Research Article

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Virtual Laboratory to Support a Practical Learning of Micro Power Generation in Indonesian Vocational High Schools

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Abstract: The rapid changes in industrial revolution 4.0 demand change in education, especially at vocational education. Teachers in Vocational High School (VHS) in Indonesia are expected to bring technology-based innovations to achieve success in learning. Learning facilities are one of the factors supporting the success of learning class. Ideally, Indonesian Vocational High Schools have facilities and infrastructure following industrial. Currently, schools have difficulty providing learning support facilities and infrastructure following those in the industry. Thus, the equipment in the school laboratory is irrelevant to the existing equipment in the industry. The practicum apparatus gap between VHS and industry requires appropriate and effective solutions. The gap occurred in practical learning of micro power generation Indonesian VHS. On the other hand, virtual laboratories in the learning process can help students learn an object that cannot be presented in the classroom. By using virtual laboratories, students learn to use industry apparatus through virtual forms. This research aims to overcome the problem of practical learning in VHS, especially on practical learning of micro power generation through the virtual laboratory. This study used the 4D model approach (Define, Design, Develop, and Disseminate). The result showed that the virtual laboratory of micropower generation effectively supported learning and transfer of knowledge in practical learning, especially during the covid 19 pandemics.

Keywords: Virtual Laboratory, Vocational High School, Practical learning of micro power generation

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1 Introduction

Several new ideas have been developed in the current era related to future education, especially in vocational high schools. As part of the national education system, vocational education plays a very strategic role in creating a skilled workforce. Vocational education has a vital role in all education systems in developing countries [1]. Vocational High Schools have the primary mission of preparing students to enter the workforce. Most developed countries also view vocational education to reduce youth unemployment [2–4]. The existence of Vocational High Schools is expected to produce middle-level workers who are ready to use. The problems currently being faced by vocational high schools include the absence of a match between the competencies expected by the world of work and school graduates [5]. The success of programs at Vocational High Schools is not just graduating students but also from graduates' appearance when in work [6]. The learning objectives' success is determined by several factors, including the teacher's factor in implementing the teaching and learning process. The teacher can directly influence, foster, and improve students' intelligence and skills [7, 8]. The factors supporting the success of learning in Vocational High Schools are facilities and infrastructure following industrial needs. One example of the standard of facilities and infrastructure is the standard of the practice room and laboratory used for the learning process. The industrial revolution 4.0 demands learning to follow technological advances. In this era, it has a design in the form of interconnection through the Internet of People (IoP), transparency of information, technical assistance, decentralized decisions [9].

Technologies relevant to future education are distance learning, e-learning, virtual laboratories, and dynamics-based virtual systems. The education system in vocational high schools, including information and communication technology, has been widely used [10–13]. Technology in the form of advanced applications has been incorporated into various learning activities, including virtual laboratories [14], which have the goal of improving learning

performance [15] and training students to learn independently [16]. Distance education appeared first as a response to the development of education in the future. Leading institutions such as the Immersive Education Initiative and the Immersive Learning Research Network iLRN have conducted research related to the concept of education in the future. It is hoped that future education can remove barriers that limit access to education so that education is available to all who have the right to learn. The increasing demand for distance education at the vocational high school level is causing educators to adjust to formal education.

Virtual laboratories allow students to learn with limited facilities and infrastructure, but not many schools have facilitated this. A virtual laboratory is a laboratory that uses simulations to display the experimental process. In their research, Powell & Aldredge, 2016 defines a virtual laboratory as the software used to simulate a laboratory environment. A virtual laboratory can be a pre-practicum tool before students carry out the real practicum in a conventional laboratory. In its use, virtual laboratories have a good impact on student development. Virtual labs make it easier for students to connect theoretical and practical aspects [17]. Besides, virtual laboratories can also improve conceptual thinking and performance investigations [18]. The success of using a virtual laboratory must be supported by using the correct procedure. The success of learning activities in this laboratory must be supported by selecting the right tools and materials [19].

The virtual laboratory developed in this study contains additional material related to micropower generation's essential competencies. Micropower generation is a small-scale power plant that utilizes heat energy generated from a mechanism [20–22]. The most crucial component in a micro-generator is micro combustion. The development of virtual laboratories is carried out with the aim of students being able to understand micro combustion material and systems that work in real and clear ways. Saputro *et al.*, 2018 revealed that the demand for micro-scale energy generation needs would increase along with microtechnology development. This virtual laboratory is a learning media product compiled based on micropower generation research at the Energy Conversion Combustion Laboratory (ECCL) of Universitas Sebelas Maret Indonesia. Furthermore, the development of a virtual laboratory will be used as a learning media in Vocational High Schools (VHS), especially during the Covid-19 pandemic.

2 Research methodology

This research focused on developing instructional media, which uses four-D model (4D-model) development. The Four-D Model was developed by Thiagarajan *et al.*, 1976 [23]. The 4D learning device development model consists of 4 main stages: define, design, develop, and disseminate. The Four-D Model was chosen to produce a product in virtual laboratory media for micropower generation learning. Figure 1 shows the flow chart for the development of a virtual laboratory for micropower generation learning.

Figure 1: Flowchart Four-D Model [23]

Stage I: Define

The defined stage is the stage for determining and defining the requirements for micropower generation learning. The defined stage includes five main steps, as follows: 1) front-end analysis, 2) learner analysis, 3) task analysis, 4) concept analysis, and 5) specifying instructional objectives.

Stage II: Design

The design stage aims to design a virtual laboratory for micropower generation learning. Four steps must be taken at this stage, *i.e.*, (1) criterion-test construction, (2) media selection according to the characteristics of the material and learning objectives, (3) format selection, (4) initial design.

Stage III: Develop

The development stage is the stage to produce virtual laboratory products for micropower generation learning. The virtual laboratory's development is carried out in two steps:

(1) expert appraisal and (2) developmental testing. Experts in learning media from the center of learning Sebelas Maret University validated virtual laboratory for micropower generation learning practice. The instrument for validation of the virtual laboratory for micropower generation learning practice is shown in Table 1. Experts in the Energy Conversion Combustion Laboratory (ECCL) of Universitas Sebelas Maret Indonesia validated the subject micropower generation's content.

Table 1: The instrument for validation of the virtual laboratory for micropower generation learning practice

No	Indicator
Learning Design Aspects	
1	Elegant appearance and background suitability
2	The attractiveness of the background and layout design
3	Image placement suitability, navigation buttons
4	The media developed is easy to use and simple to operate
5	Media developed can be used anywhere and anytime
6	Media can help students in independent learning
7	The developed media can be run on the available devices
8	The media being developed is free of advertisements and there are instructions for use
9	Sound effect selection suitability
10	Can be managed / maintained easily
11	Application selection accuracy

Stage IV: Disseminate

The dissemination process is the final stage of development. The dissemination stage is carried out to promote virtual laboratories in Vocational High Schools. Due to the Covid-19 pandemic conditions the trials were carried out on a limited scale. Trials were conducted on small groups of VHS teachers.

The virtual laboratory media has been developed, and then its feasibility is tested by validators of learning media experts and practitioners from several Vocational High Schools in Indonesia. The feasibility test of instructional media was carried out to determine the effectiveness of virtual laboratories as micropower generation learning media in Vocational High Schools. This study used a qualitative approach for data analysis. Method and data triangulation was employed for data analysis. Interviews and question-

naires carried out triangulation methods with practitioners from 4 Vocational High Schools in Indonesia. Data triangulation was performed using additional literature data and validation data from learning media experts.

3 Result and discussion

3.1 Learning needs analysis

Learning is a process of interaction between students and the learning environment that aims to change behavior positively. The essential purpose of education at Vocational High Schools is to form students with competencies, knowledge, and skills according to the industry's needs or the job market. The success of learning at Vocational High Schools is influenced by several factors, such as students, teachers, and learning support facilities. The obstacle faced by Vocational High Schools in Indonesia is the availability of practicum apparatus relevant to the industry. Practical support facilities and infrastructure are needed to smooth the transfer of knowledge and skills from teachers to students. The results of preliminary observations made in vocational high schools in the field of a micropower generation found that learning could not be maximally carried out because the school did not have practical facilities.

The results of interviews with productive teachers in vocational high schools show that students still have difficulty understanding theoretical and practical learning. In the learning process, it was found that students still lacked self-confidence. This could be seen during the student competency test. The productive teacher who teaches this practice also admits that he still has difficulties in delivering the material. Therefore, it is not easy to understand students who have different abilities. The interview results showed that the learning obstacle in practice was the lack of tools and non-standard tools.

The observations and interviews with productive teachers in vocational high schools can be analyzed that the learning process has not been maximized. Inappropriate learning media and non-standard student practice places are factors that are not optimal in the learning process. The solution to the above problems is developing learning media that can accommodate teachers' transfer of knowledge. Virtual laboratory learning media is considered appropriate to answer existing problems. Virtual laboratories allow students to learn with limited facilities and infrastructure, but not many schools have facilitated this. Previous research results also said that the virtual laboratory makes it easy for students to connect theoretical and practical aspects [24].

3.2 Virtual laboratory development design

Digital technology simplifies the learning process by presenting innovation through the use of the internet in education Zawacki-Richter & Latchem, 2018 [23] states that digital devices are increasingly being adopted for learning and educational purposes. Based on the existing problems in micropower generation learning, a virtual laboratory was developed. A virtual laboratory is a multisensory software that has interactions to simulate certain practicum by replicating conventional laboratories. Correct procedures must support the successful use of virtual laboratories. The development of a virtual laboratory starts from making a storyboard, as shown in Table 2. The storyboard was devel-

oped from the results of defining micropower generation learning needs in Vocational High Schools. At this stage, the researchers conducted a needs analysis related to the needs for developing instructional media. The storyboard that has been compiled was consulted with two instructional media experts. After the storyboarding is completed, the virtual laboratory is created. The manufacturing stages include designing the product design, compiling the material’s text, and compiling the media assessment grid. Software used in media development includes Adobe Animate, Blender, Corel Draw, SuperMii, Pixel Lab, Kinemaster, and Camtasia. Table 3 shows the stages of making a virtual laboratory for micropower generation learning.

Table 2: Storyboard of a virtual laboratory for micropower generation learning

No	Page view	Information
1		<ol style="list-style-type: none">1. Click to start2. UNS and ECCL logos3. Micro Combustion learning
2		<ol style="list-style-type: none">1. Type the identity of the name
3		<ol style="list-style-type: none">1. Library room2. Machine lab3. Assessment room

Table 2: ...continued

No	Page view	Information
4	<p>Library room</p>	<ol style="list-style-type: none"> 1. Energy topic 2. Material topic 3. Fluid flow topic 4. Fuel topic 5. Flame stability topic 6. Energy conversion topic
5	<p>Machine Lab</p>	<ol style="list-style-type: none"> 1. Micro combustion assembly place 2. Part of the assembled object 3. Assembly orders
6	<p>Experiment Room</p>	<ol style="list-style-type: none"> 1. Material type 2. Kind of flame 3. Vulnerable speed 4. Sign of reducing fuel 5. Signs of adding fuel 6. Electric flame application 7. Experimental image 8. Graph of susceptible temperature velocity 9. The descriptive, experimental result
7.	<p>Assesment Room</p>	<ol style="list-style-type: none"> 1. Crossword menu 2. Evaluation menu 3. Election order

Table 3: Virtual laboratory design

No	Display Design	Information
1		The stages of making a design in a virtual laboratory use animate software. In its use, a virtual laboratory requires hardware that supports specific input from its users
2		Blender software is used to create a laboratory atmosphere in a virtual laboratory. Virtual laboratories can provide a complete laboratory with expensive equipment but at a low cost

Table 3: ...continued

No	Display Design	Information

3		Designing experimental tools using Corel Draw software

Based on storyboards and designs that have been refined by instructional media experts, a virtual laboratory media application is created for micropower generation learning. In the early stages of development, virtual laboratory applications were designed for personal computers or laptops. Figure 2 shows the initial appearance when opening the virtual laboratory application. Select “click to start”, a screen will appear, as shown in Figure 3. Students log in to the virtual laboratory by inputting a name, for example, “Marshall”. After a successful login, students will be guided to start learning micropower generation. Students can choose three available rooms (Figure 4): 1) library room, 2) laboratory machine and 3) assessment room. For students who are learning micropower generation for the first time, the learning sequence starts from rooms 1, 2, and 3. However, if students have studied micropower generation, they are allowed to choose which room to use. The

library room is a space where students can learn about the basics of micropower generation. There are six collections of reference materials related to micropower generation, such as 1) energy, 2) material, 3) fluid flow, 4) fuel, 5) flame stability, and 6) energy conversion (Figure 5). A machine laboratory is a room where to conduct experiments on micropower generation, as shown in Figure 6. In the Machine laboratory room, students learn about: 1) tools and materials for making micropower generation, 2) Students learn how to assemble micropower generation (Figure 7), and 3) students learn to analyze the effect of fuel flow and air on the stable flame and temperature produced by the micro combustor (Figure 8). Students can measure their abilities in the assessment room, consisting of filling out crossword puzzles and analyzing micro combustion from the assembly stage to the simulation, as shown in Figure 9.

Figure 2: The virtual laboratory home screen

Figure 6: Machine laboratory

Figure 3: Log in virtual laboratory

Figure 7: Assembling the micro power generation

Figure 4: Rooms in a virtual laboratory

Figure 8: Display simulation in the virtual laboratory

Figure 5: Library room

Figure 9: Assessment room

3.3 The results of validation and virtual laboratory testing

Before being tested on students, the virtual laboratory learning media was validated by learning media experts and micropower generation learning content experts. Learning media validation is carried out to determine the feasibility

of the media that has been developed. The results of validation by instructional media experts obtained input and improvement, as shown in Table 4. Simultaneously, the input from micropower generation learning content experts stated that the virtual laboratory content of learning materials was by Vocational High School students' needs.

Table 4: The results of validation by learning media and micropower generation experts and

No	Before revision	After revision
1	Advice from instructional media experts: icons and logos are moved downwards to add aesthetic value and media appeal.

2	Advice from learning media experts: Virtual laboratory need to add a room in the virtual laboratory by including an assessment room. This aims to measure students' abilities after learning with a virtual laboratory.

3	Suggestions from content experts in micropower generation learning: the display of micro combustion experiments should be added with a graph of the results of this experiment so that students know the results of what they are doing.

The expert appraisal is one of the steps in the 4D development model [23]. The media expert validation results show that the virtual laboratory learning media shows relevant results for learning in vocational high schools. Virtual laboratory learning media is feasible because media development is carried out effectively and efficiently and can be used easily by students and teachers as distance learning during a pandemic. The stage after media validation is a trial through the practitioner. Practitioners from four different vocational schools tested the virtual laboratory media intending to determine the level of media effectiveness. The results of the interviews from the four practitioners produced different responses. The virtual laboratory learning media supports the essential learning of learning practices of micropower generation. This is because the virtual laboratory's design is easy to understand. The same thing was expressed by the first school practitioner who said that the virtual laboratory could be an interactive learning media for students.

During the pandemic, a virtual laboratory for micropower generation learning can support distance learning Indonesian VHS. The use of virtual labs increases student achievement levels and positively impacts student attitudes [24]. The virtual laboratory that has been developed provides a different learning style. Virtual laboratory for micropower generation learning is positive because it impacts students not getting bored quickly in learning. Another thing that must be considered is that the students' abilities are not the same. This was revealed by practitioners in the fourth school, saying that virtual laboratories cannot support learning because not all students have laptops at home. One practitioner's suggestion said that a virtual laboratory could be applied during a pandemic as long as it can be used on cellphones or android platforms. Overall, in-depth interviews with learning practitioners in Vocational High Schools show that the developed virtual laboratory is suitable for micropower generation learning.

4 Conclusion

Effective learning must be followed by selecting the right media. The selection of media in learning aims to get students closer to real cases that are more concrete to convey messages and goals. Media in the learning process has an important role. In today's digital era, the media must adapt to the conditions of students. In the next few decades, it is believed that virtual laboratories' popularity will increase due to the rapid advancement of technology. In a simulation in a virtual laboratory, it will produce an interactive

learning environment and increase learning effectiveness. The virtual laboratory that has been developed is believed to increase students' knowledge because there is structured material.

The success of learning at Vocational High Schools is influenced by several factors, such as students, teachers, and learning support facilities. The obstacle faced by Vocational High Schools in Indonesia is the availability of practicum apparatus relevant to the industry. Based on the existing problems in micropower generation learning, a virtual laboratory was developed. Virtual laboratory media can be used to support distance learning. The virtual laboratory that has been developed provides a different learning style. The media expert validation results show that the virtual laboratory learning media shows relevant results for learning in vocational high schools. Micropower generation learning content experts stated that the virtual laboratory content of learning materials was Vocational High School students' needs

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