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Misconceptions among University Students Regarding Convex Lenses Caused by the Drawing Method at Junior High Schools

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Abstract

In Japanese junior high schools, when studying convex lenses, first graders learn that the distance between the lens and an object is closely connected with its image. In order to help students understand this phenomenon, the drawing method is used in junior high schools. However, it has been indicated that learning by this method does not necessarily lead to an understanding of the properties of the convex lens itself. In order to determine the misconceptions caused by the drawing method used in junior high school lens lessons, we used a naive concept survey method, studying 104 university students in Japan (68 from the Faculty of Science and Engineering and 36 from the Faculty of Sociology). We asked students about the path followed by the incident light when passing through a convex lens. The results showed that many university students have misconceptions concerning the path of the incident light passing through a convex lens. By examining students' descriptions in the survey regarding their understanding of the lens, we found that their misconceptions might be caused by the influence of the drawing method used in junior high school lens lessons. The students could not understand the properties of the lens in connection with the phenomenon of refraction, which plays an important role in the study of optical lenses.

Keywords: *misconception, convex lens, junior high school, teaching method*

1. Introduction

In Japanese junior high schools, when studying convex lenses, first graders learn that the distance between the lens and an object is closely connected with its image. In order to help students understand this phenomenon, the drawing method is used in junior high schools. The incident light path drawn by this method shows the light refract only at the center of the lens, while in reality it refracts twice, when entering and exiting the lens.

We administered a naive survey to university students in Japan to ask them about the path followed by the incident light when passing through the convex lens.

The survey results showed that the students could not understand the properties of the lens through the phenomenon of refraction, and that the drawing method used in junior high school lens lessons can cause misconceptions. In the following sections, we report the survey results and considerations.

2. Purpose of study

This study aims to determine how and why misconceptions concerning the path of incident light through convex lenses occur in Japanese university students.

3. Methodology

In 2015, we used a naive concept survey method (Fig. 1) to examine 104 third-year Japanese university students (68 from the Faculty of Science and Engineering and 36 from the Faculty of Sociology). The survey asked students about the path followed by the incident light when passing through the convex lens. The question (along with the choices) are given in Fig. 1. The choices were as follows (③ is the correct answer):

Diagram ① "Refracts only when the incident light enters the lens,"
Diagram ② "Refracts only at the center of the lens,"
Diagram ③ "Refracts twice, when it enters and when it exits the lens,"
Diagram ④ "Refracts only at the exit," and
Diagram ⑤ "Not applicable to ① to ④."

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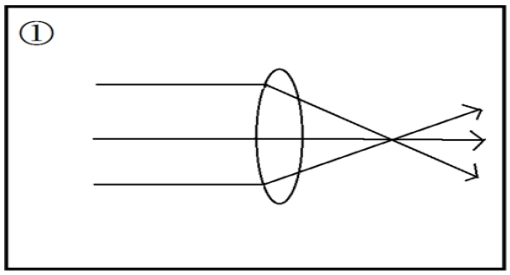
Convex lens

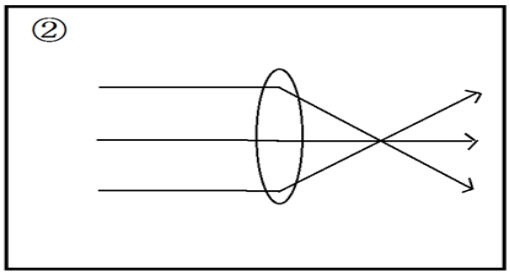
This is not a test. Please answer according to what you think.

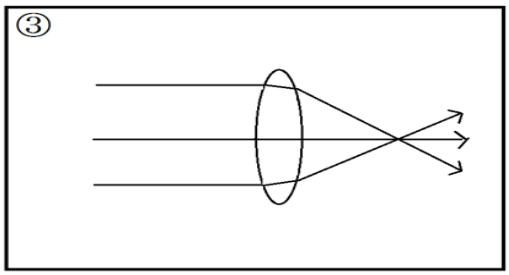
Number _____ **Name** _____

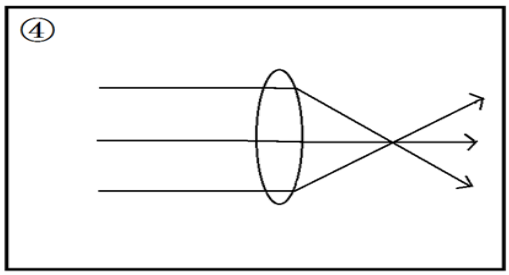
(Question) There is a convex lens. You need to determine the path that light follows when passing through the lens. Three parallel rays of light enter the convex lens. Which of the following diagrams shows the correct path that these light rays will follow when entering and exiting the lens?"

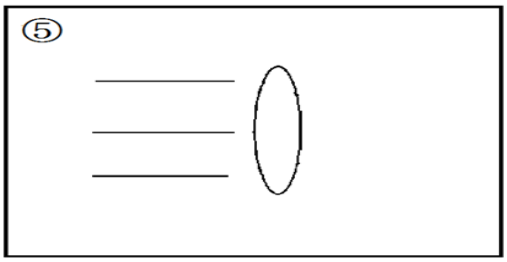
Choose the diagram that you think best represents the path that light will follow. If you think none of the choices (① to ④) is correct, then please draw your answer in ⑤.











Answer	Reason for your selection

Fig. 1 Naive concept survey method

After answering, the students wrote their reason in the space provided under "Reason for your selection." If they selected ⑤, they were required to draw lines representing their answer in ⑤.

4. Results

Table 1 shows the results of the survey. The number of students who selected the correct answer ③ "Refracts twice, when it enters and when it exits the lens" was 33 (32%), while 62 students (60%) selected the wrong answer ② "Refracts only at the center of the lens." This shows that many university students have misconceptions concerning the path followed by the incident light when passing through a convex lens. Using Fisher's exact test, we examined the significance of the survey results. We found a significance level of 5%; there were significantly more students who chose ② than those who chose ③ (Table 2-A). Out of the 36 sociology students, 8 students (22%) chose the correct answer ③ (Table 1-C). On the other hand, out of the 68 science and engineering students, 25 students (37%) chose ③ (Table 1-B). Many of the science and engineering students chose the correct answer, but based on Fisher's exact test, there was no significant difference in misconceptions between students of the two faculties (Table 2-B).

The results of the analysis of students' reason for their answers (based on Fig. 1) are given in Table 3. We examined students' descriptions regarding the reason for their answers. The descriptions were

classified into three: “My own thoughts,” “Memory of learning at school,” and “No comment.” We found clear differences in students’ reason for choosing ② and ③. Among students who selected Diagram ②, many students (25) answered “Memory of learning at school,” but among those who selected Diagram ③, only a few students (3) answered “Memory of learning at school.”

Table 1. Survey results

(A)Table for all students of both faculties

N=104.

Diagram No.	Number of student	%
①	5	5%
②	62	60%
③	33	32%
④	3	3%
⑤	1	1%
Total	104	101%

(B)Table for the Faculty of Science and Engineering

N=68.

Diagram No.	Number of student	%
①	0	0%
②	42	62%
③	25	37%
④	0	0%
⑤	1	1%
Total	68	100%

(C)Table for the Faculty of Sociology

N=36.

Diagram No.	Number of student	%
①	5	14%
②	20	56%
③	8	22%
④	3	8%
⑤	0	0%
Total	36	100%

Table 2. The 2×2 cross-table for ② and ③

(A) 2 × 2 cross-table of students who answered ② and ③

N = 104.

Diagram No.	Number of students who answered	Number of remaining students
②	62	42
③	33	71

p = 0.0000 (p < .05) meaningful increase

(B) 2 × 2 cross-table of students who answered ② and ③ by fuculty

N = 95.

Diagram No.	The Faculty of Science and Engineering	The Faculty of Sociology
②	42	20
③	25	8

p= 0.4839 (p > .05)

Table 3. Students’ reasons

N=104.

Diagram No.	My own thoughts	Memory of learning at school	No comment	Number of students
①	4	1	0	5
②	33	25	4	62
③	30	3	0	33
④	2	1	0	3
⑤	1	0	0	1
Total	70	30	4	104

5. Description of lenses in junior high school textbooks

Concerning rectilinear propagation and convex lenses, elementary school third graders in Japan observe light paths by a mirror and capture sunlight using a magnifying glass. After that, in junior high school science classes, first graders study the properties of light and convex lenses, learning that the distance between the lens and an object is closely connected with its image, that is, a real image and a virtual image.

In accordance with Japanese teaching guidelines, junior high school first graders learn the nature of light as follows [1]. In junior high school science textbooks (five companies), there are descriptions regarding convex lenses in terms of focus, focal length, and real and virtual image, which are described as “the function of a convex lens.” Furthermore, in Japanese science textbooks, “focal length, real image, and virtual image” are described as “the function of a convex lens” using the drawing method (Fig. 2-A, B).

In the drawing method, the light is shown to refract at the longitudinal center of the lens. Fig. 2-A and 2-B show examples of the drawing method used in Japanese textbooks.

(A) (B)

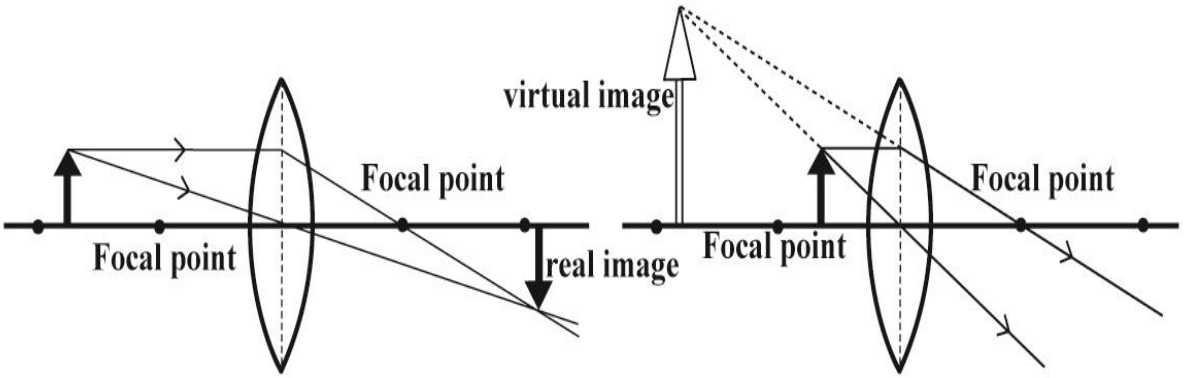


Fig. 2 The drawing method in Japanese junior high school science textbooks

Fig. 2-A represents a real image, and Fig. 2-B represents a virtual image. In this drawing method, the light ray is shown to bend at the center of the lens. All Japanese science textbooks use this method.

6. Discussion

6.1 Cause of misconception

As shown in Table 1-A and Table 2-A, Diagram ② “Refracts only at the center of the lens” (60%) was selected more than Diagram ③ “Refracts twice, when it enters and when it exits the lens” (32%). This shows that there are many students who have the misconception that light “refracts only at the center of the lens.” This is the same understanding taught by the drawing method in junior high schools (Fig. 2).

Furthermore, students’ reasons for their answers in the survey (Fig. 1) were examined to check whether there is an association between their misconception and the drawing method (Table 3). Among the 62 students who selected Diagram ②, 25 students described their reason for selection, which were as follows: “because the student learned it in a science class,” “school textbook said so,” “because the student learned in school that light refracts at the center of the lens and learned how to draw the diagram as well,” etc. These descriptions suggest that they remember the convex lens lessons and the drawing method taught in science classes, and therefore selected Diagram ② as their answer. Consequently, it was found that the drawing method plays a crucial role in students’ misconception, and that many university students have had misconceptions regarding convex lenses since junior high school. In addition, this means that junior high school science teachers do not associate “the refraction of light” (taught just before students learn about the convex lens) with convex lenses when teaching students about the nature and mechanism of the lens.

6.2 Description in textbooks and misconceptions

In all junior high school textbooks, the explanation of convex lens is as follows: “it actually refracts twice on the surface of the lens, but in the drawing method, it can be shown that the light refracts at the center of the lens.” However, this description is written in small letters, and thus most students might not notice it. As the teacher also aims to make students understand real and virtual image, it seems that the relationship between refraction and lenses is rarely explained in a science class. In class, students learn how to draw a diagram showing refraction at the center of the lens and learn about real and virtual image, and so their misconception might remain unconsciously ingrained in their memory and they might consider it a fact that light refracts at the center of lenses.

6.3 Misconceptions of students majoring in science and sociology

This study conducted a survey of students majoring in science and sociology. Since high school, students in the Faculty of Science and Engineering study more science subjects than those in the Faculty of Sociology. We verified whether there are differences in misconceptions between the two groups of students and whether they can correct them.

Tables 1-B and 1-C show the survey results of students from the two faculties. As seen in Table 2-B, there was no significant difference between students majoring in science and those majoring in sociology. We can thus infer that this is the case because even students majoring in science could not correct their misconceptions. This possibly indicates the strength of their misconceptions acquired in their junior high school science lessons.

6.4 Misconceptions with their own thoughts

As shown in Table 3, 33 students chose Diagram ② because of “My own thoughts.” These students did not mention the convex lens lessons learned at school, but expressed that they are convinced that their misconceptions are their own. To identify the reason behind this, an interview survey was conducted. The student who was interviewed did not remember studying about convex lens and its drawing method in the past, but she still intuitively chose Diagram ②. This shows that even though students forget what they have learned in school lessons about convex lenses and the drawing method, due to the past influence of the lesson, they might think that the misconceptions are their own. However, among these 33 students, there might be some students who simply did not mention the past lessons or the drawing method, and therefore, further research is necessary to identify the reason for the development of such misconceptions.

6.5 Teaching method and materials to prevent misconceptions

In junior high school textbooks for first graders, a clearer description about the path that light follows when passing through a convex lens might help prevent such misconceptions. Taga (2016) developed teaching materials showing light passing through a uranium-glass lens with fluorescence emission [2]. These materials show incident light, refracted light in a lens, and transmitted light that passes through quercus water (water-soaked acorn tree branch) and a uranium lens. We can observe refraction twice at the surface of the lens through these materials. In order to prevent misconceptions related to convex lenses, it is necessary to develop new teaching materials, new teaching methods, and textbooks with better descriptions.

Acknowledgements

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