Development of physical practicum tools to determine the refractive index through measurement of real depth and apparent depth

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Abstract: This study aims to develop and determine the feasibility of a physics practicum tool to determine the refractive index of fluids through measurement of apparent depth and real depth. The product development method used in this study was Research and Development (R&D) with the ADDIE model. The results of this study, the refractive index of water is \( n = (1.3158112 \pm 0.0000303) \) with a relative error of 1.07%, the refractive index for saltwater is \( n = (1.4476904 \pm 0.0000387) \) with relative error by 1.37%, the refractive index for sugar water is \( n = (1.355680 \pm 0.000145) \) with a relative error of 1.02%, and the refractive index for cooking oil is \( n = (1.4525593 \pm 0.0000694) \) with a relative error of 1.36%. The results of the feasibility test of media experts, material experts and users for practicum tools and practicum guides were 90.69% which included in the Very Good category, 94.17% which was in the Very Good category, 90.62% which was in the Very Good category. Based on the results of these percentages, the practicum tools, and the practicum guides are declared to be suitable as learning media on Optics Geometry material, especially for the determination of the refractive index with real depth and apparent depth.

1. Introduction
The problem in teaching physics, especially the refractive index material is that students have difficulty in understanding the concept, so there is a concept error because the refractive index material is abstract [1]. In this case, the lecturer uses instructional media that serves to clarify the presentation from abstract to concrete concepts. This will be a new challenge for students so that they can activate the curiosity of students to continue to dig deeper information so that students' understanding of refraction material will continue to increase [2]. Students have difficulty in taking complicated data, especially distinguishing the refraction angle and the angle of incidence, determining the scale and writing data [3].

Students must be equipped and trained on how to solve physics problems in the context of physics learning [4]. Problem-solving is an important element in learning [5]. The most important part of teaching problem-solving skills is that students must be given a problem and to solve these problems students must use a tool [6]. This opinion is in line with the research of [7], namely by using practical tools students' problem-solving abilities increase. One method of learning physics that uses tools in learning is the experimental method [8].

Laboratory activities are important things to do in learning physics because laboratory activities aspects of products and processes can be further developed [9]. The quality of physics learning
processes and outcomes is determined by many factors, one of which is the availability of laboratory facilities [10]. The implementation of physics practicum is very important in order to support learning and emphasize aspects of the process [11]. In the opinion of [12], in his research stated the facts in the university field did not utilize all the physics practicum tools available in the learning process, one of which was refraction material on liquid. This factor causes many students to experience difficulties in solving problems [13].

Learning on the light refracting material itself is usually only by using aqua glass filled with liquid and then inserted a pencil. It is only able to show refraction events but does not include the relationship between the angle of incidence, the angle of refraction, the refractive index of the medium and the perfect reflection event. As for the tools that have been developed, namely the AP-KOS developed by [14] and [15] have not been able to show the event of perfect reflection. by [16], [17], and [18] showed quite good results but still had considerable errors.

Therefore, a Mirror-assisted physics practicum tool was made and tested for the determination of the refractive index of a liquid by measuring the apparent depth and real depth of an object. The reason for choosing the research topic is to equip the Geometry Optics learning tool with pseudo-depth measurements and the real depth of an object to determine the refractive index of fluids and is expected to increase students' understanding of Optometry Geometry material.

2. Theoretical Framework

| Table 1. Refractive index value of liquid [19] |
|---|---|
| Medium                  | Refractive Index |
| Water                   | 1.333           |
| Sugar Water with 30%    | 1.37            |
| Cooking Oil             | 1.47            |
| Salt Water with 30%     | 1.46            |

The refractive index can be determined by determining the real depth and apparent depth in a medium.

![Figure 1. Real depth and apparent depth](image)

A pencil is in the water, seen from the air. From Figure 1 the following equation is obtained Snellius Law :

\[ n_1 \sin i = n_2 \sin r \] (1)

To determine the refractive index through real depth and apparent depth, where for small angles apply:

\[ i \approx \tan i \approx \sin i \]
\[ r \approx \tan r \approx \sin r \] (2)

Then,
\[ n_1 \tan i = n_2 \tan r \]  
(3)

\[ n_1 \frac{OC}{CB} = n_2 \frac{OC}{CA} \]  
(4)

\[ \frac{n_2}{n_1} = \frac{CA}{CB} \]  
(5)

So,

\[ n = \frac{CA}{CB} \]  
(6)

\( n \) is the refractive index of the medium, \( CA \) is the real depth of the object and \( CB \) is the apparent depth of the object. By combining all available theories, a practical tool was designed to determine the refractive index of fluids through measurements of real depth and apparent depth.

**Figure 2.** Refractive index practicum tools

The way the above tool works through measurement of the real depth and apparent depth of an object. Events that occur in the observation of a flat mirror for objects in the water are a refraction event as if the object is not at the bottom of the measuring cup. The real depth is measured by a ruler from the bottom of the measuring cup to the surface of the water in the measuring cup, while the apparent depth is measured by observing the height of the needle from the surface of the water in the measuring cup by aligning the shadow of the needle seen on the mirror with an object. Apparent depth is obtained because the distance of the needle's shadow from the surface of the water seen in the mirror is equal to the distance of the object in an apparent-state. In accordance with the nature of a flat mirror where the distance of the image is the same as the distance of the object. The farther the distance of the shadow, the farther the object is, the closer the object is. Through this measurement, the refractive index of the liquid is obtained by comparing the real depth and apparent depth of an object.

3. **Research Method**

The model used in this study is the ADDIE model. The ADDIE model shows the basic stages of a simple and easy to learn learning system design. According to [20] this model consists of five main phases or stages namely Analysis, Design, Development, Implementation, and Evaluation or in Indonesian the Analysis, Design, Development, Implementation, and Evaluation models. The subject in this study was an experimental tool for determining the refractive index of fluids through measurement of the real depth and pseudo depth of an object and students of the Master of Physics Education and students of semester 2, semester 6 and semester 8.

Data can be categorized into two big groups namely quantitative and qualitative data. Data obtained through an assessment questionnaire on the development of instructional media in the form of physics practicum tools to determine the refractive index of fluids through measurement of the real depth and apparent depth of an object is presented in quantitative form. For the rating of "Very Good"
given a score of 4, "Good Enough" was given a score of 3, "Good Enough" was given a score of 2 and
"Not Good" was given a score of 1. After analysis and the final results obtained in the form of a
percentage then requalified to conclude about the feasibility of the product which was developed.

4. Research Findings and Discussion

| No | Liquid          | Refractive index | Error          | Relative error |
|----|----------------|------------------|----------------|---------------|
| 1  | Water          | 1.32             | 0.0000303      | 1.07%         |
| 2  | Sugar Water    | 1.36             | 0.000145       | 1.02%         |
| 3  | Salt Water     | 1.44             | 0.0000387      | 1.37%         |
| 4  | Cooking Oil    | 1.45             | 0.0000694      | 1.36%         |

Based on table 2, the errata is caused by several factors, including the tool that was developed
initially when the red line data collection that points to the ruler is too large and does not directly point
to the number, confusing in reading the size of the ruler. Therefore, in revising the last tool, a red line
is added according to the ruler's size so that the reading is more thorough.

Accidental changes or shifts of the needle due to pounding or other movements that change the
height of the needle. For more accurate observations you need a quiet place and a table that does not shift
to reduce the vibration or pounding that occurs. Objects that are compared have different types so it is less accurate to look for a position that is parallel (coincide). Therefore, to make it easier to
observe parallel events (coincide) objects with their shadows on the developed instrument, a coin is
added to the tip of the needle. The webcam, the needle, and the object are not in the upright position of
the base, so the webcam, needle, and object must always be considered before conducting an
experiment in order to obtain accurate data.

Based on Figure 3 practicum tools and practicum guides are included in the category of Very Good
so that the practicum tools and practicum guides are declared suitable to be used as learning media on
Geometry Optics material specifically for the determination of refractive indices with real depth and
apparent depth.

Practicum guides are made with a display that is as attractive as possible, with language that is easy
to understand and clarity in graphics and graphics. The practicum guide has also been adapted to the
practicum tool so that it has become an inseparable unit. Equipped with an example analysis table so
that it makes it easy for the practitioner to analyze the data. Besides, there are questions at the end of
the guide to measure how understanding is practiced in the practicum material. This practicum guide
also uses clear references from trusted books and journals.

Some of the deficiencies found in the practicum guide made are the incompatibility of the corner
symbols in the picture with the equations and the layout of the tables and sub-chapters that are still not
quite suitable. Therefore, an improvement is made in the image by adjusting the symbols in the picture
with the equation and improving the layout of the table so that it is not cut off and improving the
writing rules of the section. Besides, there are still some errors in typing so that it can confuse the
practice, consequently, the lab guide will be difficult to understand. Therefore, improvements are
made to some ambiguous sentences and to words that are still experiencing errors in typing so that the practitioner can understand the practical guide well.

The impact on learning the use of experimental methods by the statement of [21], namely the experimental method can improve cognitive results. Besides, the problem-solving method according to [22] can develop students' problem-solving abilities. These results are consistent with the results of research by [23] and [24], which the problem solving method according to [22] can improve students' problem solving abilities. Besides, the use of the [22] method also motivates students to be able to learn independently and train students to think logically and thoroughly so that students' mistakes in the process of completing the mass are controlled by looking back on the steps that have been taken [25].

5. Conclusion
The results of the development of practicum tools for determining the refractive index of fluids through measurement of real depth and apparent depth are the existence of a webcam along with a white screen, modification of needles and coins as well as modification of measuring cups and mirrors.

The results of this study indicate the results of the refractive index of water written $n = (1.3158112 \pm 0.0000303)$ with a relative error of 1.07%, the refractive index for saltwater obtained is $n = (1.4476904 \pm 0.0000387)$ with errata relative by 1.37%, the refractive index for sugar water obtained is $n = (1.355680 \pm 0.000145)$ with a relative error of 1.02%, and the refractive index for cooking oil obtained is $n = (1.4525593 \pm 0.0000694)$ with a relative error of 1.36%. The results of the feasibility of media experts and material experts with a percentage of ideals of 90.69% which is included in the category of Very Good, along with practicum guidelines have also been made and tested for eligibility by media experts and material experts with a percentage of ideals 94.17% which is included in the category of Very Good. Based on the results of these percentages, the practicum tools, and the practicum guidelines are declared to be suitable as learning media on the Optics Geometry material especially for the determination of the refractive index with real depth and apparent depth.

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