

Design of virtual laboratory media based on HTML 5 Canvas and graphical user interface in physics learning

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ABSTRAK

Physics is an important part of the science curriculum at both the high school and college levels. Physics learning requires students to master abstract theoretical concepts, so it is not uncommon for these theoretical concepts to be difficult for learners to perceive. Abstract concepts in physics learning can be overcome through practical activities in concrete laboratories or virtual laboratories. This study aims to produce virtual laboratory media based on HTML 5 Canvas and Javascript programs packaged in Graphical User Interface (GUI) format in terms of experts, practitioners, and students. The research method used is research and development (R&D), using the 4D model (Define, Design, Develop, and Disseminate). The subjects were conducted in second-years physic students which consisted of 8 students (small group test) and in class XI high school students which consisted of 20 students (large group test). The instrument used were interview sheets, documentation, and questionnaires. The data were analyzed using descriptive analysis techniques. The results showed that virtual laboratory media was valid with a CVI score of 0,87 and reliable with a Percentage of Agreement score of 85,95% based on experts and practitioners judgment. In addition, based on the results of the practicality test for students, the test results were in the very practical category with a practicality score of 86,4% and 88,6% respectively for small group test and large group test. So it can be concluded that virtual laboratory media can be used to support physic learning.

INTRODUCTION

Physics is an important part of the science curriculum at both the high school and college levels. Physics is a branch of science closely related to fundamental scientific principles. Amin et al. (2019) stated that there are two types of scientific concepts, namely factual concepts and theoretical concepts (abstract concepts). Geometric optics is an abstract physics concept, so it can only be learned through practical activities. Physics practicums often face challenges, one of which is understanding abstract physics concepts, because it is difficult to describe or display physics processes directly through experiments in the laboratory (Roosyanti, 2022).

In geometric optics, lenses are an abstract topic. Sholikah et al. (2020) stated in their research that the topic of lenses is one that is considered difficult for students to learn, so learning media are needed that can illustrate and simulate the topic of lenses. According to Pangestu et al. (2019), conventional learning methods have not been fully able to describe abstract physical and natural phenomena; therefore, the use of appropriate media can help teachers deliver topic more effectively. A computer-based virtual laboratory is one of the learning mediums that helps deliver abstract topic. Verdian et al. (2021) stated that virtual laboratories can function as experimental simulation tools for topic that tends to be abstract and difficult to understand to overcome the limitations of facilities, tools, and topics in the laboratory and the difficulty of visualising them.

Based on the results of interviews and initial observations with physics teachers at SMAN 1 Batukliang, physics learning has used the PhET Simulation virtual laboratory as a means of delivering learning topics. According to Masita et al. (2020), PhET Simulation is a virtual

laboratory application developed by the University of Colorado in the United States. This application allows users to simulate physics experiments anywhere and anytime via a computer or smartphone because it can be accessed online or offline. The availability of practical tools in the physics laboratory of SMAN 1 Batukliang is sufficient, but it is still incomplete for the KIT (Integrated Instrument Component) of Geometric Optics, so that experiments have never been carried out on the lens topic. According to the Physics Teacher of SMAN 1 Batukliang, PhET has only been used on the mechanics topic and never for the geometric optics topic. In addition, students have difficulty manipulating variables in PhET, so learning using PhET is still ineffective. According to the Physics Teacher of SMAN 1 Batukliang, computer-based learning media are very much needed on the lens topic due to the limited geometric optics practical tools. In relation to this condition, an alternative is needed to carry out practical work on geometric optics topics such as lenses.

According to [Abdullah](#) (2017), in the teaching and learning process, there are two important elements that must be considered, namely the learning model and learning media. Geometric optics: lenses are a topic of physics that requires visualisation and simulation in the learning process. As an alternative to visualising and simulating phenomena between objects and shadows and other variables, a virtual laboratory can be used. According to [Wibawanto](#) (2020), a virtual laboratory is multisensory software that uses interactivity to simulate and visualize certain practicum by replicating conventional laboratories. In line with this, research conducted by [Sari et al.](#) (2015) showed that more than 80% of student learning outcomes achieved graduation in cognitive and affective aspects. This shows that there is student interest in using virtual laboratories as a support for the learning process. [Sukenti](#) (2021) stated that the use of virtual laboratories can improve students' mastery of concepts in the subject of the circulatory system; thus, it can be concluded that virtual laboratories not only play a role in supporting the learning process but are also important to attract student interest.

The general structure of a virtual laboratory that is often used is a web-based virtual laboratory. According to [Setiawan et al.](#) (2019), creating a website requires the use of Hypertext Markup Language (HTML), Cascading Style Sheet (CSS), Hypertext Preprocessor (PHP), JavaScript, and others. HTML5 is the fifth generation of the HTML programming language. According to [Wibawanto](#) (2020), HTML5 is a programming language for creating structures and displaying a web display, which is the internet's main element. HTML 5 will be used as a compiler programme to open a virtual laboratory. The development of a virtual laboratory is very important to pay attention to visuals and interactivity; therefore, two more programming languages are needed, namely CSS and JavaScript. CSS (Cascading Style Sheets) is a coding language that contains a series of rules for managing the visual appearance of elements on a web page. Meanwhile, JavaScript is used to provide additional interactivity on web pages ([Muslim & Dayana](#), 2016).

According to [Jaya](#) (2012), virtual laboratories can be used to support conventional practicum systems, but limited equipment in physics laboratories requires educators (teachers or lecturers) to innovate so that practicums can still be carried out conventionally. One solution is to utilise virtual laboratories. So far, learning has been done using virtual laboratories on the subject of geometric optics. Lenses are still rarely used as one of the media to support the learning process. Based on these considerations, researchers are interested in developing a Lensa virtual laboratory using HTML5-based technology and JavaScript as one of the media to support physics learning.

Various research projects have been carried out to produce virtual laboratory media in physics learning assisted by computer software, [Maulinda & Ishafit](#) (2017) succeeded in designing a virtual laboratory based on LabVIEW for RLC series circuit topic. [Luki & Kustijono](#) (2017) succeeded in developing a virtual laboratory based on Algodoo for projectile motion topic.

Febriani et al. (2021) succeeded in creating a virtual laboratory based on Unity 3D for waves and light topic. Sudana et al. 2022 succeeded in developing a virtual laboratory based on Macromedia Flash for archimedes force topic. Zulkarnain et al. succeeded in producing an application projects can be used as virtual laboratoty based on Matlab for projectile motion topic (Zulkarnain et al., 2023; Zulkarnain, Darmayanti, Utami, Sabaryati, & Isnaini, 2024). Rahmah et al. (2023) succeeded in developing a virtual laboratory based on Unity 3D, Vuforia and Blender for arrhenius equation and activation energy topic. The previous studies have been developed virtual laboratory media using various platforms or computer software for various physics topics, various subjects from high school to college, and with various development models, but there are still limited in HTML 5 canvas and Javascript based. Therefore, this study aims to produce virtual laboratory media based on HTML 5 Canvas and Javascript on the Lens topic, in addition to conduct the validity, reliability, and practicality tests.

RESEARCH METHOD

This research is a research and development (R&D). The research design used in this study refers to Thiagarajan, namely the 4D model (four D models), which consists of 4 stages of development: define, design, develop, and disseminate (Pasaribu, Khairuna, Adlini, & Abrori, 2023). The subjects were conducted in second-years education physic students Universitas Muhammadiyah Mataram which consisted of 8 students (small group test) and in class XI high school students SMAN 1 Batukliang which consisted of 20 students (large group test). The instruments used in this study were interview sheets, documentation, and questionnaires.. The interview sheets are addressed to practitioners to seek information needed for development of laboratory virtual media. Meanwhile, documentation is used to collect activity data during research and to collect data in the form of topic to be included in learning media. The questionnaire was used to find the validity, reliability, and practicality level of experts, practitioner, and students. The data were analyzed using descriptive analysis techniques. The validity test results were analysed using Content Validity Ratio (CVR) and Content Validity Index (CVI) developed by Lawhse which follow Equation 1 and Equation 2 (Singh et al., 2022).

$$VR = \frac{n_e - (N/2)}{N/2}$$

$$CVI = \frac{\text{Total number of CVRs}}{\text{Number of items}}$$

n_e is the number of validators who agree, whereas N is the total number of validators. The categories of CVI calculation results based on Lawhse presented in Table 1 (Romero Jeldres, Díaz Costa, & Faouzi Nadim, 2023).

Tabel 1. CVI assessment category

Validity Value Interval	Category
$-1 \leq CVI < 0$	Not Valid
$0 \leq CVI < 0,83$	Pretty Valid
$CVI \geq 0,83$	Valid

The level of agreement between validators according to Arsanty & Wiyatmo (2017) can be calculated using the Percentage of Agreement (PA) equation, written as follows (Equation3) :

$$PA = \left(1 - \frac{A - B}{A + B}\right) \times 100\%$$

A is a higher validator score, while B is a lower validator score. If the percentage of agreement value is $\geq 75\%$, then the virtual laboratory can be said to be reliable. The practicality analysis of student responses was carried out using the following equation (Equation 4):

$$P = \frac{A}{N} \times 100\%$$

P is the percentage of student responses, A is the number of respondents' scores, and N is the maximum number of scores. The criteria for the percentage of student responses are presented in Table 2 (Jasmadi, 2018).

Tabel 2. Practicality assessment category.

Score Interval (%)	Category
0 – 10	Not Practical
11 – 40	Pretty Practical
41 – 60	Practical
61 – 100	Very Practical

RESULT AND DISCUSSION

Define stage is the first stage that aims to determine the problem and purpose of developing a virtual laboratory. The initial-final analysis aims to examine the problems faced when implementing physics learning activities in class by interviewing physics teachers at SMAN 1 Batukliang regarding the use of learning media on the lens topic. The results of the interview revealed that there had never been any learning media applied in the learning process; in addition, physics teachers at SMAN 1 Batukliang had never used a virtual laboratory for the lens topic. User analysis was conducted to determine who would use the virtual laboratory later. The target users of this virtual laboratory development are physics teachers and high school students. The topic in the virtual laboratory is organized based on the basic competencies in the applicable high school physics curriculum. A device needs analysis was conducted to determine what software and hardware can support the development of a virtual laboratory. The software that supports the development of a virtual laboratory is a Visual Studio Code, Paint, and Photoshop and browser such as Google Chrome. In addition the hardware required is a computer or laptop.

Design stage is the process of creating a design for a predetermined product. Based on the initial-final analysis results, an initial virtual laboratory product design is made in the form of a rough sketch that includes the display, menu, and sub-materials to be simulated. The virtual laboratory is created using HTML 5 Canvas, and JavaScript programming languages, and displayed in Graphical User Interface format so that it can be run offline using a laptop or computer.

Develop stage involves activities that transform a design into a product and conduct product testing. The product creation stage includes coding and deployment. The coding stage is the process of writing a script used to develop media. The deploy stage is the stage where the virtual laboratory code is uploaded and can be used by users. The first test is validation to determine the validity and reliability of the product. Validation is carried out by three lecturers as expert validators and three teachers as practitioner validators. The results of the virtual laboratory validity calculations can be seen in Table 3.

Table 3. Virtual laboratory validity calculation results

Assessment aspects	Statements	CVR	CVI	Category
Appearance	The selection of colors, text, images, and interesting animations enhances the overall design.	1	0.92	Valid
	Images are clearly visible.	1		
	The text, image, and button layout are correct.	1		
Typography	Fonts are easy to read.	1		
	The font size is appropriate.	1		
Language	The language used is easy to understand.	0.33		
Material	The material is in accordance with the contents of the syllabus.	0.67		
	The material aligns with basic competencies and competency achievement indicators.	0.67		
	Material presentation systematically presented sequentially	0.67		
User Guide	Instructions in the virtual laboratory are easy for high school students to understand.	0.67		
	The language used is not ambiguous.	0.33		
Simulation	The layout of buttons, sliders, text input, and object movement is very interesting and appropriate.	1	0.92	Valid
	Slider and text input settings are in accordance with the values of the quantities used.	1		
	Object movement settings are in accordance with theory.	1		
Usefulness	It clarifies and facilitates the delivery of lesson materials.	1		
	It helps improve students' mastery of the subject matter lenses help visualize and illustrate the properties of light and shadow formation.	1		

Based on Table 3, the CVI value is greater than 0.83, so the virtual laboratory can be said to be valid. The validator's assessment of the visual and simulation aspects is considered valid because the appearance and simulation of the virtual laboratory that was developed are already attractive and interactive. According to Jasmadi (2018), stimuli in the form of dynamic images (animation), and color variations recorded into the program can arouse students' learning motivation. Learning media that have an attractive appearance and supporting components such as animation can increase students' enthusiasm for learning. The language aspect's assessment is still low because the language used in the virtual laboratory is entirely English. According to Asyhari & Silvia (2016) learning media is not only characterized by its appearance, but also by its grammatical components, specifically its adherence to good and correct Indonesian language rules.



Figure 1. Virtual laboratory home page view.

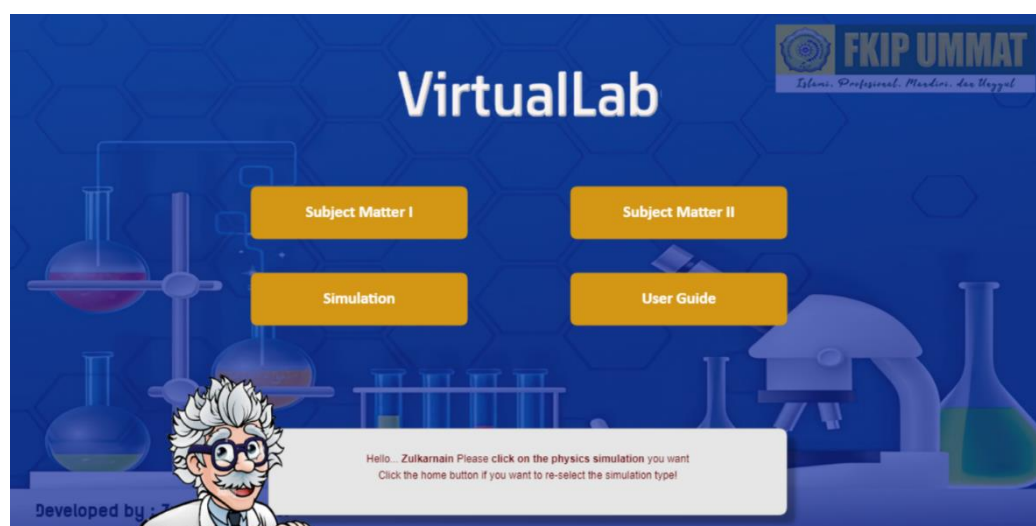


Figure 2. Virtual laboratory menu page view.

In this study, reliability means that the validation results are consistent across validators. According to the calculation results, the Percentage of Agreement (PA) between expert validators and practitioner validators is 80.95%, which is a reliable category. In most of the virtual laboratory validation results, the consistency between validators is more than 75%. This is because the virtual laboratory that was developed is interesting and can be used as a learning medium. The validator also provided comments and suggestions for improving the virtual laboratory, and the results of these improvements can be seen in Figure 1 and Figure 2.

The virtual laboratory response questionnaire was given to 8 second-years students of the physics education Universitas Muhammadiyah Mataram as small group test subjects, and 20 grade XI students of SMAN 1 Batukliang as large group test subjects. The response questionnaire was given with the aim of determining the practicality of the virtual laboratory that had been developed. Table 4 displays the results of the virtual laboratory's practicality calculation.

Table 4. Virtual laboratory practicality calculation results.

Uji coba	Number of Respondents	Average number of respondents' scores	Response Percentage (%)	Category
Small group test	8	4.3	86.4	Very Practical
Large group test	20	4.4	88.6	Very Practical

The analysis of the student response questionnaire in Table 4 shows an average percentage of 86.4% for the small group test and 88.6% for the large group test, so it can be categorized as very practical. This shows that the virtual laboratory media that was developed received a positive response from students. This is consistent with [Jasmadi \(2018\)](#), which found that the use of virtual laboratory media is interesting for students, has a positive impact, and provides enthusiasm for learning, so that it influences student learning outcomes.

Numerous studies have looked at the development of virtual laboratory, but each study has unique characteristics and different from each other. Research conducted by [Kertanegara & Anggaryani \(2023\)](#) under the title "Validity of Virtual Laboratory of Phylasicsas an Alternative to Real Laboratory on the Material of Temperature and Thermometer Calibration". The Validity assesment analysis from this study, shows that the virtual laboratory was valid and reliable. The similarities between the two studies is found in the applications utilized, where the applications utilized was HTML 5 Canvas. The distinction between the two studies is found in the material covered, where the material covered namely the temperature and thermometer calibration. Differences are also found in the development model used, in this study using the ADDIE model. The results of the study [Revanza et al. \(2023\)](#) under the title "Virtual Laboratory Design Based On Ijen Geopark on Science Material in Junior High School as an Interactive Learning Media" also showed the validity assessment result had a valid category. The similarities between the two studies is found in the applications utilized, where the applications utilized was HTML 5 Canvas. The distinction between the two studies is found in the material covered, where the material covered namely the Environmental science. Differences are also found in the development model used, in this study using the 3D model

CONCLUSION

Virtual laboratory media based on HTML 5 Canvas and JavaScript has been developed by following the 4D development research model through the define, design, development, and dissemination stage. Based on the description of the research results and discussion, it is clear that the virtual laboratory falls into the valid and reliable category, as confirmed by the validation results from experts and practitioners. Based on the practicality test conducted on students, the virtual laboratory can be classified as very practical.

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