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Student's misunderstanding in using a ray diagram in light refraction

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This paper shows the results of an investigation in conceptual understanding of light refraction of 261 Thai high- school students. The students of grades 11-12 were asked to explain a simple refraction phenomenon. They were asked to draw a ray diagram to indicate the position of an image of a light bulb which was located under the water. The results from the investigation were very surprising. Most of the students could not apply the refraction principles to explain the real world situation. Moreover, even if they have studied simple geometrical optics they still had misunderstanding in drawing rays according to refraction principles. Although this investigation was conducted at four different Thai high schools, when we categorize their answers, the tendency was similar. These results make us realize that Thai high school students still have naive knowledge in geometrical optics and refraction.

1. INTRODUCTION

Even if we can see light phenomena every day, it does not mean that teachers can make all students understand all light phenomena. Refraction and reflection actually are the first basic topics which students study in secondary school in Thailand. In 1985, Watts [1] interviewed a 14 year old student for a case study about the nature of light and optics instrument system. He found that the student described light in different forms, such as electric, ultraviolet or radioactive. Goldberg and McDermott [2] investigated students' understanding about real image formed by a converging lens and a concave mirror by using individual interview. They found that many students lacked understanding in the role of eyes and in using a ray diagram to identify an image position. In 1986, Goldberg and McDermott [3] surveyed students' understanding about an image formation by a plane mirror by using individual interview. They found that their students did not think that the mirror as a reflecting surface. They believed that an observer can see an image only if it lies along their line of sight to the objects. This paper suggested some strategies for teaching in the class. In 1992, Feher and Rice [4] used a clinic interview to investigate conceptions of 110 children who came to science museum (9-13 years old) about light and vision. The students were asked to predict a light pattern on the screen. Light source were two crossed perpendicular fluorescent tubes which shine through different pinhole sizes. They found that children did not understand the process when light passing through a pinhole and the image formation.

In 1991, Saxena [5] used multiple-choice-type questions which require reasoning to support selecting choices to investigate the understanding of light properties of students in India. This research found that students could not apply a principle of reflection to explain light phenomena nor use a ray diagram to predict an image pattern on the screen. Many of the students did not consider it necessary for a light ray to enter the eye of the observer to make the object visible.

The purpose of this paper is to show the results of investigation in light refraction conception of 261 high-school students in Thailand by using the conceptual opened-end question. They were asked to use a ray diagram for indicating the position of a virtual image of an object under water.

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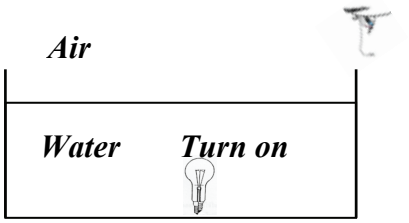
2. EXPERIMENT

We firstly designed open-ended questions by considering the contents about refraction in Thai high-school curriculum. There were many conceptual questions that we constructed and used for testing students' understanding in refraction. For this paper, we chose only the one question which let high-school students to sketch and locate an image position appeared under water by using a ray diagram. The question which was used to ask students was:

"From the picture, a light bulb is turned on at the bottom of the reservoir which contains water. Locate an apparent image of the light bulb which an observer can notice by using ray diagram."



The samples of this research were 261 Thai high-school students of grades 11-12 who already studied basic topics on geometrical optics and refraction. These students were from four different schools. All student responses were categorized and interpret by grouping the answers corresponding to the main concepts which students lacked. The main concepts which were used to categorize students' answers were:

1) We can see the object because light from each point of the object surface propagate to our eyes.

2) When light passes through two different media, it will refract at the media surface.

3) When light travels from the media that has higher refractive index to another that has lower refractive index, an incident angle is smaller than refractive angle.

According to the above main concepts, student incorrect answers were classified into 7 groups:

Group 1: Do not consider concept 1
Group 2: Do not consider concept 2
Group 3: Do not consider concept 3
Group 4: Do not know the answer
Group 5: No response
Group 6: Do not use a ray diagram

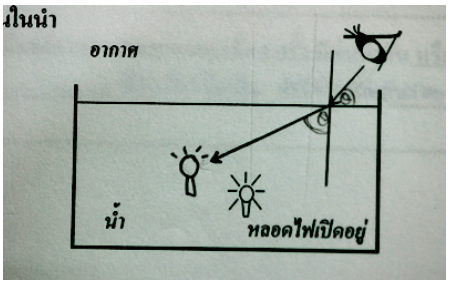


FIGURE 1. An example of group1 answer.

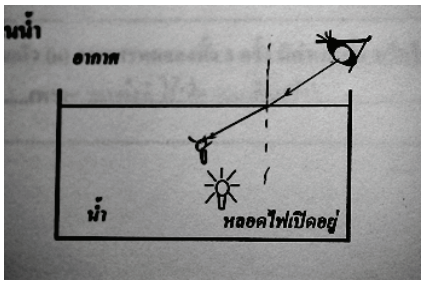


FIGURE 2. An example of group 2 answer.

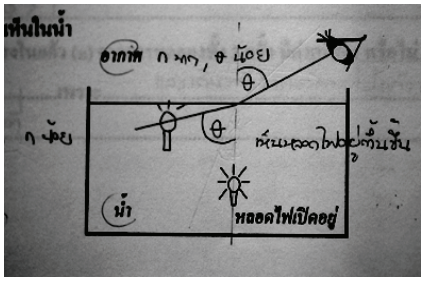


FIGURE 3. An example of group 3 answer.

Group 7: Others

Note that in group 4, students wrote in the answer "I don't know the answer", while in group 5 students wrote nothing.

3. RESULTS AND DISCUSSIONS

Fig. 1-3 show some responses categorized in groups 1, 2 and 3, respectively. The percentage of students giving answer in each group is summarized in table 1. It can be seen in table 1 that most students lacked knowledges in using a ray diagram to explain refraction phenomena. See the fig. 1, many of them (47%) did not consider that it is necessary for a light ray to enter the eye of an observer to make the object visible, they thought that light travels from their eyes to the object. Besides, some of them (18%) did not realize that when a light ray passes through two different media it will refract. In this case they only drew a straight line of a light ray at a conjunction surface of those media (see fig. 2). Moreover, 47% of the students did not know the relationship between the incident angle and the refractive angle of light at the media connection. They were confused about the size of incident angle and refractive angle. For group 6, 8% of students usually drew only a virtual image of the object but did not use a ray diagram to explain their answers. Group 7 was an interesting group because they (14%) used other principles to explain their answers such as reflection, total reflection, etc. Most students usually were in group1, group 2 and group 3, it is very surprise that there is only one student who considered all three main

TABLE 1. Percentage of student giving answer in each group.

Group	Number of students
Group 1	47%
Group 2	18%
Group 3	47%
Group 4	8%
Group 5	5%
Group 6	8%
Group 7	14%

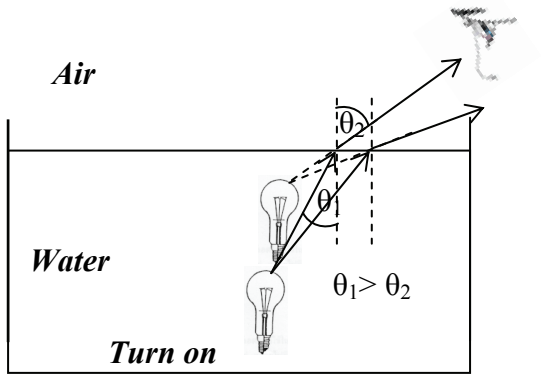


FIGURE 4. A correct answer.

concepts but the position of an apparent image which he located was incorrect position. The correct answers is shown in fig. 4. It is necessary for drawing at least two rays to identify the position of an apparent image of the light bulb. The location of an apparent image is above and toward an observer

From all results, it indicates that most of the students did not have a deep understanding in refraction and light perception. They could not apply those principles to present their idea and solve the problem. This problem Knight [6] suggested that a teacher should invite their students to have real experiences by demonstration or let them to have hands-on activities. It can help students to have better understanding in light refraction.

4. CONCLUSION AND DISCUSSIONS

Most students still lacked knowledge in using a ray diagram to explain refraction phenomena. The two main concepts that most of the students missed were the propagation of light from the object to observer's eyes and the law of refraction. The results presented in this paper are critical evidences which might reflect physics teaching in Thailand. It is important for physics teacher to improve a teaching process and help students for better understanding. At present we are constructing the learning a module and learning media in light refraction based on the results reported here. It is hope that the learning module would be able to enhance students conceptual understanding and would be suitable for Thai high school students.

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