Active learning environment with lenses in geometric optics

Güner TURAL

Ondokuz Mayıs University Faculty of Education, Secondary Sci and Math Educ Kurupelit Campus 55139 SAMSUN, TURKEY

E-mail: guner.tural61@gmail.com

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Contents

Abstract

Geometric optics is one of the difficult topics for students within physics discipline. Students learn better via student-centered active learning environments than the teacher-centered learning environments. So this study aimed to present a guide for middle school teachers to teach lenses in geometric optics via active learning environment including hands-on activities. Teachers and students' views were taken about the activities via opinion form. The results showed that teachers and students found the activities instructive, motivating and interesting.

Keywords: geometric optics, active learning environment, lenses

Introduction

Students find the topic of geometric optics to be obscure and difficult (Galili & Hazan, 2000). Studies show students have learning difficulties with lenses in geometric optics (Galili, 1996; Galili, Bendall, & Goldberg, 1993; Galili & Hazan, 2000; Goldberg & Bendall, 1992; Goldberg & MacDermott, 1987). Galili, Bendall and Goldberg (1993) carried out a detailed research to investigate the knowledge about image formation of students in geometric optics. The twenty-seven students were enrolled in a section of an activity-based physics course designed for students preparing to teach in elementary school. The following topics were discussed in class: light and illumination, shadows and pinhole patterns of light, reflection and image formation by plane mirrors, refraction and distortion of objects viewed through transparent materials, and image formation by converging lenses. Students were interviewed indivually after they completed a unit. The findings showed that students had incomplete formal understanding of the process of image formation. The diagrams of students about image formation by a converging lens were incomplete representations. It was concluded that alternative instructional strategies and/or more instructional time might be needed to help students achieve a formal understanding of image formation. To overcome these learning difficulties, new learning materials and active learning environments should be developed. Active learning environments for students occur in an activity, in a group, in pairs, or alone. Students review and reflect upon the activity, and the teacher acts as a facilitator to encourage the students to apply their learning to their own situation (Anderson & De Silva, 2007). Research indicates students, who are actively involved in their learning tasks, enhance their retention of concepts (Cherney, 2008; Taraban, Box, Myers, Pollard & Bowen, 2007) and ensure better acquisition of scientific concepts than traditional instruction (Acar Sesen & Tarhan, 2011; Aydede & Matyar, 2009; Shieh, Chang &Tang, 2010; Taraban, Box, Myers, Pollard & Bowen, 2007). Designing an inquiry learning environment around how an optical system forms images may be an ideal method to overcome learning difficulties relating to optics' concepts.

Students use their existing prior knowledge as a reference when constructing new information. So, primary and middle school education has an important place in science learning. Studies (Chang, 2001; Zoller & Pushkin, 2007) show traditional science learning practices are not effective to promote higher order cognitive skills. Constructing knowledge and effective learning requires active participation by the learners. The student-centered learning environment in which students actively engage hands-on activities supports a deeper knowledge (Marx et al., 2004; Singer, Marx, Krajcik, & Chambers, 2000). Also studies report that such hands-on activities attract students' interest and enhance their motivation (Holstermann, Grube, & Bögeholz, 2010; Tuan, Chin, Tsai, & Cheng, 2005; Wen-jin, Chia-ju, & Shi-an, 2012). For example; Wen-jin, Chia-ju, and Shi-an (2012) investigated the effect different hands-on activities on female students' learning motivation towards science. Five hundred female students filled out the learning motivation scale before and after exercising hands-on activities. The results showed that all types of hands-on activities in this study could promote female students' learning motivation towards science. Also, hands-on activities about daily life issues could better promote female students' learning motivation toward science than the others. Hence, in the following it is suggested an active instructional application, involving a series of simple and inexpensive hands-on activities is needed to learn about optical lenses at the middle school level. With this step-by-step active learning environment, it is thought that students would distinguish the two types of lenses during the first step. The students will learn properties of converging and diverging lenses in the second step. They will observe application of optical lenses to cure eye defects in the third step. Finally, they will explore image formation via making a refracting telescope.

The present paper aimed to present a guide for middle school teachers to teach lenses in geometric optics via active learning environment including low cost hands-on activities.

Optical lenses in life

The optical lenses in human eye

Lenses of the eye are thicker in the center than at the edges. Therefore, they are positive and converging, and form a real, inverted image on the retina. The image on the retina is formed by two lenses: the cornea and the crystalline lens (Levine, 2001). The cornea is responsible for two-thirds of the focusing, and the crystalline lens does the fine focusing. Light rays are refracted by the cornea and the crystalline lens. The image is formed on the retina and is upside down or inverted. Visual cortex in the brain inverts the image back to normal (Maheshwari & Williams, 2001).

The optical lenses for eye defects

The optical lenses are widely used in the correction of eye defects. One of the common eye defect is myopia (near-sightedness). Myopia is inability of the eye to see a distant object. A myopic eye has more than necessary refracting power and so light rays from a distant object focus in front of the retina. Diverging lens is used for the cure of myopia as to refocus light rays from far distances onto the retina (Maheshwari & Williams, 2001). Another common eye defect is hyperopia (far-sightedness). Hyperopia is inability of the eye to see a nearby object. The hyperopic eye has too little converging power than necessary and the images of nearby objects are focused at a location behind the retina. Converging lens is used for the cure of hyperopia to move the hyperopic near and far points inward (Maheshwari & Williams, 2001).

The optical lenses in instruments

The optical lenses are used in many instruments as camera, projector, microscope, telescope, binoculars and etc. in our life. Students will be more interested in this physics topic if they discover optical lenses have wide application field in daily life. So below activities as refraction of light by lens in our eye, using of optical lenses to cure eye defects, refraction of light in a camera and making a refracting telescope will draw students' attention.

Methodology

Researcher examined the lens topic in current science textbooks in Turkey. And it was determined that the activities in textbooks are not enough for students to learn the subject in-depth and to relate with daily life.

Six science teachers from three cities were also consulted about the current textbooks and the activities prepared by the researcher. Evaluations of teachers were taken with the opinion form which consists of three questions. The questions were: 1. *Do you find activities related to the lenses in the present textbooks enough for students to understand the topic and to be able to relate with daily life? Please explain.* 2. *What are your views on researcher's proposed activities in terms of taking place in the textbook or teachers' guide book?* 3. *Can you evaluate researcher's activities in terms of students' understanding the topic and their motivations?*

Activities prepared by the researcher were applied by a middle school science teacher in his class during the lens topic. After the topic was completed, views of seven voluntary students from class were taken about the activities they did relating to lenses with the opinion form. The question in the form was: *What are your views on activities you applied for lens topic?*

Guide for middle school teachers about lenses in geometric optics

Divide the students into groups of two or three students to perform the following activities. Also, ask them to discuss what's happening during these activities. You can use predict, observe, and explain (POE) strategy developed by White and Gunstone (1992) as previous studies (Hsu, Tsai, & Liang, 2011; Radovanović & Sliško, 2013; Rakkapao, Pengpan, Srikeaw, & Prasitpong, 2014) have reported positive outcomes in learning physics topics via this strategy. During following activities, the students can be asked to predict what will happen during activity, observe what they see, and explain reconciliation and conflict between their prediction and observation.

Discrimination of converging and diverging lenses

In this activity, students will distinguish the two types of lenses by looking at the thickness of their center and the edges. Students will observe converging lenses are thicker in the middle than at the edges, while diverging lenses are thicker at the edges than in the middle.

Apparatus

- Converging lens types
- Diverging lens types

Activity

- ➢ Provide converging and diverging lens types to all groups and tell them to distinguish them.
- ➢ Ask students to place the lenses between their thumbs and forefingers, and run their fingers from the center of the lenses to their edges.

Properties of lenses

In this activity, students will explore the properties of converging and diverging lenses.

Apparatus

- Hand-held laser pointer (not exceed 1 mW output) or flashlight and plastic comb
- Converging lens
- Diverging lens

Safety precautions: For these activities Class 1 (not exceed 1 mW output) hand-held laser pointer should be used as a training aid. Class 1 lasers the output power is below the level at which it is believed eye damage will occur. Exposure to the beam of a Class 1 laser will not result in eye injury. Class 1 lasers may therefore be considered safe (Public Health England, 2010). However before beginning the activity, please warn your students about laser pointers. Tell them never look directly into a laser pointer and never direct it towards another person. Do not give hand-held laser pointer to students just in case and you apply below activities that require the use of a laser pointer.

❖Refractions by converging and diverging lenses can be observed better via laser light as it doesn't scatter and moves in a straight line. However, if you don't have a laser pointer or don't want to use it, you can complete these activities with a flashlight and a plastic comb. You can obtain parallel rays, if you put plastic comb in front of the beam emitted from flashlight.

Activity

- ➢ First, ask students to hold a converging lens close to an object. Then, students can look through it at something a few meters from the lens. (If you have a large window in the classroom, students can focus on objects outside.)
- ➢ Ask students to repeat the procedure with a diverging lens.
- ➢ Shine the laser carefully through the lenses. Dimming the classrom lights may ensure easier observation. Starting from one end to the other end of the lenses, ask the students to observe how the paths followed by the light through converging and diverging lenses as showed below (Figures 1-2).

(a) (b) (c)

Figure 1. Activity of refraction by a converging lens

(a) (b) (c)

Figure 2. Activity of refraction by a diverging lens (a-b) and converging and diverging lenses together (c)

Finding the focal length of a lens

In this activity, students will measure the focal length of a lens.

Apparatus

- Converging lens
- Diverging lens
- White piece of paper
- Ruler
- Light source

Activity

➢ Ask students to hold the converging lens up towards the window and hold a piece of paper on the other side of the lens. Then, they move the lens closer to or farther from from the paper until a focused image of the outside or a distant object is formed on paper. Measuring the distance between the lens and the paper, they can determine the focal length of the lens.

➢ Ask students to determine the focal length of a lens using the light source. Direct students to place the converging lens on a white piece of paper and send a beam of light from the light source. After parallel rays pass through the converging lens, the point where they converge is defined as the focal point for that lens (Figure 3). Students measure the distance from the focal point to the center of the lens.

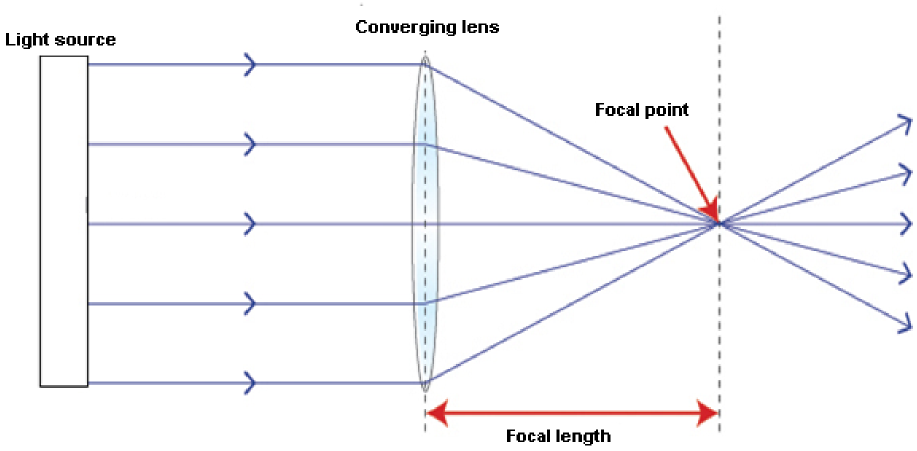


Figure 3. Refraction of light by converging lens

Ask students to repeat the procedure with a diverging lens. Students will observe when parallel rays of light pass through a diverging lens the refracted rays diverge so they appear to come from one point (Figure 4). Direct students to extend refracted rays to this point with a ruler and measure the distance from this point (focal point) to the center of the lens.

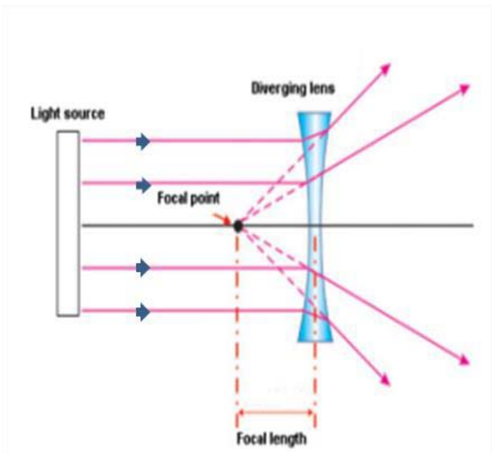


Figure 4. Refraction of light by diverging lens

Refraction of light by lens in our eye and in camera

In this activity, student will observe refraction of light by lens in our eye and function of lens in a camera.

Apparatus

- Converging lens
- Eye model figure (You can draw it easily on a white paper as Figure 5)
- Camera figure
- Light source

Activity

➢ Ask students to place the converging lens on eye model figure as shown Figure 5 and send light from the light source. Students will observe light from a distant object focus on the retina for healty eyes.

(a) (b)

Figure 5. Refraction of light (from flashlight (a) and laser pointer (b)) in healty eyes

➢ Ask students to repeat the procedure with a camera figure (Figure 6).

➢ Tell students the structure and opereation of a camera is very similar to human eye.

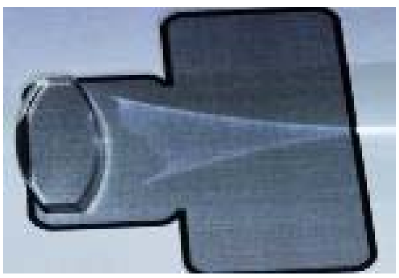


Figure 6. Refraction of light in a camera

Optical lenses to cure eye defects

In this activity, student will observe eye defects and functions of lenses to cure them.

Apparatus

- Two converging lenses
- One diverging lens
- Eye model figure
- Light source

Activity

➢ Ask students to place the converging lens on eye model figure (eyeball is taller than normal eye figure) as shown Figure 7 and send light from the light source. Students will observe light from a distant object focus in front of the retina for a myopic eye.

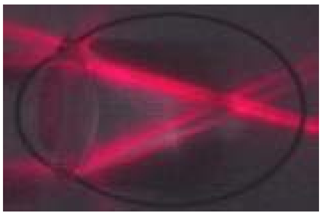


Figure 7. Light focusing for a myopic eye

➢ Ask students to place the diverging lens in front of converging lens (eye lens) as shown Figure 8 and send light from the light source. Students will observe light from a distant object focus on retina.

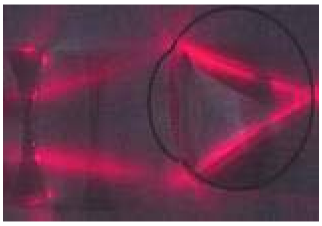
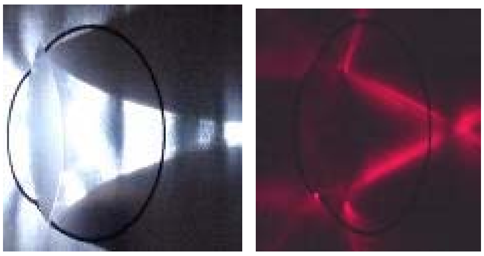


Figure 8. Cure myopic eye via diverging lens

➢ Ask students to place the converging lens on eye model figure (eyeball is shorter than normal eye figure) as shown Figure 9 and send light from the light source. Students will observe light from a distant object focus behind of the retina for a hyperopic eye.



(a) (b)

Figure 9. Light focusing (from flashlight (a) and laser pointer (b)) for a hyperopic eye

➢ Ask students to place the converging lens in front of eye lens as shown Figure 10 and send light from the light source. Students will observe light from a distant object focus on retina.

Figure 10. Cure hyperopic eye via converging lens

Making a refracting telescope

From this activity, students will learn the functions of two lenses when they use them together in a refracting telescope. To build a refracting telescope which is made inexpensive and easy-to-find materials also with adjustable focus will be useful for teachers and students.

Apparatus

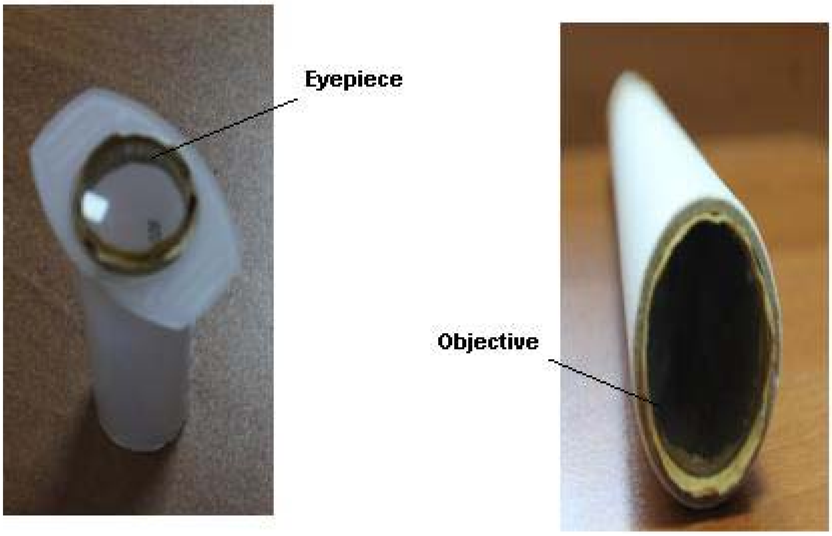
- A cardboard tube (aluminium foil roll helps, if it is long)
- A 50 ml injector
- Two converging lenses of differing focal lengths
  (one width is according to the cardboard tube for the objective, the other width is according to the injector for the eyepiece). Lenses can be obtained from an optician.
- Duct tape
- Black wrapping paper

Figure 11. Apparatus for refracting telescope

Activity

➢ Direct students to tape around the little lens and to place in injector as shown on the right side image Figure 12(a)). Now, the eyepiece for the telescope is ready.

➢ Ask students to repeat the procedure for the big lens to place inside the cardboard tube (Figure 12(b)). This is the objective of the telescope.



(a) (b)

Figure 12. Eyepiece and objective parts of refracting telescope

- Show students how to insert injector into the cardboard tube.
- Ask students to wrap the cardboard tube and injector with black wrapping paper.
- Now the refracting telescope is ready (Figures 13(a) and (b)).
- Direct students to focus on a distant object and to slide the injector tube in the cardboard tube slightly to ensure the image comes into focus.
- Tell students they can also observe the moon and stars at night.
- Warn students never look at the sun through the telescope since it causes serious eye damage.

(a) (b)

Figure 13. The final version of the refracting telescope

➢ Students may have difficulty understanding the function of the lenses in a refracting telescope. To support this activity and to visualize what is happening inside a refracting telescope you can draw below figure. Also tell students how a refracting telescope works on the figure. Tell them the objective lens collects light from a distant object and brings it to focus. This lens creates a real image of the object. The eyepiece lens magnifies the image created by the objective lens.

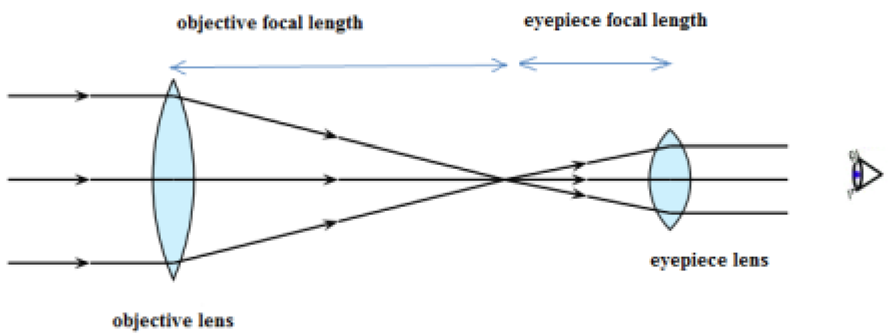


Figure 14. Basic optics of a refracting telescope

Results

In this part, views about activities obtained from science teachers and students were given.

Results obtained from science teachers' views

Q1: Do you find activities related to the lenses in the present textbooks enough for students to understand the topic and to be able to relate with daily life? Please explain.

T1: The activities students can associate concepts with daily life are insufficient. It is not possible associate topic with daily life with a few activites.

T2: Students have difficult in learning topic of lenses. Activities are not enough. They are learning convex and concave lenses as memorization.

T3: Activities are insufficient about association the topic of lenses with daily life.

T4: In textbooks there are only two activities on refraction of light and the focal point of lenses. Activities and visuals are not enough.

T5: There are fewer activities. Students have difficulty in understanding this topic.

T6: Students cannot adequately comprehend what they don't see concretely, although they appear ready for abstract concepts in these education levels (aged 12-14). And they do not associate with daily life. In this sense, it is important to increase the activities in the textbook.

Q2: What are your views on researcher's proposed activities in terms of taking place in the textbook or teachers' guide book?

T1: The topic will become more concrete with researcher's activities. Students will be aware of the usage areas of the lenses in everyday life.
T2: Students confuse lens types and their functions. They can distinguish lenses from each other with these activities and connect with everyday life.
T3: Such activities make students active will help to concretize the concepts. They will draw attention students to the topic.
T4: Students' textbooks and teachers guide book should be supported with such activities students can do easily.
T5: Such activities students and teachers can do easily should take place in textbooks. Especially activities related usage areas of the lenses.?
T6: Textbooks and teachers' guide books including researcher's activities will allow students and teachers concretize the concepts better.

Q3: Can you evaluate researcher's activities in terms of students' understanding the topic and their motivations?

T1: I do not find enough activities in present textbooks. Students forget concepts quickly. These activities show treatment of eye defects, usage of lenses in camera and the telescope will be effective in concrete and permanent learning. I think it will increase the motivation of students.
T2: These activities will attract students' interest. They will increase students' motivations. I think permanent learning will be provided as associating the lenses with daily life.
T3: These activities will make students eager to learn. Learning will be more permanent.
T4: There will be more permanent and understandable learning environment. These activities will draw students' attention and so they will be more motivated for lesson.
T5: Students will understand the topic more easily with these activities and so their motivation will increase.
T6: Students will understand the topic better as they are active during activities and it will be difficult to forget. They will be highly motivated as they are active in lesson. They will be able to relate more links with topic and daily life.

Results obtained from students' views

Q: What are your views on activities you applied for lens topic in your classroom?

S1: I learned more knowledge about lenses. Activities were quite amusing. I saw usage areas of the lenses.

S2: Converging lens collected the light but diverging one scattered it. Activites were challenging but amusing. I saw functions of lenses to cure eye defects. I learned how to use the lenses in our lives in many places.

S3: We began to course with curiosity. I could not understand well with lecture method. With activities I could see what happen. And I think permanent learning occurred. Also this course was amusing.

S4: I learned that we use lenses in many places. Activities were interesting. I learned the topic better. My interest in science has increased through this activities.

S5: Activities provided curiosity to topic. They motivated me to course. So I learned the topic better. I saw that the lenses make our lives easier in a sense.

S6: I saw that the lens has an important place in human life. Camera, glasses, telescope and etc. I learned the topic better with activities and also they were amusing. Now I'm showing more interest in science course.

S7: I learned more information about functions of the lenses through activities. I learned where the lenses are used and I began to share my knowledge to people in my environment. To see where the lenses are used impressed me in a positive way.

Discussion and Conclusion

The results showed that science teachers don't find activities enough relating to lenses in the present middle school textbook. Also they stated that these activities are insufficient for students to associate concepts with daily life. And they suggested to use researcher's activities to attract students' interest and to motivate them to topic and science. They stated that the activities will contribute students to relate more links with lenses and daily life and understand the topic more easily. The present study has provided science educators a series hands of activities to guide them for teaching middle school students the basic principles of lenses in geometric optics. Sometimes, under the right conditions lecturing could be an effective method for students learning however wholesale lecturing method is not effective means of getting the majority of students engaged in constructing knowledge during class time (Mestre, 2001). Above suggested student-centered learning environment including hands-on activities supports students doing and discussing physics. Instructional approaches allow students discussing physics, doing physics, teaching each other physics and offering problem solution strategies for evaluation by peers will facilitate the construction of physics knowledge (Mestre, 2001). Also students need to be well motivated for learning physics as other disciplines. It is thought that providing students such a student-centered learning environment they do activities and design a refracting telescope as an optical system will help to motivate students for learning the topic. Students' views after application of these activities in a class during the lens topic showed that activities were amusing for them. They stated activities motivated them to science and attracted their interest in science. This result of the research is consistent previous ones (Holstermann, Grube, & Bögeholz, 2010; Tuan, Chin, Tsai, & Cheng, 2005; Wen-jin, Chia-ju, & Shi-an, 2012) on this topic. According to results of students' views, they learned the topic better and be able to relate with daily life via activities. Using hands-on activities on this topic seemed to support motivation, interest and learning. Further research may be able to identify how influential these activities in academic achievement really are.

References

Acar Sesen, B., & Tarhan, L. (2011). Active-learning versus teacher-centered ınstruction for learning acids and bases. *Research in Science & Technological Education*,*29*(2), 205-226.

Anderson, M., & De Silva, S. (2007). *Active Learning*. UK: Me-and-Us.

Aydede, M. N., & Matyar, F. (2009). The effect of active learning approach in science teaching on cognitive level of student achievement. *Journal of Turkish Science Education*, *6*(1), 115-127.

Chang, C. Y. (2001). Comparing the impacts of a problem-based computer-assisted instructionand the direct-interactive teaching method on student science achievement.*Journal of Science Education and Technology*, *10*(2), 147-153.

Cherney, I. D. (2008). The effects of active learning on students' memories for course content. *Active Learning in Higher Education*, *9*(2), 152-171.

Galili, I. (1996). Students' conceptual change in geometrical optics.*International Journal of Science Education*, *18*(7), 847–868.

Galili, I., Bendall, S., & Goldberg, F. (1993). The effects of prior knowledge and instruction on understanding image formation. *Journal of Research in Science Teaching*,*30*(3), 271–301.

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: Interpretation, structure and analysis. *International Journal of Science Education*, *22*(1), 57-88.

Goldberg, F. M., & Bendall, S. (1992). Computer-video-based tutorials in geometrical optics. In R. Duit F. Goldberg & H Niedderer (Eds.), *Research in Physics Learning: Theoretical Issues and Empirical Studies* (pp.356–379). Kiel: IPN.

Goldberg, F., & MacDermott, L. C. (1987). An investigation of student understanding of the real image formed by a converging lens or concave mirror. *American Journal of Physics*, *55*(2), 108–119.

Holstermann, N., Grube, D., Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education*, *40*, 743-757.

Hsu, C. Y., Tsai, C. C., & Liang, J. C. (2011). Facilitating preschoolers' scientific knowledge construction via computer games regarding light and shadow: The effect of the prediction-observation-explanation (POE) strategy. *Journal of Science Education and Technology*, *20*(5), 482-493.

Levine, J. (2001). Retrieved Retrieved March 5, 2014, from http://www.colorado.edu/physics/phys1230/phys1230_fa01/topic36.html .

Maheshwari, A., & Williams, D. R. (2001). Learning optics using vision. Biomedical Engineering Center for Visual Science University of Rochester Rochester, NY. Retrieved March 5, 2014, from http://www.cfao.ucolick.org/EO/Resources/Learn_optics_AO.pdf .

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier,R., & Tal, R. T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching*, *41*, 1063-1080.

Mestre, J. P. (2001). Implications of research on learning for the education of prospective science and physics teachers. *Physics Education, 36* (1), 44-51.

Public Health England (2010). Retrieved February 26, 2014, from http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733794576#classes.

Radovanović,J., & Sliško, J. (2013). Applying a predict–observe–explain sequence in teaching of buoyant force. *Physics Education, 48* (1), 28-34.

Rakkapao, S., Pengpan, T., Srikeaw, S., & Prasitpong, S. (2014). Evaluation of POE and instructor-led problem-solving approaches integrated into force and motion lecture classes using a model analysis technique. *European Journal of Physics*, *35*, 1-10.

Shieh, R. S., Chang, W., & Tang, J. (2010). The impact of implementing technology-enabled active learning (TEAL) in university physics in Taiwan. *Asia Pacific-Education Researcher*, *19*(3), 401-415.

Singer, J., Marx, R. W., Krajcik, J. S., & Chambers, J. C. (2000). Constructing extended inquiry projects: Curriculum materials for science education. *Educational Psychologist*, *35*, 1-23.

Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes and behaviours in high school biology. *Journal of Research in Science*, *44*(7), 960-979.

Tuan, H. L., Chin, C. C., Tsai, C. C. & Cheng S. F. (2005). Investigating the effectiveness of inquirym instruction on the motivation of different learning styles students.*International Journal of Science and Mathematics Education*, *3*, 541–566.

Wen-jin,K., Chia-ju, L., & Shi-an, L. (2012). Promoting female students' learning motivation towards science by exercising hands-on activities. *US-China Education Review B, 2*(6), 572-577.

White, R., & Gunstone, R. (1992). *Probing Understanding*. New York: Falmer Press.

Zoller, U., & Pushkin, D. (2007). Matching higher-order cognitive skills (HOCS) promotion goals with problem-based laboratory practice in a freshman organic chemistry course. *Chemistry Education Research and Practice, 8*(2), 153-171.