

# Measurement of the Refractive Index with PhET

Yamato Hasegawa, *Tokyo Tech High School of Science and Technology, Tokyo 108-0023, Japan*

Kasumi Endo, *Niigata Meikun High School, Niigata 950-0116, Japan*

Ryunosuke Ozaki, *Tokyo University of Science, Tokyo 162-8601, Japan*

Hiromi Matsuoka, *Tokyo University of Science, Tokyo 162-8601, Japan*

Kosuke Nakamura, *Tokyo University of Science, Tokyo 162-8601, Japan*

Shuji Ukon, *Tokyo City University, Tokyo 158-8557, Japan*

Fumiko Okiharu, *Tokyo University of Science, Tokyo 162-8601, Japan*

**Abstract.** In distance education, we gave students the assignment of measuring the refractive index. Students watched a film on refraction between transparent material and air, and measured the refractive index from the relationship between the angle of incidence and the angle of refraction. There is a calculation of the critical angle as a means of verifying whether or not the obtained refractive index is appropriate. This time, not only the calculation of the critical angle but also the PhET simulation Bending Light was used. We discuss the effect of using PhET for verification.

## 1 Introduction

In physics, more than only one representational format is often used to convey information and support knowledge construction [1]. It is well known that the use of multiple representations can enhance learning. PhET simulations were developed to support active learning [2]. Due to the COVID-19 pandemic, Japanese universities have been forced to provide distance education. The purpose of the study was to find out how effective the use of PhET is for students on the introductory physics course at a certain university. We report on the effect of using PhET for verification in the refractive index measurement.

## 2 Research Method

### 2.1 Survey Subjects

As a part-time lecturer, one of the authors taught introductory physics classes (algebra-based physics) in the first semester of 2020 and 2021 at a certain university in the faculty of home economics. There were 66 (2020) and 38 (2021) students. The students' high school physics courses were examined. In Japanese high schools, waves traveling on a straight line are treated in basic physics, while waves traveling on a plane are treated in advanced physics. The numbers of students taking advanced physics, which includes the content of light refraction, were 16 (2020) and 4 (2021).

### 2.2 Assignment in Light Refraction

Students were asked to measure the refractive index following a film [3]. Refraction occurs when light enters a different medium. The index of refraction is the ratio of how light is refracted. Usually, the refractive index obtained can be verified by calculating the critical angle.

### 2.3 Using PhET Simulation for Verification

It is difficult for students to find the refractive index following the experimental film, as the students are unfamiliar with the index of refraction. The critical angle is calculated after the

refractive index is calculated, for verification, but this calculation is also difficult. We therefore focused on the PhET simulation Bending Light, which can verify the refraction of light by the refractive index [4]. In 2020, students used PhET for verification to measure the index of refraction, while in 2021, they were given a two-step refractive index measurement to clarify the effect of PhET. That is, it was confirmed whether the refractive index was measured correctly at the stage where PhET was not used.

### 3 Results and Conclusion

We analyzed the task evaluation of 58 (2020, with PhET), 34 (2021, first step without PhET), and 32 (2021, second step with PhET) students. From the results in Table 1, it can be seen that PhET is effective for this assignment.

Table 1. Measurement of the refractive index(2020,2021)

		2020 $N = 58$	2021 1st* $N' = 34$	2021 2nd $N'' = 32$
Measured correctly	Understanding deeply	38	9	19
	Not understanding deeply	9	11	6
Measured incorrectly		11	14	7

\* We did not suggest that students use PhET in the first 2021 assignment.

In 2020 and 2021 (second assignment), after submitting the assignment, a further questionnaire was conducted. The purpose of the questionnaire was to determine whether PhET was useful for determining the refractive index in the experimental film. It can be said that the answers show that the simulation functions very effectively when used properly for verification (Fig. 1).

By using PhET simulations, it is possible for students to verify the refractive index obtained.

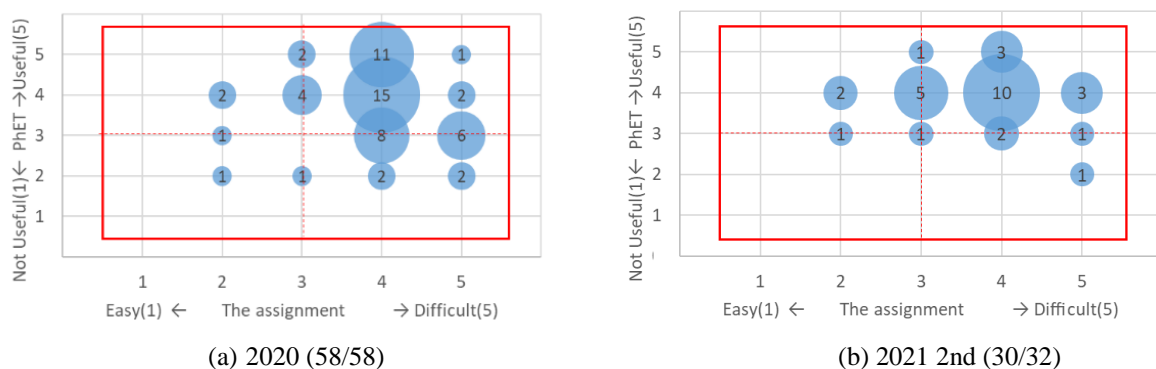


Fig. 1. Bubble chart showing questionnaire results obtained after submitting the assignment. We asked the students was the assignment difficult and was PhET useful, on a scale of 1 to 5 each.

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### References

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