“Staying in Focus” – An Online Optics Tutorial on the Eye

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The human eye and its vision problems are often used as an entry subject and attention grabber in the teaching of geometrical optics.[1] While this is a real-life application students can relate to, it is difficult to visualize how the eye forms images by studying the still pictures and drawings in a textbook. How to draw a principal ray diagram or how to calculate the image distance from a given object distance and focal length might be clear to most students after studying the book, but even then they often lack an understanding of the “big picture.” Where is the image of a very far away object located? How come we can see both far away and close-by objects focused (although not simultaneously)? Computer animations,[2] popular with our computer-game savvy students, provide considerably more information than the still images, especially if they allow the user to manipulate parameters and to observe the outcome of a “virtual” experiment. However, as stand-alone learning tools, they often don’t provide the students with the necessary physics background or instruction on how to use them.

We present a new online learning tool that introduces students to some of the basic concepts of geometrical optics in the context of the human eye. The online optics tutorial “Staying in Focus” combines interactive animations, videos, slides with graphics, and continuous narration that guides the user along in his/her study, as if he/she were sitting in a lecture. In addition, the student is explicitly encouraged to play with the interactive animations and to perform virtual experiments, thus becoming an active learner rather than a passive listener. At Cal Poly Pomona, the tutorial is used to help freshmen physics students in their preparation for the thin lenses lab experiment. In its original version, designed as a self-study online lesson for science teacher preparation, it focuses mostly on a conceptual approach to the study of lenses and how they form images. In addition, a step-by-step derivation of the thin lens equation is provided. In the following, we will describe the different elements of the tutorial and present the results of student learning.

Elements of the optics tutorial

The online optics tutorial was created using the software Adobe Presenter and is available to the general public under https://connect.csupomona.edu/optics132122/ (version for physics students) and https://connect.csupomona.edu/opticstutorialpublic/ (version for science teachers). Adobe Flash Player is required to view some of its components. All elements were developed by the team of I&IT Learning at Cal Poly Pomona.

The tutorial consists of a sequence of 14 “slides,” some of which are indeed animated PowerPoint slides. Three of the slides contain short videos that are embedded in this PowerPoint show, while four more display interactive animations. Continuous narration, complete with transcript as required by universal accessibility rules, provides guidance, explanations, and instructions for the student. The user is in complete control of the tutorial and can navigate back and forth between the slides as desired. Figure 1 shows slide 10 of the tutorial as it appears in the browser. The panel on the right-hand side displays the outline of the tutorial or thumbs of the slides, while the notes contain the transcript of the narration. The different elements of the tutorial are introduced below in detail.

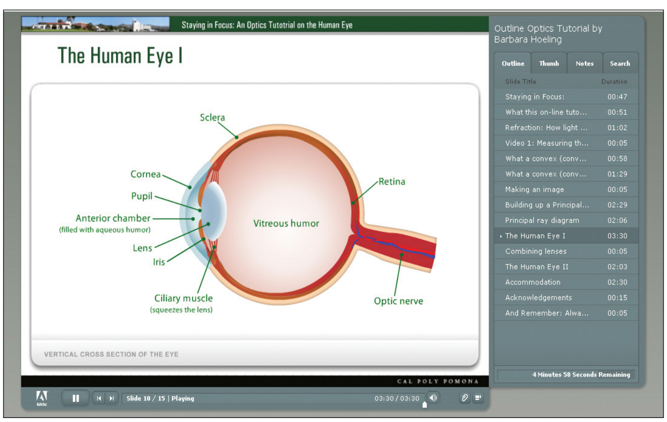

Fig. 1. Slide 10 of the tutorial, displaying an animated graphical depiction of the eye. On the right-hand side, the user can choose between four tabs: outline, thumb, notes (the transcript of the narration), and search. The labels for the different parts of the eye pop up as they are discussed in the narration.

Fig. 2. A still image of video 1: Measuring the focal length of a convex lens using the sunlight and a ruler.

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• *Slides with graphics*

The slides with graphics or photos and narration are meant to give the students the background information necessary to understand the activities performed in the videos. For example, the first slide shows photos demonstrating the concept of refraction. Other slides display schematics with descriptions, such as the one in Fig. 1 introducing the structure of the eye. Synchronous with the narration, the labels for the different parts of the eye pop up.

• *Videos*

Three videos show the instructor perform activities with lenses using very simple and inexpensive equipment. In the first one, taped outside in the sunlight, the concept of the focal point of a convex lens is demonstrated. Figure 2 is a still image of the video where I measure the focal length of a convex lens. I also point out that a "thicker" (higher curvature) convex lens has a shorter focal length, and show that a concave lens spreads out the light rather than bundling it. To demonstrate that caution has to be used when doing this activity in the sunlight and to amuse the viewers, I then use the convex lens to set the board on fire and produce a little smoke.

The second video shows how you can produce an image with a convex lens, using a flashlight as a light source, a cut-out arrow as an image, putty for a lens holder, and a white sheet of paper attached to a box or book as a screen. This activity will prepare the student for an understanding of the function of the eye and help him or her to identify the parts of the eye with the objects used in the experiment. In the third video, I demonstrate what happens when two lenses are used in combination. This provides a model for the correction of vision problems.

• *Interactive animations*

The interactive animations allow the students to perform virtual experiments and to explore "hands on" the presented concepts. The first one shows several parallel rays incident on a convex lens and converging in the focal point. The user can move the mouse to squeeze the lens and observe how the focal length shortens when the lens becomes thicker. The second interactive animation uses the principal ray diagram that has been constructed in a previous slide. The student can move the object, a candle, with the mouse (from very far away from the lens to almost the focal point) and observe what happens to the position and size of the image. Vision correction with lenses can be explored in the third interactive animation. Parallel rays are incident on a normal sighted eye and are converging on the retina. A nearsighted or far-sighted eye can also be selected instead, and it can be combined with a convex or a concave lens, or no lens at all, to correct the vision problem. Figure 3 shows the fourth interactive animation, which demonstrates the distance accommodation of the eye. It also shows a principal ray diagram, but this time the screen's position is fixed, like the retina in the eye. Students can move the object with the mouse, and as they bring it closer to the eye, the lens automatically becomes thicker such that the image on the screen is always in focus. This simulates the combined reaction of the brain and the ciliary muscle squeezing the lens as we bring an object closer to our eyes to see a larger image of it.

Results of student learning

In spring quarter 2008, the optics tutorial was used at Cal Poly Pomona by four instructors in six different sections of the freshman laboratory Phy132 as an optional tool to prepare for the "thin lenses" experiment. In the corresponding lecture Phy132, optics is not covered due to time constraints, and the students are exposed to the subject only in one of the lab experiments. They were asked to take an eight-question multiple-choice pre-test, then study the optics tutorial on their own, and finally take a post-test (which consisted of the same eight questions). A total of 98 students completed both

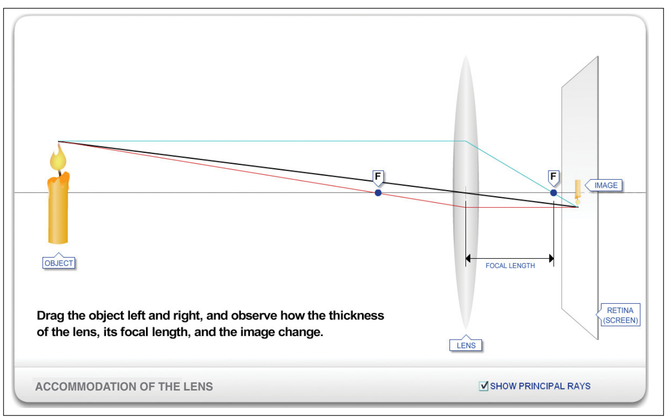

Fig. 3. Interactive animation demonstrating the distance accommodation of the eye. When the student drags the object to the left or right, the thickness of the lens adjusts such that the image is always focused on the screen (i.e., the retina).

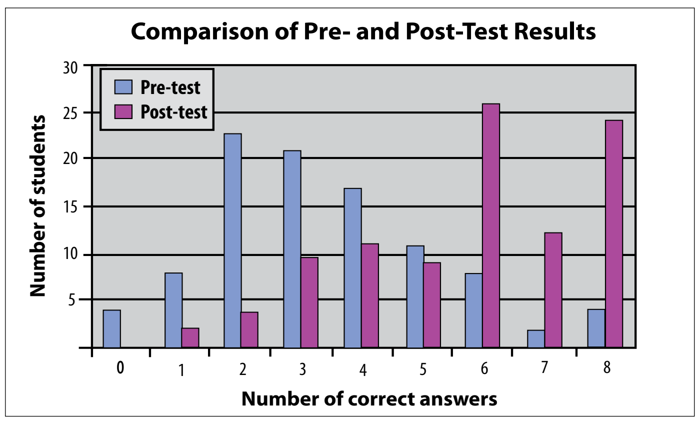

Fig. 4. Histogram of the number of correctly answered questions for pre- and post-test.

pre- and post-test and received participation credit for it from their instructors. Figure 4 is a histogram of the number of correctly answered questions for both the pre- and the post-test. It clearly shows that the number of correct answers increases significantly from pre- to post-test, with the average rising from 3.4 to 5.7. The learning results for future elementary school teachers look very similar.

In an anonymous survey that 39 of our students completed, the optics tutorial received overwhelmingly positive marks. Eight-five percent agreed or strongly agreed that it was useful for the preparation of the thin lenses lab, and about as many (84%) thought that studying the optics tutorial was more interesting than reading the corresponding chapter in the textbook. In particular, 90% agreed or strongly agreed that the interactive animations helped them understand the material better than the textbook. Finally, students were asked: "Do you have any comments or suggestions for improvement of the optics tutorial?" Some of their answers were quite enthusiastic ("Had a great time learning in this format." "Perfect!! Better than the class lectures!"). Several students pointed out that the tutorial made understanding the unfamiliar subject of optics easy, and that they enjoyed this way of learning.

Given these positive student reactions and the encouraging test results, we believe that the online optics tutorials can make a useful contribution to student learning in the preparation of lab experiments, as an enrichment and addition to the physics lecture, and as a self-study tool for the education of science teachers. In particular, the interactive animations encourage the user to become an active learner and explorer even in the theoretical study of the subject, a goal that is difficult to achieve in a conventional lecture. Perhaps most importantly, today's students, who typically spend considerable amounts of their time on computer games and other online activities, are very familiar with this online interactive format and find working with it more appealing than studying a textbook.

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