

## Design of a Practicum Tool for Studying Lens Characteristics and Lens Aberration in Basic Physics Practicum II

Upik Rahma Fitri<sup>1</sup>, Mira Ziveria<sup>2</sup>, Gina Nurhasanah<sup>3</sup>, Muhammad Ardi Budiawan<sup>4</sup>, Aprilia Dwi Lestari<sup>5</sup>, Syifa Kamelia<sup>6</sup>, Andry Fitrian<sup>7</sup>

<sup>1,3,4,5,6</sup>Department of Physics Education, Universitas Negeri Jakarta, Jakarta, Indonesia

<sup>2</sup>Department of Information System, Institut Teknologi dan Bisnis Kalbis, Jakarta, Indonesia

<sup>3</sup>Department of Physics Education, Universitas Indraprasta PGRI, Jakarta, Indonesia

### Abstract

*This research aims to design and develop a practical tools for studying the characteristic of lenses and shadow defects using the 4D model (Definition, Design, Development, Dissemination), albeit limited to the early stages of development. During the definition stage, a field study was conducted to assess the need for improving existing practical tools and a literature review was carried out to gather design references and material information. Subsequently, in the design stage, a conceptual drawing and prototypes of the practical tools was produced for further development in the next phase. The practical tools includes several components such as a lamp, positive lenses, negative lenses, objects, screens, tracks, and translucent glass. In the development stage, the practical tools was constructed according to the designed specifications, and evaluations and revisions were conducted to refine the instrument until a suitable version was achieved for laboratory-scale testing. The practical tools developed in this research are said to be very feasible based on assessments from experts.*

**Keywords:** practical tools, shadow defects, 4D Models.

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### Corresponding Author:

Upik Rahma Fitri

Department of Physics Education, Universitas Negeri Jakarta, Indonesia

Jl. Rawamangun Muka Raya No. 11, RT.11/RW.14, Rawamangun, Kec. Pulo Gadung, Kota Jakarta Timur, Daerah Khusus Ibukota Jakarta 13220

Email: [upikrahma@unj.ac.id](mailto:upikrahma@unj.ac.id)

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## 1. INTRODUCTION

Science consists of three aspects, namely the scientific process, scientific products, and scientific attitudes (Juhji, 2016). One of the processes of scientific investigation can be conducted through practical activities. Learning activities will be more meaningful if accompanied by practical activities, as practical activities are more effective in fostering the acquisition of scientific process skills (Restiana and Djukri, 2021). The correlation between learning and work skills underscores the importance of practice-based learning (Zaker Ul Oman, Sumeet Pandey and Ashitosh Gaddam, 2022). Laboratory work is one effective method that can be used in physics education, as it can be used to train all three domains of intelligence (cognitive, psychomotor, and affective) simultaneously (Voitkiv and Lishchynskyy, 2023).

Learning media play a crucial role in creating an optimal learning process (Kause and Boimau, 2019). The availability of learning media in the field of education is particularly essential, considering that the use of media can facilitate the learning process, support learning activities, and maximize educational potential (Sumantika *et al.*, 2023).

Experimental activities and laboratory work, such as physics experiments using demonstration tools, play a crucial role in enhancing the effectiveness and efficiency of the learning process (Bhakti, Arthur and Supriyati, 2023)(Voitkiv and Lishchynskyy, 2023). The use of tools in laboratory work as media or demonstration aids can facilitate learning. Additionally, it is expected to help construct understanding in learning, starting from formulating problems, hypothesizing, analyzing experiments, collecting data, to drawing conclusions (Huriawati, 2016).

One physics laboratory experiment in optics involves observing the characteristics of images formed by lenses, measuring the focal length of lenses, and observing shadow defects formed by lenses. Lenses consist of converging and diverging lenses (Ayuningtyas and Sulisworo, 2017). Refraction by lenses involves converging lenses that bring parallel light rays to a focal point and diverging lenses that cause rays to diverge as if from a focal point on the same side (Wörner *et al.*, 2022). The concept of refraction can be applied to the characteristics of images formed by lenses. The process of image formation by lenses, whether positive or negative lenses, follows the following equation:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad (1)$$

With  $s$  as the object distance from the lens,  $s'$  as the distance from the lens to the screen, and  $f$  as the focal length of the lens. In lenses, undesired images can sometimes form. For example, the appearance of colored fringes around the image. This occurs when all rays from a point object are not focused to a single point image, resulting in multiple images or the appearance of a blurred image, known as aberration. Aberration is a distortion in the shape of the image produced by the lens (Chen *et al.*, 2021). Experiments on the properties of lenses and shadow defects can be observed through laboratory work using equipment for studying lens characteristics and shadow defects.

Laboratory equipment is used to conduct experiments or direct practical activities related to concepts or subject matter (Yeşiloğlu and Köseoğlu, 2020). It provides hands-on experience in understanding and applying these concepts. Good laboratory equipment is focused on the goals, curriculum, and learning assessment. Therefore, the equipment used should be in good condition and easy to use. Laboratory equipment is active and can be used for measurements, observations, or experiments (Subotić *et al.*, 2018). It is designed to enable students to practice the theories they learn (Suryana *et al.*, 2024).

The Practicum of Basic Physics II course is one of the compulsory subjects offered in the Physics Education undergraduate program at Universitas Negeri Jakarta. One of the experiments conducted by students is an optics experiment titled "Lens characteristics and Shadow defects." Based on field observations, including surveys and interviews with students who participated in the basic physics laboratory for lens characteristics and shadow defects, several difficulties were identified (Adams and Wieman, 2015). These include challenges in using laboratory equipment, understanding procedural steps, and obtaining as well as processing data. Given these issues, it is crucial to address and improve the condition of the lens characteristics and shadow defects laboratory equipment.

Based on the background regarding the issues with the use of lens characteristics and shadow defects practicum tools in Basic Physics II laboratory sessions, the limitations of inadequate equipment in clearly illustrating the properties of lenses and shadow defects have led to difficulties for students in comprehensively understanding optics concepts. Therefore, the author is interested in designing lens characteristics and shadow defects practicum tools for the Basic Physics II practicum sessions.

## 2. METHODS

The development method used in this research is Research and Development (R&D). This method was chosen because it provides a systematic approach to instructional development. The research and development in this study follow the 4D development model (Define, Design, Development, and Disseminate) (Miaz *et al.*, 2019). The 4D development model is a framework for developing educational tools that has been widely used by researchers and proven effective in conducting simple development research (Wenno, Limba and Silahoy, 2022).

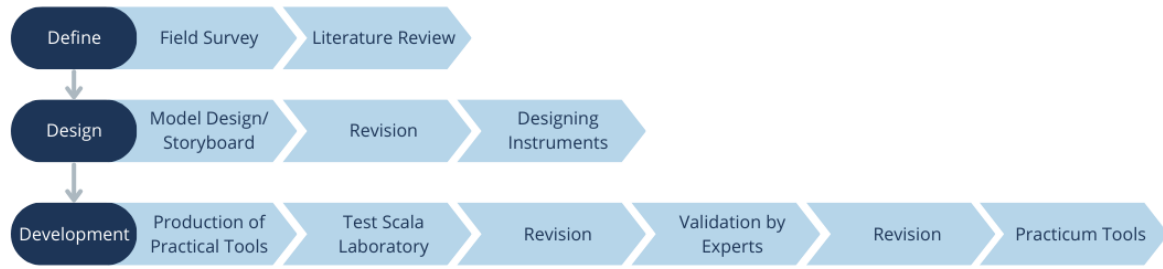


Figure 1. Practicum Tools Development Steps

The design of the lens properties and shadow defects laboratory equipment for Basic Physics II practicum begins with the defining phase, where the researcher conducts preliminary analysis consisting of field studies and literature review. The design phase involves creating the design drawings of the equipment, which are then developed in the development phase to produce the actual laboratory equipment for lens characteristics and shadow defects (Bely, 2003). Once the product is created, it undergoes laboratory-scale testing and feasibility testing by experts.

### 3. RESULT AND DISCUSSION

This section is the main part of the research article and is usually the longest, with the Results and Discussion section accounting for about 60% of the total body of the article. The data analysis process, such as statistical calculations and hypothesis testing, does not need to be presented. Only the results of the analysis and hypothesis testing need to be reported. Tables and graphs can be used to clarify the presentation of research findings verbally.

In the Results and Discussion section, the following should be included: (1) Answers to the research questions and problem formulations; (2) Explanation of how the findings were obtained; (3) Interpretation of the findings; (4) Relating the research findings to the existing body of knowledge; and (5) Presenting new theories or modifications to existing theories.

#### Characteristics of the Developed Practicum Tools

Based on the needs analysis, this research focuses on designing image defect laboratory equipment for Basic Physics II practicum. In designing the image defect laboratory equipment for Basic Physics II practicum, several characteristics of the equipment need to be considered. Firstly, the practicum tools uses a positive lens and negative lens. This lens is used as the study object to observe image formation, magnification, and other optical properties of the lens. Objects such as arrows and diaphragms are placed in front of the lens. These objects assist in studying image formation by the lens and magnification effects.

Additionally, to help reduce shadow defects, a translucent glass is placed in front of the lens. A light source, such as a lamp, is used to provide light that is focused through the lens onto the object or projection screen. This light enables the formation of images by the lens. Guide rails or support tools are used to support the lens, light source, object, and projection screen to keep them in the correct positions during the experiment. The projection screen and guide rails are equipped with measurement scales to measure the focal length of the lens or the distance between the lens and the object, as well as the distance between the lens and the screen where the projected image forms.

#### Design of the Developed Equipment

The design of this laboratory equipment is the result of modifications and adaptations from previous tools, integrating new elements to enhance functionality and effectiveness. These changes aim to create various types of adjustable image defects that can be flexibly controlled and customized according to experimental needs.

The series of lens properties and image defect laboratory equipment to be developed is illustrated in the figure below.

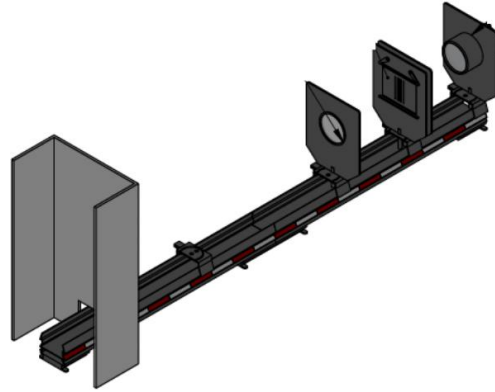


Figure 2. Initial Design Of Practicum Tools

The practicum tools for lens characteristics and shadow defects consists of:

- a) Light source (LED lamp)
- b) Positive lenses (100 mm and 50 mm)
- c) Negative lenses (-100 mm and -50 mm)
- d) Object or diaphragm
- e) Projection screen
- f) Precision guide rails of 100 cm
- g) Slides with integrated lamp
- h) Translucent glass
- i) Power supply

### Results of Laboratory Equipment Development

The developed laboratory equipment has specifications for its components, including a light source in the form of an LED lamp, positive lenses with focal lengths of 100 mm and 50 mm, negative lenses with focal lengths of -100 mm and -50 mm, an arrow object with a height of 1 cm, a five-slit diaphragm, a circular diaphragm, a projection screen equipped with shadow measurement scales, a 100 cm long guide rail, slides with integrated lamps for easy reading of measurement scales on the guide rail, diffusing glass for observing image defects, and a power supply as the voltage source connected to the LED lamp light source.

The results of the developed laboratory equipment are shown in the figure below.

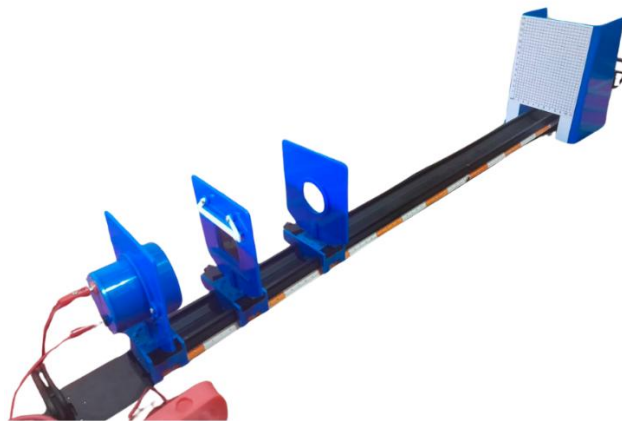


Figure 3. Set Of Practicum Tools

### Feasibility Test Results of Laboratory Equipment

The developed image defect laboratory equipment underwent feasibility testing conducted by media experts and subject matter experts to assess the product's feasibility before student trials. The feasibility test was conducted using an assessment instrument in the form of a questionnaire.

#### *Feasibility Test Results by Subject Matter Experts*

The material feasibility test instrument consisted of a questionnaire containing 13 questions covering 4 aspects: (1) Suitability, (2) Completeness, (3) Ease of Use, and (4) Clarity. The feasibility test results by subject matter experts are presented in the following table:

**Table 1. Feasibility Test Results by Material Experts**

No	Aspect Assessed	Score Interpretation	Description
1	Suitability	95,83%	Very Feasible
2	Completeness	100%	Very Feasible
3	Ease of Use	100%	Very Feasible
4	Clarity	100%	Very Feasible
<b>Average</b>		98,96%	Very Feasible

Based on the feasibility test results by subject matter experts, the average percentage obtained across all aspects is 98.96%. Therefore, it can be concluded that the developed lens characteristic and shadow defect practicum tools is assessed as "very feasible" for use as a Basic Physics II practicum sessions.

*Feasibility Test Results by Media Experts*

The feasibility test instrument for media consisted of a questionnaire containing 11 questions across 5 aspects: (1) Effectiveness, (2) Ease of Use, (3) Suitability, (4) Completeness, and (5) Interactivity. The feasibility test results by media experts are presented in the following table:

**Table 2. Feasibility Test Results by Media Experts**

No	Aspect Assessed	Score Interpretation	Description
1	Effectiveness	100%	Very Feasible
2	Ease of Use	100%	Very Feasible
3	Suitability	87,5%	Very Feasible
4	Completeness	93,75%	Very Feasible
5	Interactivity	100%	Very Feasible
<b>Average</b>		96,25%	Very Feasible

Based on the feasibility test results by media experts, the average percentage obtained across all aspects is 96.25%. Therefore, it can be concluded that the developed lens characteristic and shadow defect practicum tools is assessed as "very feasible" for use as a Basic Physics II practicum sessions.

**4. CONCLUSION**

In The development design of the lens characteristic and shadow defect practicum tools was adapted from existing tools, with updates made to several components to enhance usability and improve data accuracy. These updates included improvements to the light source, object and diaphragm slides, and the projection screen. It can be concluded that the laboratory equipment was successfully developed according to requirements and is suitable for use in Basic Physics II practicum sessions.


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## BIOGRAPHIES OF AUTHORS

	<p><b>Upik Rahma Fitri</b> is a lecturer in the Physics Education Study Program at Universitas Negeri Jakarta. Her research interests lie in the development of inclusive and accessible physics education, with a particular emphasis on multisensory learning models designed to support diverse learners, including students with disabilities. She can be contacted at email: <a href="mailto:upikrahma@unj.ac.id">upikrahma@unj.ac.id</a></p>
	<p><b>Mira Ziveria</b> is a lecturer in the Department of Information System, Kalbis University, Jakarta, Indonesia. Her research focus is on information systems and community-based technology. She can be contacted at email: <a href="mailto:mira.ziveria@kalbis.ac.id">mira.ziveria@kalbis.ac.id</a></p>
	<p><b>Gina Nurhasanah</b> is an undergraduate student in the Physics Education Study Program. She can be contacted at email: <a href="mailto:gina.nurhasanah@unj.ac.id">gina.nurhasanah@unj.ac.id</a></p>
	<p><b>Ardi Budiawan</b> is an undergraduate student in the Physics Education Study Program. He can be contacted at email: <a href="mailto:ardi.budiawan@unj.ac.id">ardi.budiawan@unj.ac.id</a></p>
	<p><b>Aprilia Dwi Lestari</b> is an undergraduate student in the Physics Education Study Program. She can be contacted at email: <a href="mailto:aprilia.dwi.lestari@unj.ac.id">aprilia.dwi.lestari@unj.ac.id</a></p>
	<p><b>Syifa Kamelia</b> is an undergraduate student in the Physics Education Study Program. She can be contacted at email: <a href="mailto:syifa.kamelia@unj.ac.id">syifa.kamelia@unj.ac.id</a></p>
	<p><b>Andry Fitriani</b> is a lecturer in the Physics Education study program at Indraprasta PGRI University, Jakarta, Indonesia. His research focuses on physics education. He can be contacted via email at: <a href="mailto:andryakira@gmail.com">andryakira@gmail.com</a></p>