarında görüntü oluşumu ve gözlenmesinde gözlemcinin gözünün rolünün göz ardı edildiği ya da özellikle öneminin vurgulanmasında eksiklik olduğu tespit edilmiştir. Ders kitaplarının uzmanlar tarafından tekrar gözden geçirilip daha iyi öğrenmenin gerçekleşebilmesi için özellikle optiğe giriş konularında gözlemcinin gözünün rolü ve öneminden bahsedilmesi tavsiye edilmiştir.

Anahtar sözcükler: fizik eğitimi, fizik ders kitabı, geometrik optik, gözlemcinin gözü

1. INTRODUCTION

The concept of "light" in physics is one of the concepts in which everyone may have some understanding from at least the daily life experiences or the language used beginning from the early years of childhood. Studies on students' conceptions and reasoning in optics in the last three decades have displayed that students have scientifically incorrect knowledge or lack of understanding even in interpreting some basic optical phenomena. Identification of these

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conceptions or reasoning alone is not adequate, the factors or sources that may cause the construction of these unscientific conceptions or reasoning should be determined.

In the literature students' personal experiences, teachers' content knowledge and language used in the classes, and textbooks are listed as the possible sources of students' conceptions or reasoning (Helm, 1980; Ivowi, 1984; Kaltakci & Eryilmaz, 2010; Kikas, 2004: King, 2010). Being one of the most important teaching aids in a physics course, textbooks are thought to contain the ultimate scientific truths and free of errors. However, ample evidences suggest that textbooks are full of flaws and errors of various kinds (Campanario, 2006). Beaty (1987) claimed that students learn misconceptions from physics textbooks since misconceptions are presented as facts in students' textbooks. Iona (1987) stated that if the textbooks had fewer errors, some misconceptions might not be widely distributed or gain acceptance. For this reason detection and correction of errors or missing points in textbooks have a great importance for students' understanding of physics topics.

Besides the correctness of information provided through textbooks, the correctness of the representations is also important for especially the conceptualization of optics. In introductory geometric optics, students may not recognize the role of the observer's eye in the formation and observation of an image. Galili, Goldberg and Bendall (1991) stated that students have difficulty in answering questions that explicitly involve the role of an observer's eye. There are several studies (Galili, 1996; Galili et al., 1991; Galili & Hazan, 2000; Goldberg & McDermott, 1986; Goldberg & McDermott, 1987; Ronen & Eylon, 1993) directly or indirectly emphasizing the importance of observer's eye in optics. For this reason, the analysis of textbooks that guide both teachers and students should become an indispensable concern in education.

In this study, nine commonly used physics textbooks around the world in colleges (Cummings, 2004; Gimbattista, Richardson & Richardson, 2007; Griffith, 2004; Hewitt, 2002; Martindale, Heath, Konrad & Macnaughton, 1992; PSSC, 1981; Serway & Faughn, 1999; 2002; Zitzewitz, 2002) and the physics textbook advised by Ministry of National Education in Turkey for high schools (Komisyon, 2012) were critically analyzed in terms of refractions on eye and the usage of observer's eye in optics for virtual image case and real image case. Examples of commonly encountered errors or missing points in representations are illustrated and their correct or more complete representations are suggested. The representations illustrated in this article are not directly taken from any of the analyzed textbooks, but drawn similar to most common illustrations by considering the copyright concerns. In 2013, the physics curriculum was revised and geometrical optics topic was moved from twelfth grade to tenth grade. However, a new physics textbook for the recently revised physics curriculum has not been published yet for tenth grade level, so the current physics textbook containing the relevant geometric optics topics for twelfth grade is analyzed in the present study. The significance of this study lies in its contribution to the literature with a detailed analysis on the accuracy and completeness of the texts and/or representations in the textbooks for teachers, textbook authors, and researchers. Specifically, this study attempts to answer the following research questions:

1. What kinds of representations do the nine commonly used textbooks in the world and the Turkish physics textbook have in terms of the usage of observer's eye in optics for virtual image case, real image case, and refraction on eye?
2. Which student misconceptions might stem from these representations encountered in the physics textbooks?

2. METHOD

In this study document analysis method was used in order to analyze physics textbooks. The use of documents often entails a specialized analytic approach called content analysis (Marshall & Rossman, 1999). Content analysis is a technique which enables researchers to study

human behavior in an indirect way through their communication (Fraenkel, Wallen & Hyun, 2011; Marshall & Rossman, 1999; Yıldırım & Şimşek, 2005). In this study, qualitative (nonfrequency) type of content analysis was used as described by Fraenkel, Wallen, and Hyun, (2011), such that instead of counting the frequencies of units fitting the categories, it was tried to ascertain whether certain categories of units were or were not present in the analyzed textbooks.

With this aim a three-step process was followed to analyze the documents. In the first step a sample was selected from the vast amount of documents. In physics there are large amount of textbooks at every stage from elementary school to university. In this study nine commonly used physics textbooks (Cummings, 2004; Gimbattista, Richardson & Richardson, 2007; Griffith, 2004; Hewitt, 2002; Martindale et al., 1992; PSSC, 1981; Serway & Faughn, 1999; 2002; Zitzewitz, 2002) around world in colleges which are emphasizing conceptual understanding of principles of physics and the physics textbook (Komisyon, 2012) advised by Ministry of National Education in Turkey for high schools were analyzed in terms of the use of observer's eye in "light and optics" chapters. Of the ten physics textbooks analyzed, three were published prior to 2000, while seven were published after 2000. That may show that the analyzed textbooks are mostly up to date. These ten textbooks were selected by purposeful sampling. The reason of choosing them was to draw attention of authorities to those widely used textbooks for their improvement or correction and the improvement and correction of other similar textbooks in Turkey.

In the second step of the analysis, categories or themes that constitute the scope of the analysis were determined and described. In this study the textbooks were analyzed in terms of the usage of observer's eye in image formation and observation. Basically the textbooks were analyzed firstly for the importance and representation of observer's eye in virtual image, and secondly in real image formation and observation. Additionally, the refraction of light on the eye to form image on the retina was discussed.

In the third step, the ten textbooks constituting the sample of the study were examined in detail in terms of the three categories determined in the second step of the analysis whether certain categories were or were not presented appropriately in the textbooks. In this three-step document analysis process, the researchers firstly worked independently on the textbooks for generating the categories, coding the representations in the textbooks, and placing coded representations into these categories. Afterwards, the researchers worked together to come up with an agreement on the categorization process and reviewed the categories to ensure that each category is externally distinct and internally consistent. Textbooks with representations that are allocated to each category were then subjected to descriptive frequency analysis and presented in the findings part of this study.

3. FINDINGS

The findings according to the three categories determined to analyze the textbooks in the present study are as follows:

3.1. Observer's Eye in Virtual Image Case

In many physics textbooks, virtual images are discussed in the context of image formation and observation in plane mirrors, spherical mirrors and lenses, and they are mostly described as an image in which light does not pass through the location of image position but appears to come from that point. In the process of virtual image formation and observation, however, the observer's role is not mentioned within the text or either not represented or unsystematically (without emphasizing the role) represented in figures or ray diagrams. In fact in the formation of the virtual image, both optical device (mirror, lens) and the observer are necessary since both perception and formation of the virtual image occur simultaneously. Therefore in the

representations of image formation, the observer's eye must be included, and light diverging from the location of image position must enter the eye.

Virtual image formation and observation in plane mirrors are encountered in nearly all textbooks, like the ones analyzed in this study. In the discussion about the virtual image formation and observation of an extended object in plane mirrors, either the role of the observer is not mentioned (and not represented) or mentioned (and represented) in insufficient level in the analyzed textbooks. Five of the analyzed textbooks explain the virtual image formation of an extended object with a representation similar to the figure illustrated in Figure 1a without emphasizing or representing the role of the observer. The place of the observer is considered in image observation process only to place it to the right position in order to see the image. This type of systematic representations in textbooks may lead students to construct the misconception that the presence and place of observer's eye is important and necessary in image observation process, but not in image formation process (Galili, 1996; Galili et al., 1991; Galili & Hazan, 2000; Langley, Ronen & Eylon, 1997: Ronen & Eylon, 1993). These types of explanations and representations may be the source of novice facet of knowledge defined by Galili (1996) in which it is thought the image is formed in the mirror from the rays. After the image is formed, light rays transfer image to the observer's eye. So whether or not the mirror image is observed, it always stays in the mirror. As a consequence it may lead to the misconception that a mirror image was formed and stayed in the mirror, independently of the observer's presence.

Although the use of observer's eye is necessary in virtual image formation and observation, the correct use of it is also important. In three of the analyzed textbooks, the role of eye in image formation and observation in the plane mirror is or is not mentioned within the related text, but in some of the representations the eye is included with representations similar to the ones shown in Figure 1b. This representation needs still some correction in the size of the eye because only one light ray reflecting from the mirror as coming from the virtual image point enters the eye. As Galili et al. (1991) stated a single ray entering the eye is incomplete since it does not represent how the observer both form and see the image. Therefore, in representations of image formation and observation in a plane mirror, the observer must be included, and at least two diverging light rays must enter the observer's eye from a single point.

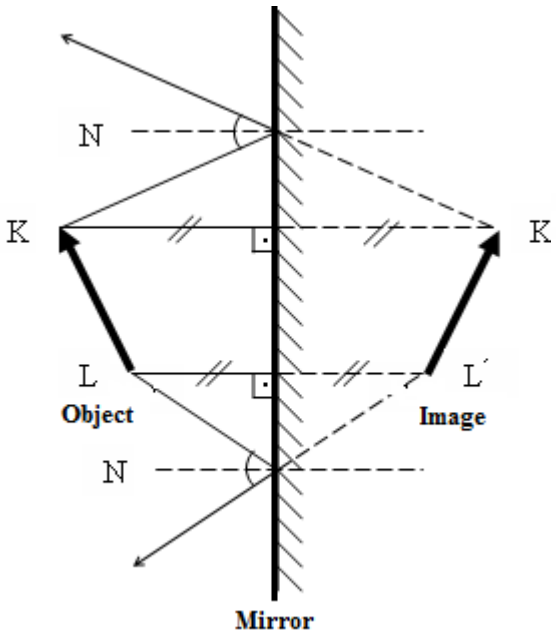

Figure 1 a

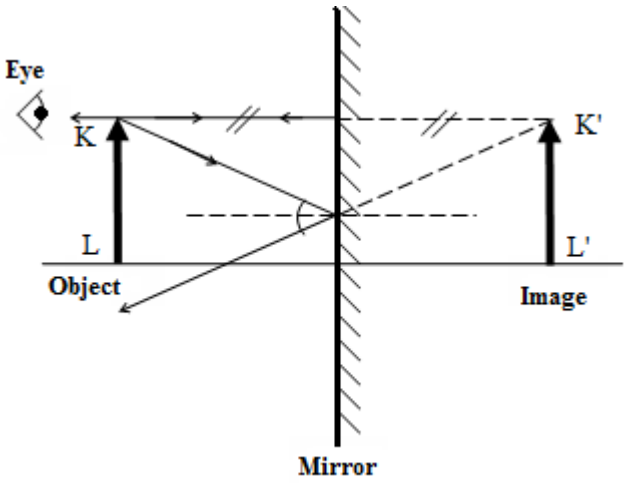

Figure 1 b

Figure 1. Examples of Incomplete Representations of Virtual Image Formation in Plane Mirror

In two of the analyzed textbooks, a more complete representation for image formation and observation in a plane mirror was encountered as illustrated in Figure 2. The Turkish physics textbook has a representation similar to the one in Figure 1a, but not like the one in Figure 2.

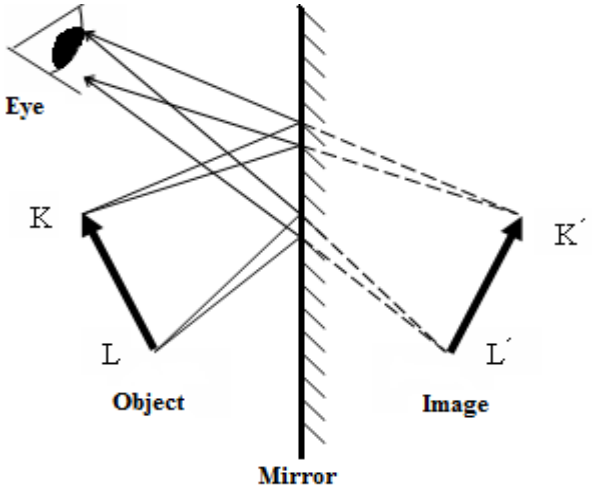

Figure 2. Example of a More Complete Representation of Virtual Image Formation in Plane Mirror

3.2. Observer's Eye in Real Image Case

It is a common misconception that a surface is necessary for seeing a real image (Conery, 1983; Goldberg, Bendall & Galili, 1991; Goldberg & McDermott, 1987). In fact, in the absence of the screen, an aerial image is formed at the same place with screen case. In observation of this image the place of the observer's eye is crucial. For this reason, if no screen is placed in the real image point, the observer's eye located within the cone of light diverging from the aerial image point can see the aerial image.

In nine of the textbooks with real image case in converging lens, we encountered with representations similar to the one depicted in Figure 3. In these representations although no screen is placed in the image point, the eye is still not represented at the appropriate position, so that the rays diverging from the image point reach to the observer's eye for the image to be seen. Any figure like this one may cause the students to think that the real image formed at a point can be seen by any observer placed in any location. Also, that kind of representations may cause students to think the light rays to terminate at point K', and not diverge after that point.

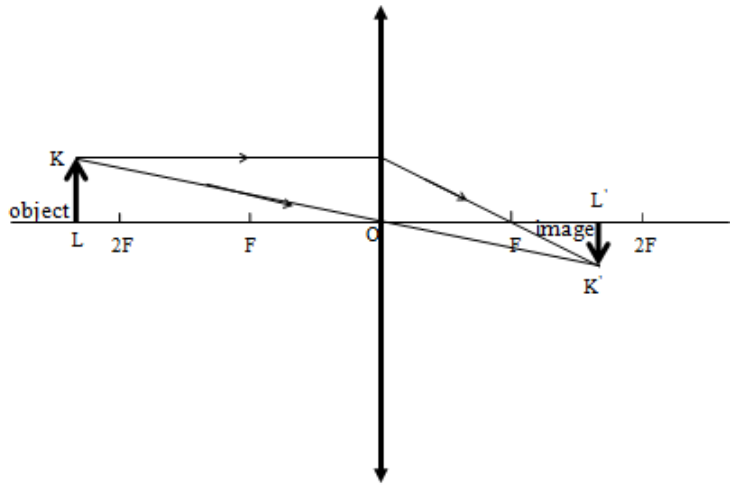

Figure 3. Example of Incomplete Representation of Real Image Formation and Observation in Converging Lens

It is important for this reason to emphasize the formation and observation of real images in the absence of the screen cases with critically discussing the role of observer's eye. In the study of Goldberg et al. (1991), the image formation in converging lenses with and without screen cases are discussed in detail. The figures similar to the ones in Figure 4a and 4b are represented in the study. In Figure 4a only the observer looking along the optical axis (O_2) or any observer located in the shaded region can see the aerial reproduction, while the other observers (O_1 and O_3) cannot see. In Figure 4b, however, all of the observers can see the image formed on the translucent screen, since a translucent screen partially reflects and partially transmits the light rays reaching to the image point. With this kind of complete representations, students become aware of the aerial real image in addition to the real image formed on the screen, and understand the importance of observers' position to see this aerial image. Neither nine international physics textbooks, nor the Turkish physics textbook in this study mentioned about an aerial real image formation and its observation, and none of them include it in their representations.

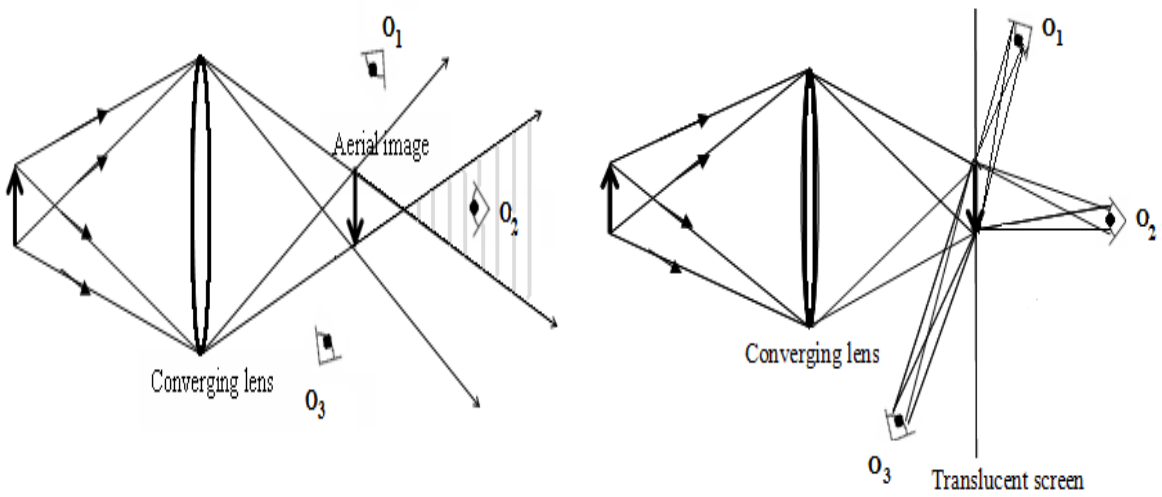

Fig. 4a **Fig. 4b**

Figure 4. Examples of Complete Representations of Real Image Formation and Observation in

Converging Lens

3.3. Refraction on Observer's Eye

It is a common practice in the physics textbooks that the light rays entering the eye ball refract only on the lens of the eye. Actually the cornea is the main lens, and most of the bending of light (about 70 %) occurs at the place where the light enters the surface of the cornea. The lens inside the eye acts to alter the focus of the eye. For this reason in the representations, the light rays coming into the eye should refract at the cornea mostly. However, in five of the analyzed textbooks (including the Turkish textbook) although in some it is stated correctly within the related text, in representations as shown in Figure 5 the refraction depicted to occur at the inside lens of the eye.

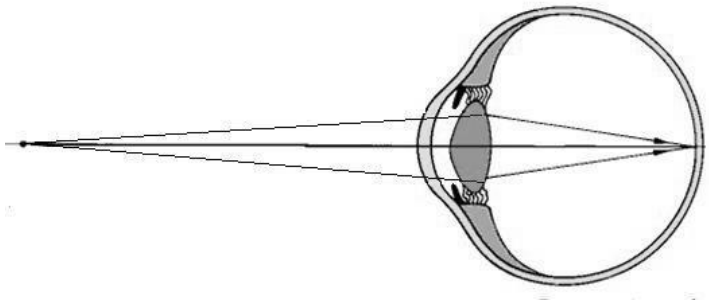

Figure 5. Example of Incomplete Representation of Refraction of Light Rays on the Eye

The representations similar to Figure 6 with clearly showing the refraction on both at the cornea and the lens of the eye are encountered in only one of the textbooks. In one of the textbooks, representations similar to both Figure 5 and Figure 6 coexist. Even though, the light rays refract as both entering and leaving the cornea and lens, the representations that show the refraction at the middle is accepted as complete, since it is beyond the focus of this study.

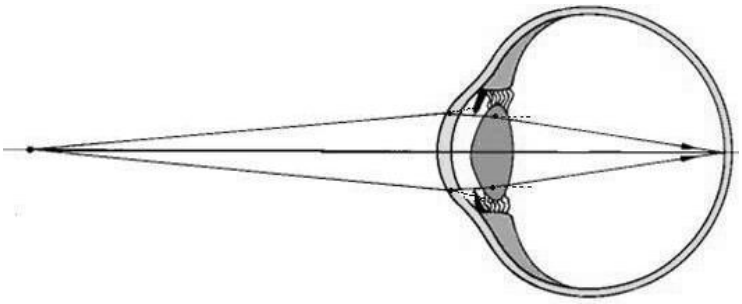

Figure 6. Example of Complete Representation of Refraction of Light Rays on the Eye

Table 1 summarizes the common student misconceptions that might stem from the analyzed textbook representations in this study with the number of textbooks (out of ten textbooks) with each incomplete representation form and the number of textbooks with the correct form of representations. According to the results, incomplete, improper or vague representations or statements in textbooks are common and might be responsible from the misconceptions of students.

Table 1: Common Student Misconceptions in Geometric Optics that Stem from the Textbooks

Misconception	Incomplete Representation	Number of Textbooks With Incomplete Representations	Complete Representation Form	Number of Textbooks With Complete Represen-tations
➢ Image formation process is separate from the image observation process in virtual image production and a mirror image is formed and stayed in the mirror, independently of the observer's presence	Figure 1	8*	Figure 2	2
➢ The existence and place of observer's eye is important and necessary in image observation process, but not in image formation process	Figure 1 Figure 3	9*	Figure 2 Figure 4	2
➢ It is impossible to see a real image without a screen	Figure 3	9*	Figure 4	0
➢ A real image already formed without a screen can be seen from anywhere, or can be seen only when the eye is located to the image position.	Figure 3	9*	Figure 4	0
➢ Most of the (or only) refraction occurs on the lens of the human eye	Figure 5	5*	Figure 6	1

* The Turkish physics textbook is also present in this category

4. CONCLUSION and RESULTS

Textbooks have played a vital role in the teaching and learning of physics topics. Teachers as well as their students seem to use textbooks most of the time during the teaching and learning process (Good, 1993) and textbooks have a very important influence on both teachers and their students. However, sometimes the textbooks become a source of student misconceptions with the information they provide (Helm, 1980; Ivowi, 1984; Kaltakci & Eryilmaz, 2010; Kikas, 2004). Teachers often have the same alternative conceptions as their students and the poorly written textbooks may be responsible for the persistence of their alternative conceptions (Wandersee, Mintzes, & Novak, 1994). Therefore, readers of the books and especially the teachers should be aware of the explanations and representations in the textbooks and discuss them with their students to prevent construction of misconceptions in the minds. Also, textbook writers and textbook analyzers should be watchful for possible sources of student misconceptions. In this study, with the analysis of ten physics textbooks, it was found that the role of the observer's eye was ignored or not specifically emphasized in the image formation and observation process. In

the sections dealing with image formation in many textbooks, the eye was not explicitly included in the ray diagrams, or it was used unsystematically.

From the findings of this study the following list of general implications or suggestions concerning students' better understanding of the optical phenomena can be concluded:

1. The function of the eye in the image formation and observation in both real and virtual images should be discussed explicitly at the beginning of the optics and light chapter in physics textbooks.
2. Also the eye should be placed at the appropriate positions with appropriate size in the representations of ray diagrams. However since including observer's eye in such detail in every representation would be cumbersome, it is suggested to discuss the function of the eye and include at least in the introductory parts of the image formation and observation sections.
3. One way of improving education is to ensure that curriculum materials are of high quality and are free of errors. This analysis has shown that current physics textbooks should be reviewed by experts, and the role of observer's eye should be considered especially at the introductory optics for students' better understanding of the optical phenomena. In this concern, informing the publishers and textbook authors with these findings may result in new editions of the textbooks with these considerations in account.
4. Finally it is suggested that teachers and students should be alert about the information presented with the textbooks since they do not always contain the scientifically accepted knowledge, but may be incorrect or incomplete, vague or misleading like in the cases discussed throughout this article.

The detailed analysis and discussion in this article provide the opportunity for authors of physics textbooks and teachers of classroom material developers to improve their work in geometric optics. With the introduction of new physics curriculum in 2013, the need for new physics textbooks becomes indispensable. Therefore, this study may guide the Turkish authors who have the attempt to write new physics textbook for the new physics curriculum.

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Uzun Özet

Otuz yılı aşkın süredir öğrencilerin çeşitli konulardaki alternatif kavramları hakkında yapılan çalışmalar öğrencilerin fizik ile ilgili birçok konuda alternatif kavramlara sahip olduklarını ortaya çıkarmıştır. Bu kavramlar arasında kuvvet-hareket, ısı-sıcaklık, elektrik akımı ve ışık en yaygın olanlarıdır. Işık kavramı bireylerin erken çocukluk yıllarından itibaren günlük yaşamdaki deneyimleri ve kullanılan dil ile, takip eden yıllarda ise bunlara ilaveten okul eğitimi, öğretmenler, ders kitapları gibi yollarla birtakım kavrama ve muhakemeye sahip oldukları bir kavramdır. Geometrik optik ve ışık konularındaki bugüne kadar yapılan çalışmalar, öğrencilerin temel optik olaylarda bilimsel olarak yanlış ya da eksik anlamalara veya muhakemelere sahip olduklarını ortaya çıkarmıştır . Tüm bu kavrama ve muhakemelerin yanı sıra bu yanlış ya da eksik anlama ve muhakemelere sebep olan faktörlerin de tespit edilmesi ve tartışılması büyük önem taşımaktadır. Alan yazınında kavramlarla ilgili deneyimler, öğretmenlerin yetersiz ya da yanlış alan bilgileri, kullanılan dil ve ders kitapları öğrencilerin bu yanlış kavrama veya muhakemelerine neden olan temel sebepler arasında sıralanmaktadır (Helm, 1980; Ivowi, 1984; Kaltakci & Eryilmaz, 2010; Kikas, 2004). Fizik derslerinde öğretime önemli bir yardımcı olan ders kitaplarının bilimsel gerçekleri içerdiği ve hatadan yoksun oldukları düşünülür. Fakat ders kitaplarının zaman zaman birtakım hata ve eksikliklere sahip oldukları unutulmamalıdır (Campanario, 2006). Hatta bazı ders kitaplarında kavram yanılgıları bilimsel gerçeklermiş gibi sunulmaktadırlar (Beaty, 1987).

Geometrik optiğe giriş derslerinde öğrenciler gözlemcinin görüntü oluşumu ve gözlenmesindeki öneminin yeterince farkına varamamaktadırlar. Bu konuda yayınlanmış birçok çalışmada (Galili 1996; Galili vd., 1991; Galili & Hazan, 2000; Goldberg & McDermott, 1986; Goldberg & McDermott, 1987; Ronen & Eylon, 1993) direk ya da dolaylı olarak optikte gözlemcinin gözünün yeri ve önemi konusuna dikkat çekilmektedir. Bu sebeplerle öğrenci, öğretmen ve araştırmacılar gibi geniş bir okuyucu kitlesine sahip olan ve bu bireylerin fiziksel kavramları oluşturması ve şekillendirmesine yardımcı olan ders kitaplarının analizinin yapılması büyük önem taşımaktadır. Tüm bu bahsi geçen nedenler çerçevesinde bu çalışmanın amacı, dünya genelinde yaygın olarak kullanılan dokuz ders kitabı (Cummings, 2004; Gimbattista, Richardson & Richardson, 2007; Griffith, 2004; Hewitt, 2002; Martindale vd., 1992; PSSC, 1981; Serway & Faughn, 1999; 2002; Zitzewitz, 2002) ile Milli Eğitim Bakanlığı tarafından Türkiye'deki liselerde okutulmak üzere tavsiye edilen fizik ders kitabının (Komisyon, 2012) gözlemcinin bu kitaplardaki kullanımı ve optikte öğrencilerin hatalı ya da eksik kavramlarının muhtemel nedeni olma açısından incelenmesidir.

Çalışmada yer alan toplam on ders kitabının analizinde doküman analizi metodu kullanılmıştır. Kitaplar zahiri görüntü oluşumu ve gözlenmesinde gözlemcinin gözünün yeri ve önemi, gerçek görüntü oluşumu ve gözlenmesinde gözlemcinin gözünün yeri ve önemi ve ışığın gözde kırılması olmak üzere üç temel konuda ayrıntılı olarak incelenmiş ve her bir kategoride hatalı ya da eksik açıklama ve gösterime sahip olan kitapların sayısı ve örnekleriyle birlikte verilmiştir. Çalışmada incelenen on ders kitabının analizi sonucunda beş ders kitabında düzlem aynada zahiri görüntü oluşumu ve gözlemlenmesi konusunda gözlemcinin yeri ve öneminden hiç bahsedilmediği ve gösterimlerde gözlemciye yer verilmediği belirlenmiştir. Diğer üç ders kitabında ise gösterimlerde gözlemcinin yer almasına karşın, uygun boyutta ve açıklama ile birlikte yer verilmediği saptanmıştır. Zahiri görüntü konusunda bahsi edilen bu hatalı ya da eksik gösterimler öğrencilerin görüntü oluşumu sürecinin görüntünün gözlenmesi sürecinden bağımsız olduğunu düşünmesine ve zahiri görüntünün gözlemciden bağımsız olarak aynada oluşabileceği kavram yanılgısına sebep olarak düşünülebilir. Benzer kavram yanılgılarının yaygınlığı Galili (1996), Galili vd. (1991), Galili ve Hazan (2000), Langley vd. (1997), Ronen ve Eylon (1993) tarafından da daha önce tartışılmıştır. İkinci kategori olan gerçek görüntü oluşumu ve gözlemlenmesi konusunda ise görüntünün oluştuğu yerde ekran olup olmamasına göre gözlemcinin görüntüyü görebileceği yerler çalışmadaki dokuz kitapta tartışılmamıştır. Gerçek görüntünün oluşumu ve gözlemlenmesindeki bu eksiklik, öğrencilerin gerçek görüntünün ancak ve ancak ekran üzerinde görülebileceği kavram yanılgısının (Conery, 1983; Goldberg, Bendall ve Galili, 1991; Goldberg ve McDermott, 1987) muhtemel nedenlerinden birisi olabilir. Ayrica kitaplardaki gösterimler gözlemcinin yalnızca gerçek ya da zahiri görüntünün gözlemlenmesinde önemli olduğu, görüntünün oluşumunda ise gerekli olmadığı düşüncesinin yayılmasında büyük bir etken olarak karşımıza çıkmaktadır. Son kategori olan ışığın gözde kırılması konusunda ise, beş ders kitabında ışığın yalnızca göz lensinde kırıldığı şekillerde belirtilmiş, yaklaşık yüzde yetmiş kırılmanın gerçekleştiği kornea yüzeyindeki ilk kırılmaya yalnızca bir ders kitabında yer verilmiştir. Bu hatalı gösterimlerin ise öğrencilerin gözdeki kırılmadan yalnızca ya da büyük ölçüde göz merceğinin sorumlu olduğu kavram yanılgısına yönelttiği düşünülmektedir.

Sonuç olarak, çalışmada incelenen ders kitaplarında görüntü oluşumu ve gözlenmesinde gözlemcinin gözünün rolünün çoğu zaman göz ardı edildiği ya da özellikle öneminin vurgulanmasında eksiklik olduğu tespit edilmiştir. Öğrencilerin ışık ile ilgili kavramları daha iyi anlayıp kavrayabilmeleri için özellikle geometrik optiğe giriş konularında zahiri ve gerçek görüntü oluşumunda ve gözlemlenmesinde gözlemcinin yeri ve önemin vurgusuna kitaplarda açıkça yer verilmesinin gerekliliğine dikkat çekilmelidir. Gösterimlerde gözlemcinin gözüne de yer verilmeli ve gözün büyüklüğünün ve yerinin uygunluğuna dikkat edilmelidir. Bu çalışmada dünyada yaygın olarak kullanılan ders kitaplarının yanı sıra, Türkiye'de kullanılan fizik ders kitabının da analizi, bugünlerde değişen ortaöğretim fizik öğretim programı ile yeniden hazırlanması sürecine gidilmiş fizik ders kitabı yazarlarına ışık olması açısından da önem taşımaktadır. Ayrıca bu çalışmada mevcut ders kitaplarının uzmanlar tarafından tekrar gözden geçirilmesinin gerekliliğine ve öğretmen, öğrenci ve araştırmacıların ders kitaplarının her zaman bilimsel doğruları eksiksiz bir biçimde içermediği gerçeğine dikkat çekilmiştir. Bu araştırma alternatif kavramların tespiti ve giderilmesine yönelik ileride yapılacak çalışmalara bu hatalı kavramların kaynakları hakkında yol göstermesi açısından örneklendirilmiş betimsel bilgiler içermesi açısından da önemlidir.

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