JPPIPA 10(3) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

VR Based Media for Three-Dimensional (3D) Visualization in Chemical Laboratory

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Received: September 12, 2023
Revised: February 22, 2024
Accepted: March 25, 2024
Published: March 31, 2024

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DOI: 10.29303/jppipa.v10i3.6180

Abstract VR (VR) is a technology created with the aim of creating a three-dimensional (3DVR) simulated environment where users can observe and interact with the contents of that environment. This research aims to develop and assess the quality of a 3D-VR-Based Virtual Lab learning media. The development of learning media in this research uses the ADDIE development model. However, in this research, it is limited only to the development stage, namely validation by media experts and feasibility testing. Based on the validation results from each media validator, covering three aspects: audiovisual, software engineering, and instructional design, good results were obtained. Therefore, 3D-VR media developed is declared valid and feasible to be tested with learners.

Keywords: R&D; Three dimensions, VR

Introduction

The use of information and communication technology in all walks of life is a demand in world development in the 21st Century, including in the learning process (Daryanto & Karim, 2017; Falode & Gambari, 2017; Jack & Higgins, 2019; Lukman & Ulfa, 2020). Through technology, an educator can improve the quality of education, by expanding access to knowledge and information technology for the implementation of education can be quality and enjoyable.

Learning media is one of the external factors, namely factors that come from outside students to achieve success in the learning process (Unaida et al., 2022). To enhance the quality of the learning process and provide engaging and productive learning activities, learning media development is essential (Porter & Woerner, 1998; Wisetsat & Nuangchalerm, 2019). A learning process that is integrated with information and communication technology should be able to improve the quality of education, both in the form of student learning outcomes and educators' abilities in carrying out the learning process to prepare the 21st Century generation.

21st century learning has a learning framework consisting of 3 main pillars, namely foundational knowledge, meta knowledge, and humanistic knowledge (Kereluik et al., 2013; Muliani et al., 2022). Foundational knowledge or what we are more familiar with as basic knowledge, there are three keys to mastering it, namely core content knowledge, digital literacy and cross-disciplinary knowledge. The 21st century learning framework provides an illustration to practitioners in the world of education that students' knowledge must be built holistically, including basic knowledge, implementation of knowledge through skills, and mastery of humanistic knowledge. The emphasis on digital literacy which is included in basic knowledge provides confirmation that 21st century learning must be supported by good ICT mastery skills (Siddiq et al., 2016; Silber-Varod et al., 2019). Digital literacy as basic knowledge in the 21st century learning framework has been included in the assessment system

How to Cite:
Fatwa, I., Lukman, I. R., Mellyzar, Dewi, U. M., & Pasaribu, A. I. (2024). VR Based Media for Three-Dimensional (3D) Visualization in Chemical Laboratory. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 1356–1361. https://doi.org/10.29303/jppipa.v10i3.6180

in various countries. Australia has become one of the countries that has implemented digital literacy assessments every three years since 2005. This is in line with UNESCO which defines educational media as a priority area for the development of educational culture in the XXI century (Fedorov, 2008). The development of learning media should not only be able to accommodate learning in the classroom but also in the laboratory.

Preparation for students is important in carrying out practicums in physical laboratories, both in the form of independent work and in groups. The main obstacle faced is the cost of laboratory equipment and materials which is expensive and limited time to carry out practicum (Tatli & Ayas, 2013). To overcome this problem, the solution provided is the use of virtual laboratories, which can reduce several weaknesses, such as the safety risk of using laboratory tools and materials and requiring more time to obtain accurate practical results (Falode & Gambari, 2017). Learning using virtual laboratories also attracts students' interest because it allows easy and flexible access anywhere and at any time, and allows students to learn independently (Fitriyana et al., 2024). Virtual Reality (VR) is a technology created with the aim of creating a three-dimensional (3D) environmental simulation, where users can observe and interact with the contents of that environment. VR technology has developed rapidly in the past decade (Anthes et al., 2016) and it has reached a stage for practical applications in recent years (Tsai et al., 2021).

The main goal of *VR* is to create an experience that allows the user to feel completely immersed in the virtual world created. Technology *VR* uses three-dimensional (3D) graphics and sound that surround the user when displayed on the screen. To explore the world *VR*, users are assisted with hardware such as VR glasses or electronic gloves. VR learning materials offer a powerful method for enhancing hands-on laboratory education (Glassey & Magalhães, 2020; Viitaharju et al., 2023). VR laboratories all appear to have as their common goal the replication of actual laboratory facilities or equipment through the use of 360-degree photographs or 3D-modeled surroundings to produce immersion, or the sensation of being in the laboratory (Reeves & Crippen, 2021; van Dinther et al., 2023).

Several examples of previous research suggest that students have been presented with 3D molecular models through virtual reality to help them understand chemical structures and processes (Ferrell et al., 2019; Pietikäinen et al., 2021). Ferrell et al. (2019) covered that, in comparison to standard textbooks, the three-dimensional virtual reality information provides a clearer illustration of chemical structures, which successfully enhances student learning. The VR experience can be seen as a useful tool for enhancing students' understanding of chemical concepts, and it is essential for a better perception of abstract notions that cannot be otherwise visualized in full detail (Maksimenko et al., 2021; Wang et al., 2022). Other research, integrating physical and virtual PhET laboratories can improve students' cognitive learning outcomes (Zulkifli et al., 2022). Use of PhET virtual media, the results of the N-gain analysis of all aspects show that the use of this device has increased, namely cognitive learning outcomes, science process skills and student creativity in the high category (Susilawati et al., 2021).

This paper is an empirical study regarding the use of virtual laboratories. The use of virtual laboratories in teaching chemistry laboratories to high school students is the subject of this paper's empirical investigation. Using 360-degree photos, a virtual laboratory area is created, and customizable educational resources such as interactive films are embedded into it. The goal of the 360-VR concept described in this paper is to create a virtual reality laboratory that simulates being in a real laboratory.

The need for media *VR* at FKIP Malikussaleh University is a need that is in line with the Ministry of Education and Culture's program, where the LPTK revitalization program which will be implemented in 2023 focuses on strengthening the quality and capacity of PPG implementation by optimizing the use of Micro Learning Laboratories, ICT integrated Learning Resource Centers, and Online Learning Implementation. One of the three objectives of implementing LPTK revitalization launched by the Ministry of Education and Culture and implemented at FKIP Malikussaleh University is to increase the capability and quality of the ICT-integrated Learning Resource Center, where the fulfillment of ICT-based learning facilities is included in the needs *VR*, this must be balanced with the availability of learning media where pupils, students and teachers need to be facilitated to use and develop learning media according to their needs

Method

This research aims to develop and determine the quality of 3D-VR-based Virtual Lab learning media. The development model used in research is the ADDIE model. According to Branch (2009) there are 5 stages in the ADDIE model, namely stages analysis; design; development; Implementation and evaluation. However, in this research it only reaches the development stage.

The analysis stage is carried out by studying the 3D VR-based Virtual Lab learning media library and analyzing the needs that must exist 3D-VR based Virtual Lab media developed. The next stage is design. At this stage, the content is determined so that the overall initial design can be developed. Next, the development stage is carried out by creating 3D-VR-based Virtual Lab learning media in accordance with the design plans that have been prepared in the previous stage. Next, a media expert validation test was carried out on 3 lecturers and a product feasibility test on high school teachers. These two tests are media assessments to determine the overall quality of the 3D-VR Based Virtual Lab learning media.

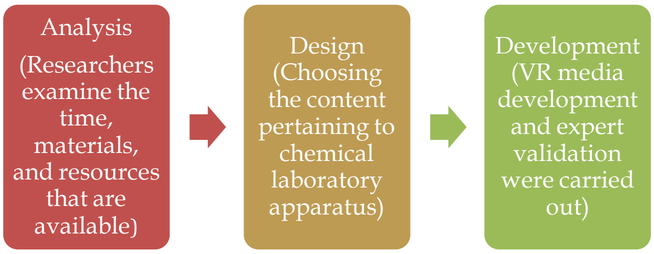

Figure 1. Research design

Once done validation test, feasibility test then improvements are made according to the test results and suggestions from the validator. This Media Quality Assessment is obtained from the scores given by validators for each aspect of the assessment. Next, each item is converted into quantitative data with an index range of 1 to 5. After analysis, the data is categorized based on a conversion table adapted from (Check & K. Schutt, 2011). The product is said to be valid and easy to use if the reviewer's score is in the good category. These criteria can be seen in Table 1.

Table 1. Quality Criteria

Interval	Quality Criteria Media
$X > 4.206$	Very good
$3.402 < X \leq 4.206$	Good
$2.598 < X \leq 3.402$	Enough
$1.794 < X \leq 2.598$	Not good
$X \leq 1.794$	Very Not Good

Result and Discussion

The learning media development carried out in this research used the ADDIE development model. However, this research is limited to the development stage only, namely validation by media experts and feasibility testing. The following is a description of the stages in developing 3D-VR-based Virtual Lab media. Details of the data obtained are as follows.

Analysis Stage

At this stage, researchers analyze the challenges that exist in the media produced by considering the available resources, namely time and energy, as well as the materials needed to produce the media. By theme introduction to chemical laboratory equipment, VR-based learning media can display various objects in the chemical laboratory in 3D form for students to see the original shape of the objects things that are hard to find. It is necessary to develop VR-based learning media equipped with information on the name and function of the laboratory equipment.

Design Stage

The design stage consists of determining the content so that the entire initial design can be developed (Ghani & Daud, 2018). At this stage, information and materials needed to develop media are collected in the form of objects chemical laboratory equipment objects and designed in such a way as to form a learning environment in two situations, namely learning carried out in the classroom in the form of an introduction to material related to the introduction of chemical laboratory equipment and continued learning with the situation of being in a chemical laboratory. The resulting chemical laboratory design contains Occupational Safety and Health regulations, 3D objects of laboratory equipment needed in chemical experiments along with their names and functions. Apart from that, the media developed also contains videos supporting learning.

Figure 2. Screenshots from VR experience: (left) the Overall chemistry laboratory plan and (right) the classroom

Figure 3. Screenshots from VR experience: (left) Front view of the chemistry laboratory and (right) Parts in a chemistry laboratory

Development Stage

This stage is the realization of what was designed in the design stage to become a media product (Anafi et al., 2021). Interactive teaching media is validated based on three aspects, namely audio visual, software engineering, and learning design. Each aspect was verified by three expert validators who were lecturers at Medan State University and Samudra University as well as one teacher validator at SMAN Modal Bangsa Arun. The results of the quantitative expert assessment will later be converted into qualitative according to category. The overall validation test results for the three aspects with a score of 4.34 are very good criteria. Each validator gives a score, namely the first validator is 4.27, the third validator has a score of 4.36, and validator 4 has a score of 4.27. Each validator gave the opinion that the VR-based media being developed was in the very good category, while the second validator gave a score of 4.05 in the good category. The recapitulation of validation results is presented via a diagram in Figure 4.

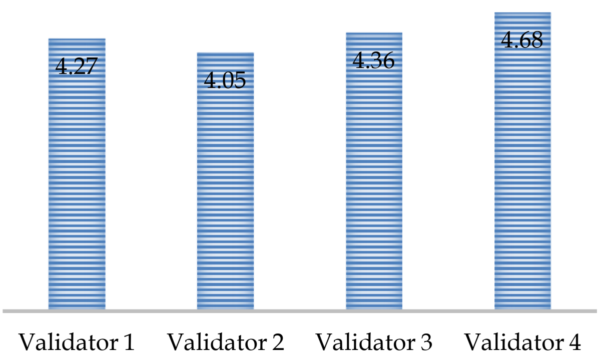

Figure 4. Learning Media Validation Results

Details of validation are discussed from each aspect. First, it is discussed from the audio-visual aspect**.** The data produced showed that validator 1, who was a lecturer at Samudra University, and validator 4, who was a teacher at SMAN Modal Bangsa Arun, obtained data of 4.3 and 4.7 respectively with very good criteria. Validators 2 and 3 who are lecturers from Medan State University obtained scores of 3.7 and 4.1 with good criteria. The recapitulation of the media validation results for the audio-visual aspect by each validator is presented via a diagram in Figure 5.

The second aspect that is assessed is the software engineering aspect. From the validation results, the average validation data obtained was a score of 4.34 with very good criteria. Data description for each validator obtained a score of 4 (good) for validator 1, very good criteria from the assessment results of validator 2 (4.25), validator 3 (4.50) and a score of 4.63 from validator 4. Recapitulation of media validation results for engineering aspects software by each validator is presented via a diagram in Figure 6.

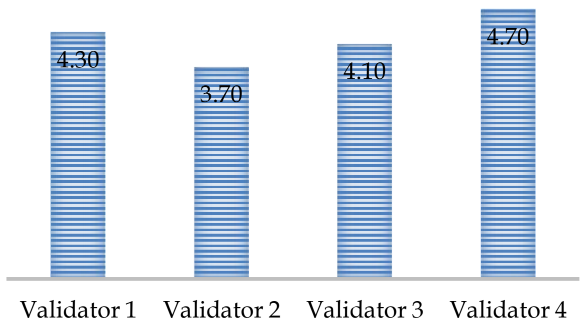

Figure 5. Aspect media validation results audio visual

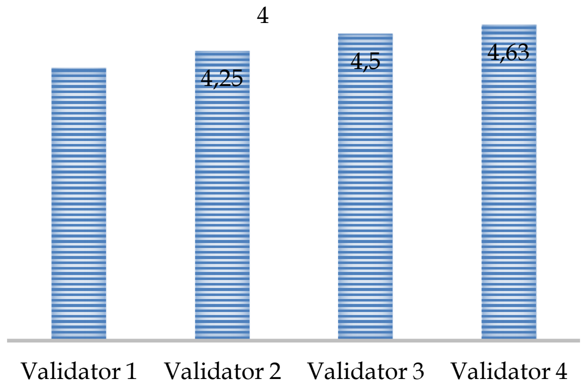

Figure 6. Media validation results for software engineering aspects

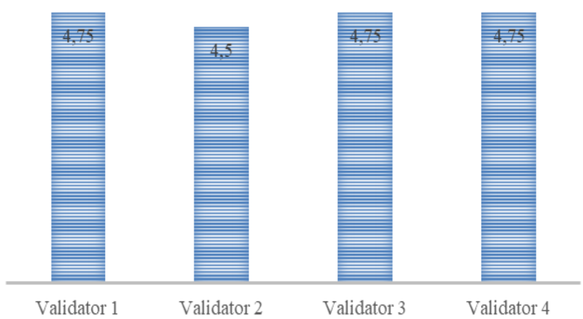

Figure 7. Results of media validation aspects of learning design

The third aspect that is assessed is the learning design aspect. From the validation results, the average validation data obtained was a score of 4.69 with very good criteria. Each validator also provides scores with very good criteria. Data description for each validator obtained a score of 4.75 for validator 1, validator 2 (4.5), validator 3 (4.75) and a score of 4.75 from validator 4. Recapitulation of media validation results for software engineering aspects by each validator presented via a diagram in Figure 7.

Conclusion

Virtual Lab Based on Three Dimensional VR (3D-VR) was developed using simple, interesting and interactive introduction to laboratory equipment. This media can be operated via an Android application on a smartphone with the help of 3D glasses with a controller, then connected via Bluetooth which can be done anywhere and anytime. The use of this media makes students feel like they are in a real laboratory. Based on the validation results from each media validator from three aspects, namely audio visual, software engineering and learning design good results were obtained so that the Virtual Lab media based on three dimensional VR (3D-VR) was developed and declared valid and suitable to be tested on students.

Author Contributions

Islamic Fatwa: Preparation of concept and research design, data collection, data analysis. Isna Rezkia Lukman: Collecting data, analyzing data and developing VR media. Mellyzar: Writing research reports and article manuscripts. Ucia Mahya Dewi: Collecting data, data analysis and editing. Ali Imron Pasaribu: Developing VR media.

Funding

We would like to express our thanks to Malikussaleh University for providing research grant funding for the Reflective Micro Learning Resources Development scheme with funds for LPTK Revitalization in 2023.

Conflicts of interest

The authors declare that there are no relevant conflicts of interest related to this research.

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