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A physics teaching material: myopia model

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Abstract

Transferring physics to daily life supports that the subjects are learned effectively. The human eye offers a rich potential for connecting optics concepts to everyday life. This study introduced a cost-effective and easily transportable eye model made from wood as an optic instructional material. With this eye model, myopia and its correction can be explained in physics courses, as well as why a person with myopic cannot see the distance clearly but can see the near clearly. The advantages of this material which is used with flashlight, light limiter and wood grid from other commercial models which is used with laser were shown experimentally. It is thought that this teaching material will important contribute to associating optics topics with daily life in courses.

Keywords: *Physics education, optics education, teaching material, eye, myopia.*

Bir fizik öğretim materyali: miyopi modeli

Öz

Fiziğin günlük hayatla ilişkilendirilmesi konuların etkili bir şekilde öğrenilmesini destekler. İnsan gözü, optik kavramlarını günlük hayatla ilişkilendirmek için zengin bir potansiyel sunar. Bu çalışmada, optik öğretim materyali olarak ahşaptan hazırlanmış, uygun maliyetli ve kolay taşınabilir bir göz modeli tanıtılmıştır. Bu göz modeli ile miyopi ve miyopinin gözlükle düzeltilmesinin yanı sıra miyop kırma kusuru olan bir kişinin neden uzağı net göremediği ancak yakını net görebildiği açıklanabilmektedir. Ayrıca el feneri, ışık sınırlandırıcı ve ahşap ızgara ile kullanılan bu materyalin lazer ışık kaynağı kullanılan ticari göz modellerinden miyopiyi modellemedeki üstünlüğü deneysel olarak gösterilmiştir. Bu öğretim materyalinin derslerde optik konularının günlük hayatla ilişkilendirilmesine önemli katkı sağlayacağı düşünülmektedir.

Anahtar kelimeler: *Fizik eğitimi, optik eğitimi, öğretim materyali, göz, miyopi.*

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1. Introduction

Optics, a sub-branch of physics, investigates the behaviour of light within a refractive and reflective environment. Optics-related events are frequently encountered in daily life [1]. Consequently, people have lots of experiences regarding light's behaviour and its interaction with various environments in their day-to-day activities from ancient times to the present [2]. Although daily experiences with optics may initially seem advantageous in terms of learning optics, these experiences cause misconceptions when explained with incomplete optics knowledge [3], this causes to variety of misconceptions about all topics of optics, ranging from plane mirrors to polarized filters, and from lenses to interference [4]. For this reason, explaining real-life situations such as refractive errors in eyes how and why occur in courses is very important in terms of reducing students' misconceptions. The human eye offers a rich potential for connecting optics concepts to everyday life. Recognizing this, researchers have developed various human eye models as instructional tools [5]. Mullin was developed an eye model from petri dishes, metal plates, and lenses [6]. With this model, along with a filament lamp, he simulated conditions like cataracts, accommodation, myopia, hyperopia, and their correction through eyeglasses. Colicchia et al. (2008) developed an eye model from a hollow polystyrene ball [7]. It contains an eye lens which was made of a petri dish and a condom. This lens model is capable of expanding by taking in water. Through this setup, researchers illustrated the eye's capability to focus on objects near and far, aided by this lens with adjustable optical power. Helene (2010) devised an innovative experiment by dividing a glass ball in half, covering one side with aluminium foil. The centre of the aluminium foil was left with a round space to simulate the pupil [8]. The other side of the model was covered with a transparent white party balloon to symbolize the retina. This setup led to the creation of inverted images within the eye model. Observers could see the image from the balloon part of the model. The model also shows that narrow pupil diameter supports image quality. Additionally, with this lens model, it could be shown that the image becomes blurred when the lens is removed from the eye model.

Refractive errors include myopia, hyperopia, astigmatism, and presbyopia [9]. Essentially, these errors occur when the light cannot focus on the fovea. People, who have refractive errors, suffer from blurred images and these refractive errors are very common [10]. This refractive error is also frequently encountered in students [11]. Even students who may not experience these issues have some friends or relatives who have got refractive errors. Consequently, the topic of refractive errors and their correction with eyeglasses is a prototype for linking optics concepts to everyday experiences. Moreover, research indicates that incorporating medical and biological content into physics instruction increases student interest [12].

Within this framework, this study introduced a cost-effective and easily transportable eye model created from wooden materials to enhance optics education. This education tool can use science lesson in middle school, physics lesson in high school and physics, physics teacher, science teacher department and opticianry program in university. This eye model can explain myopia, the correction of myopia with eyeglasses, and near and distant visions of myopia persons. We claim that using the model in physics courses will support students' attitudes and motivation toward physics.

2. Method

Theoretical background, the detail of developing material, experiments result with the material are stated this section.

2.1. Theoretical background

The eye is a specialized organ for vision. It has different parts. Below is a schematic drawing showing the basic anatomy and refraction ability of the human eye.

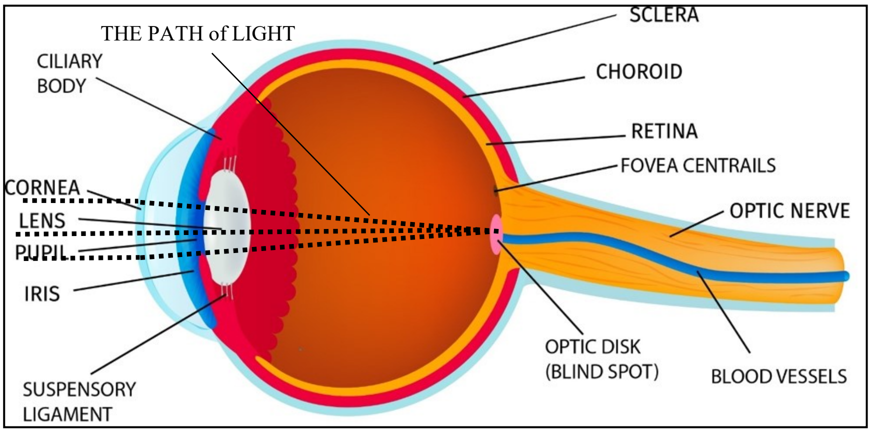

Figure 1. Schematic drawing showing the human eye.

The eye's optical mechanism starts with the entrance of rays through the aperture of the pupil. These rays are refraction by the cornea and lens, subsequently collecting on the fovea centralis on the retina. This focusing create an image on fovea centralis. Within the fovea lie millions of light-sensitive photoreceptors. Electrical signals caused by chemical changes in these photoreceptors are transmitted to the brain by traveling through successive neuronal nerves. Employing data gleaned from the optic nerves, the brain consolidates the images received from both eyes into a unified perceptual representation [13].

The person who is myopia has a longer axis extending from the cornea to the retina than a typical eye. Consequently, a myopic eye produces a sharp image of a distant object in front of the retina. However, as an object draws nearer, its image approaches the fovea, enabling the eye to perceive it distinctly. This characteristic renders myopia advantageous for professionals like watch maintenance specialists during their working hours, as Pedrotti et al. [13].

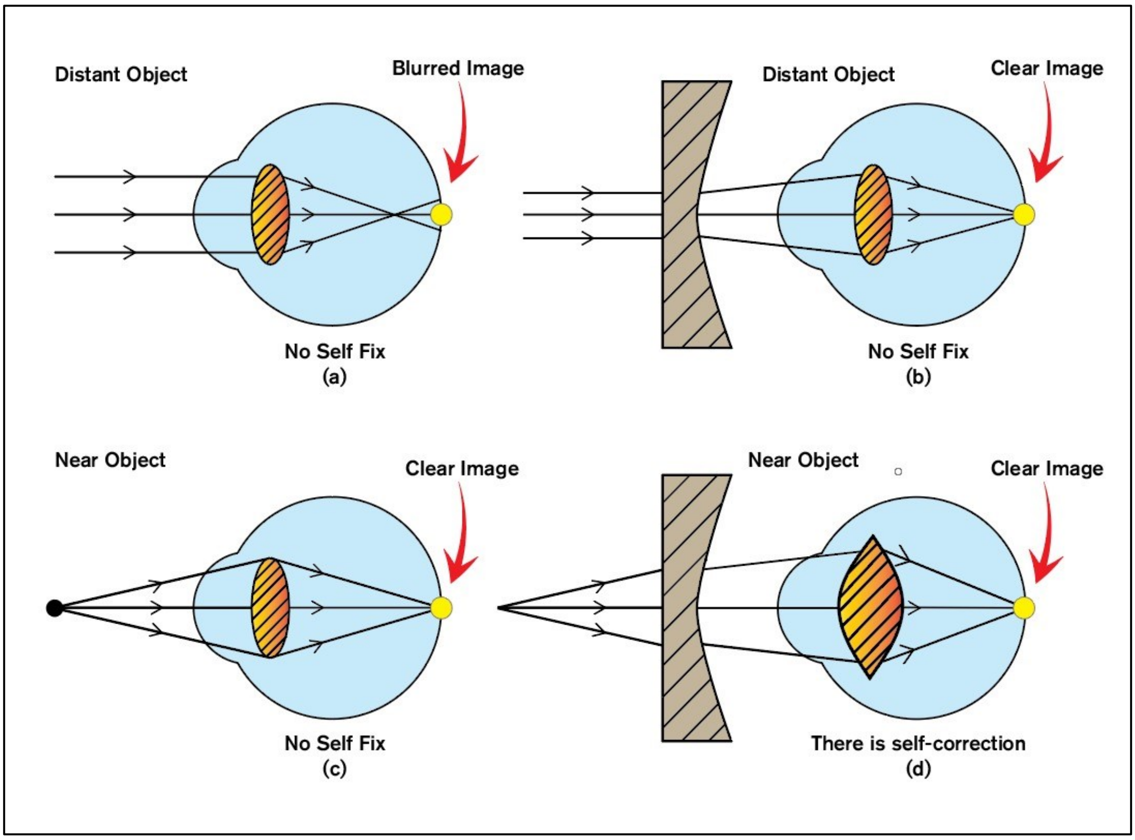

Figure 2. Distance and near vision of myopes with and without glasses

According to Figure 2, myopic vision is corrected through eyeglasses which contain negative optical power. When wearing myopia glasses, the lens disperses the rays emanating distant objects, redirecting them to converge onto the fovea, resulting in a clearer image. But rays from a nearby object fall on the fovea centralis without eyeglasses. Interestingly, myopic individuals wear their glasses even when focusing on close objects. Logically, when a myopia person wears negative optical power eyeglasses for near objects, this would imply that the image should fall behind the fovea, resulting in a blurred image for close objects. However, the eyepiece's capacity to adjust its optical power increases this power and collected the rays onto the fovea, thereby rectifying the image even with eyeglasses [13].

2.2. Teaching Material

The following set of experiments was developed to model myopia and its correction with glasses.

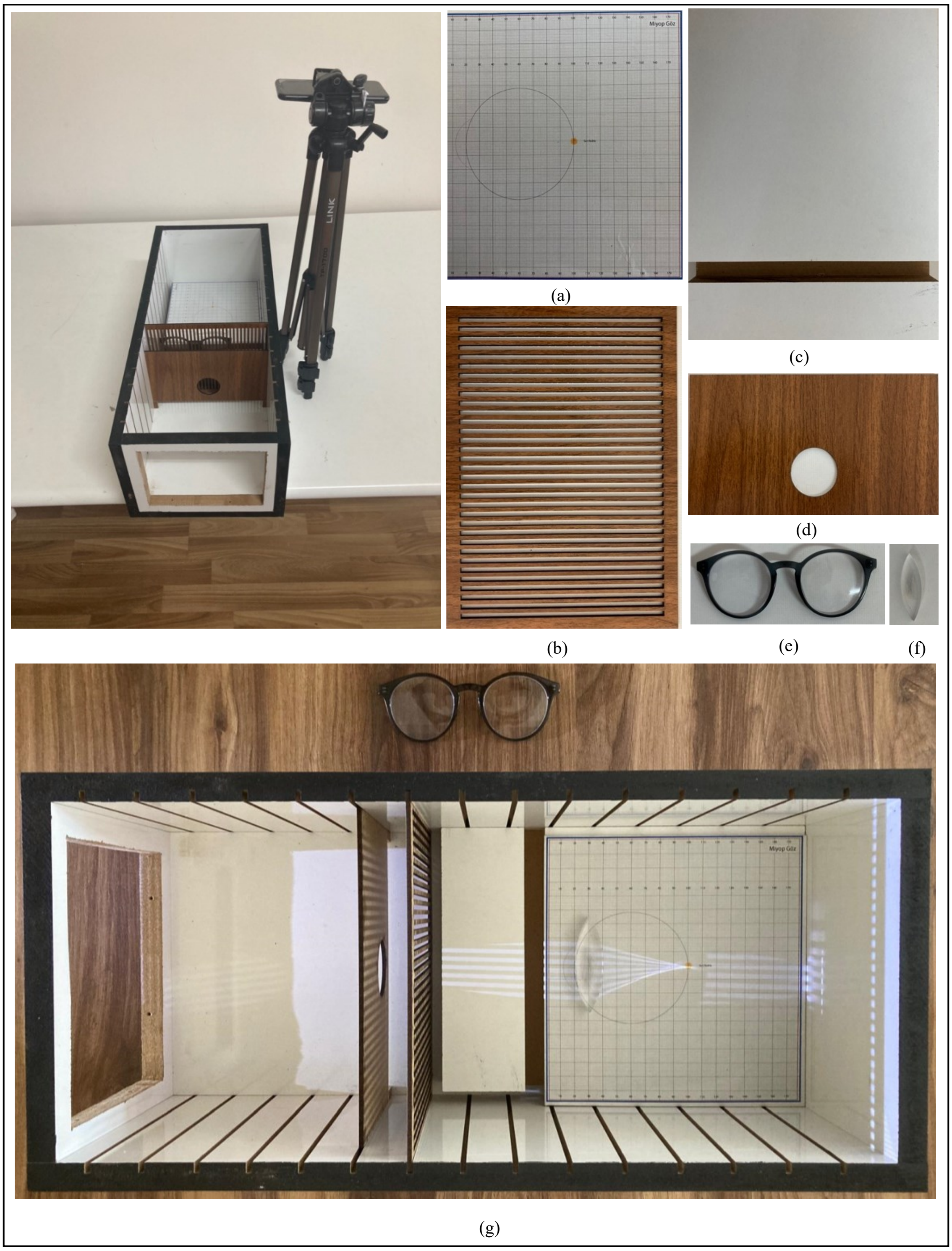

Figure 3. Experimental set and its components

The experimental set consists of seven parts. These parts are the myopia plate (a), grid (b), lower platform (c), light limiter (d), eyeglass (e), and lens (f). The box is made of MDF material with dimensions of (17.5 x 23.0 x 49.5) cm. The myopia plate consists of a wooden plate measuring (18.3 x 19.2) cm. An eye picture was drawn on the myopia plate with the CorelDRAW program. The diameter of the drawn eye picture was calibrated according to the location where the parallel laser beams sent to the lens used in the experiment passed through the lens with and without glasses with an optical power of

(-1.5) diopter. According to this calculation, the eye model on the plate is 8.0 cm in diameter. The grid was created by laser cutting a (15.7 x 21.0) cm wooden plate. Each gap on the grid is 3 mm thick. There are 33 spaces in total on the grid. The lower platform has a channel for glasses and measures (19.0 x 25.7 x 31.0) cm. The light limiter was obtained by drilling a circular hole with a diameter of 4.0 cm on a wooden board measuring (11.3 x 21.0) cm. The eyeglass frame contains a lens with an optical power of (-1.5) diopter. The eyepiece is a standard test lens made of glass material with a refractive index of 1.5 and an optical power of 15 diopter. The focusing situation created by illuminating the experimental set with a flashlight is shown in figure 3(g).

The light coming into the eye is narrowed by the pupil, refracted by the optical power medium created by the cornea and the lens, and focused on the fovea centralis. The pupil was modelled with the light limiter (d) in the experimental set. The grid (b) is used to make the orientation of the flashlight's beam visible. The lens (f) represents the refractive power of the eye and eye is placed on the myopia plate (a).

Adjustable flashlight with was used as a light source in the experimental set.

Figure 4. Light sources

The front section of the flashlight is movable. By moving this part, the area illuminated by the light from the flashlight can be changed. In Figure 4 the widest and narrowest illuminated regions of the flashlight are shown in Figures 4(a) and 4(c). In this study, the beams were sent to the experimental set at the illumination width in Figure 4(b), where the flashlight provides medium illumination.

Light sources emit light in all directions from every point on their surface. Flashlight is more successful simulation of the light sources instead of parallel lasers. Thanks to the light limiter, when the lights are emitted from a flashlight which is located a far distance from this model, only parallel lights can reach the lens. But when the lights are emitted from a flashlight which is located a close distance from this model, parallel and some nun parallel lights can reach the lens. Parallel laser sources which are used in some commercial eye models [14, 15] have the same behaviour both far and close distance.

2.3. Experimental procedure

During modelling myopia with the eye model, the distance between the flashlight and the lens was determined as 86.0 cm to represent distance vision in myopic, and the distance between the flashlight and the lens was determined as 53.0 cm to represent near distance.

These distances were detected according to collecting rays' location in the eye model which represents distance and near vision of myopic.

Experiment I: Distance Vision of Myopic with an Eye Model

The flashlight and parallel laser sources were held at a distance of 86.0 cm from the eye model. The collection of the beams was examined both with and without glasses with an optical power of (-1.5) diopter placed in front of the eye model. The images of the eye model at a distance of 86.0 cm with a flashlight and laser source with and without glasses are shown in Figure 5.

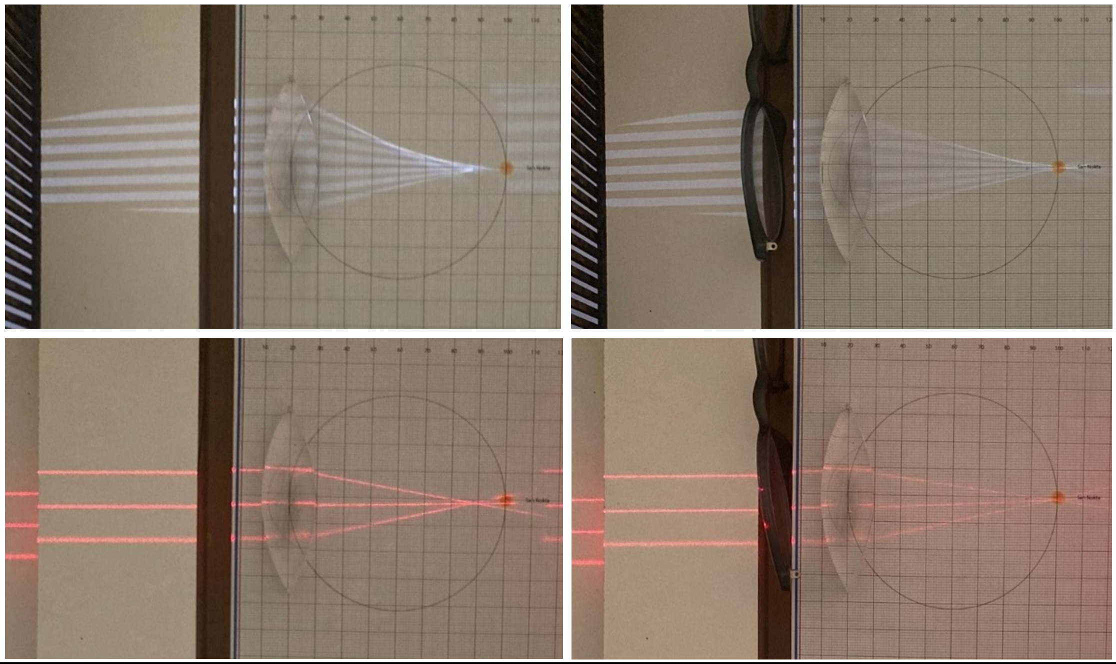

Figure 5. Modeling myopia with flashlight and laser for distant objects

The distances between the lens and the places of focusing the lights on the eye model were measured. The measurement results are given in the table below.

Table 1. Measurement results for distance (86.0 cm) without and with glasses

Flashlight		**Laser**	
Without glasses (cm)	**With glasses (cm)**	**Without glasses (cm)**	**With glasses (cm)**
6.8	7.7	6.8	7.9
6.9	7.9	6.8	7.8
7.1	8.0	6.8	7.8
7.3	8.1	6.8	7.8
7.4	8.3	6.8	7.8

When Figure 5 and Table 1 are examined, both lesser and flashlight with eye models can explain the distance vision of myopic. The average of data in Table 1 for without condition of glasses is 7.1 and with condition of glasses is 8.0.

Experiment II: Near Vision of Myopic with an Eye Model

The flashlight and parallel laser sources were held at a distance of 31.5 cm from the eye model. The collection of the beams was examined both with and without glasses with an optical power of (-1.5) diopter placed in front of the eye model. The images of the eye model at a distance of 31.5 cm with a flashlight and laser source with and without glasses are shown in Figure 6.

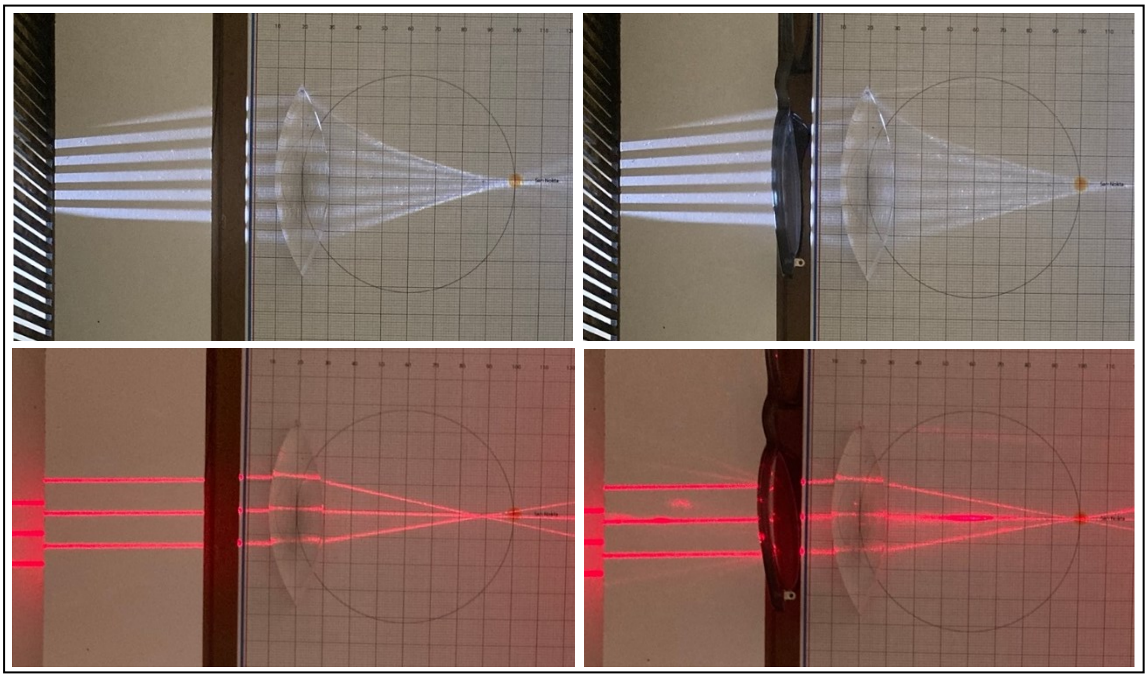

Figure 6. Modelling myopia with flashlight and laser for nearby objects

The measurement results are presented in the table below.

Table 2. Measurement results for near distance (31.5 cm) without glasses

Flashlight source		**Laser source**	
Without glasses (cm)	**With glasses (cm)**	**Without glasses (cm)**	**With glasses (cm)**
7.7	9.7	6.8	7.9
7.6	9.7	6.8	7.8
7.8	9.8	6.8	7.8
7.9	9.9	6.8	7.8
7.8	9.9	6.8	7.8

Flashlight with eye model can explain near vision of myopic but laser with eye models cannot explain. The average of data in Table 2 for without condition of glasses is 7.8 and with condition of glasses is 9.8.

4. Result and discussion

Classes with a medical and biological context are significantly more interesting for students than classes using a more traditional approach. [5, 12]. Students are more motivated to learn interesting topics [16]. It is also recommended that optical learning content be enriched for optics subjects [1]. The eye and its optical structure are prototypes for associating optics with medicine and biology and enriching the teaching environment. This potential contained in the optical structure of the eye was noticed long ago by physics educators and various teaching materials modelling the optical structure of the eye were developed [5, 6, 7]. In this study, an eye model was developed. With this developed eye model, it is aimed to enrich the optical teaching environment at secondary school, high school and university levels and to provide students with a material that will increase their interest and motivation in optics. The laser light source used in the mentioned commercial experiment sets emits parallel light for both long and close distances. But, the light source used in the developed experiment set with light limiter in Figure 3(d) emits parallel light at long distances and non-parallel light at close distances. In this way, it is possible to demonstrate the distance and near vision conditions of myopia with this experimental set. In this study, a physics teaching tool was created to combine daily life with optic courses. This teaching tool is about myopia. This model effectively represents both near and distance vision conditions of myopic persons with a flashlight, a light limiter, and a grid unlike common commercial eye models [14, 15], which use three parallel lasers.

This model serves as an excellent demonstration for explaining eye accommodation—the eye's capability to alter its optical power—particularly when examining a nearby object. The eye model holds distinct advantages due to its affordability and portability. In this study, special attention was given to developing a standardized and aesthetically pleasing model. However, a comparable model can be fashioned using readily available materials like a shoebox, a piece of cardboard with a central aperture, a paper cut-out in the shape of an eye, a comb, a student's glasses, and a flashlight. Creating the model with these straightforward materials can potentially promote its widespread utilization.

Research on utilizing human eye models as educational tools in physics instruction has been longstanding by various researchers [6, 7, 8]. This study is anticipated to make a meaningful addition to the existing literature in this domain. Moreover, this model has the potential to inspire researchers to devise diverse and innovative eye models for educational purposes.

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