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PAPER

Effectiveness of Mobile Virtual Laboratory Based on Project-Based Learning to Build Constructivism Thinking

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ABSTRACT

Constructivism as a theoretical basis in education is key, considering that this approach views learning as an active process where students play a role in constructing their own knowledge. Apart from that, the development of mobile and virtual technology is increasingly growing in the educational environment. This research explores the effectiveness of this approach in building constructivist thinking in learning electrical installation practices. The method used in this research is the 4D Define, Design, Develop and Disseminate model. The research instruments include an expert review validity questionnaire and an evaluation instrument for students' perceptions of the effectiveness of the Mobile Virtual Laboratory Based on Project-Based Learning in building constructivism. The research results show that the Mobile Virtual Laboratory is valid based on expert assessment, in addition there has been a significant increase in students' understanding of concepts and practical skills, with a high level of satisfaction with the use of the Mobile Virtual Laboratory. So, it can be concluded that the Mobile Virtual Laboratory based on Project-Based Learning can be an effective tool to support constructivist learning in electrical measurement practice. The results of this research open opportunities for further research on how Artificial Intelligence can build constructive thinking.

KEYWORDS

mobile virtual laboratory, project-based learning, constrictivism, electrical measurement

1 INTRODUCTION

Higher education today is required to continue to innovate and adapt to technological developments, especially in the context of learning electrical engineering [1]. Constructivist thinking, which emphasizes the active role of students in building their knowledge, has become an important cornerstone in updating learning methods [2]. The emergence of the need to integrate constructivist approaches in the learning of

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electrical measurement practicum requires a good understanding of concepts and practical skills [3].

The high demand for the use of mobile technology in the world of education. The application of this concept can be enriched by technology integration, one of which is through the development of a Mobile Virtual Laboratory based on Project-Based Learning (PjBL). Electrical measurement practicum as an integral part of the electrical engineering curriculum requires a learning approach that provides practical experience, reflection, and active knowledge construction.

Several previous studies have described the success of Mobile Virtual Laboratory in supporting active learning. Like research conducted by [4], this research shows that the integration of the Virtual Laboratory significantly improves students' understanding of electromagnetic concepts. The results illustrate that the use of mobile technology facilitates active and exploratory learning, in line with the principles of constructivism. Although not specifically focused on electrical engineering, these findings provide a basis for further exploration in more specific contexts. In line with this, [5] compared the application of the Project-Based Learning (PjBL) and paper-based approaches in chemistry subjects. The results show an increase in students' practical skills and conceptual understanding. However, the shortcomings in the integration of mobile technology and the lack of focus on practical electrical measurements make this research a relevant starting point for more in-depth research. Likewise, the results of research conducted by [6] provide insight into the use of virtual simulations in electrical circuit practicum. Findings show that students tend to be more engaged and gain better understanding through simulations. However, the lack of Project-Based Learning aspects and the need for further mobility indicate the potential for developing a PjBL-based Mobile Virtual Laboratory which could provide greater benefits.

From the results of previous research, it can be concluded that the combination of Mobile Virtual Laboratory, Project-Based Learning, and a focus on electrical measurement practicum has not been fully explored. Therefore, this research aims to fill this gap by finding out how effective the PjBL-based Mobile Virtual Laboratory is in increasing constructivist thinking in Electrical Installation Practicum learning?

2 LITERATURE REVIEW

The constructivist approach in education is very important, especially in learning that requires practical skills such as Electrical Installation Practicum, with an emphasis on the active role of students in building their own knowledge. According to constructivism theory, learning is an active construction process in which students develop their understanding through interaction with learning materials and personal experiences [7]. In the context of electrical engineering education, the integration of Mobile Virtual Laboratory (MVL) and Project-Based Learning (PjBL) is a promising strategy for creating constructivist learning experiences.

A study highlights that Virtual Laboratory brings a new dimension to the learning process, allowing students to interact with practical learning concepts through virtual simulations and experiments [8]. The implementation of Virtual Laboratory not only enriches learning by visualizing complex concepts, but also provides opportunities for students to learn independently and exploratively. Similar research in the context of educational learning confirms that Virtual Laboratory can improve students' understanding of learning material [9]. The findings show that students are more involved and enthusiastic in understanding learning concepts through the Virtual Laboratory.

Meanwhile, the PjBL approach was introduced as a strategy that supports constructivism in education [10] PjBL encourages student-centered learning, where they engage in practical projects or assignments that reflect real-world situations [11]. PjBL can improve students' critical thinking and problem-solving skills [12], which is of course in line with the goal of constructivism in developing active thinking. In the context of electrical engineering, this approach provides students with the opportunity to apply their knowledge in a contextual and relevant context.

The integration of Virtual Laboratory and PjBL in the context of electrical engineering learning is the focus of research to explore its potential effectiveness in building students' constructivist thinking. In the study, it was found that the PjBL-based Virtual Laboratory was successful in improving students' critical thinking skills in language learning [13]. The results of this study indicate that students involved in MVL-based projects show significant improvements in their analysis, synthesis, and evaluation skills of electrical engineering concepts.

Other research highlights that the integration of Virtual Laboratory and PjBL can create a more interesting and motivating learning experience [13]. The findings show that students tend to be more involved and enthusiastic in completing Virtual Laboratory-based projects than conventional learning. The interactive nature and authenticity of learning provided by the PjBL-based Virtual Laboratory creates an environment that supports constructivism, where students not only receive information but also actively build their understanding.

In the context of this research, constructivism theory, supported by previous research, provides a strong theoretical basis for the development and implementation of a Mobile Virtual Laboratory based on Project-Based Learning. This concept provides an opportunity for students to engage in more active learning, allowing them to build an understanding of electrical engineering concepts through exploration, collaboration, and practical application. While constructivism theory provides a philosophical and pedagogical foundation, previous research shows that the integration of Virtual Laboratory and PjBL provides an effective practical solution in achieving these goals. So, this research aims to determine the effectiveness of the Mobile Virtual Laboratory Based on Project-Based Learning in increasing constructivist thinking in Electrical Installation Practicum learning.

3 METHOD

The research design used in this study is based on the 4D model. The 4D Model, also known as the Four-Dimensional Model of Research and Development, is a systematic framework commonly used in developmental studies. It consists of four iterative phases, namely Define, Design, Develop, and Disseminate [14].

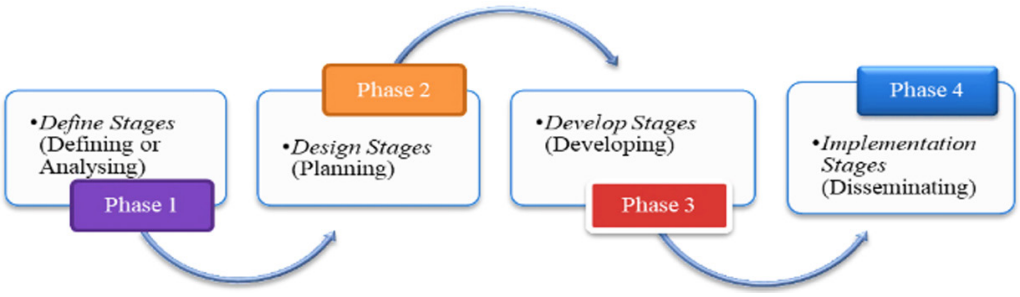

Fig. 1. Research procedure

Define, During the Define stage, two primary tasks are executed, specifically observing and evaluating the attributes of the research population. The purpose of observation is to acquire a precise comprehension of real-life conditions, while the assessment of population characteristics is crucial for identifying the research sample to be involved in the study. These tasks play a vital role in establishing clear guidelines and defining the research scope, ensuring that the study remains focused and pertinent to the specified objectives. Through comprehensive observations and the scrutiny of population characteristics, the research can advance with an informed approach aligned with the intended goals.

Design, In the Design stage, two crucial steps need to be undertaken. The initial step involves crafting a prototype for the Mobile Virtual Laboratory that corresponds to the electrical measurement practice syllabus. During this phase, the educational content is tailored to align with the relevant syllabus material. Subsequently, the focus shifts to constructing a Project-Based Learning (PjBL)-oriented Mobile Virtual Laboratory. These sequential steps ensure a methodical approach that is in harmony with the designated educational goals and syllabus criteria. Concurrently, in this design stage, a research tool in the form of a questionnaire was developed. This questionnaire will be used to assess the validity and effectiveness of the platform in improving constructivist thinking.

Develop, During the Develop phase, several crucial tasks need to be executed. Initially, researchers implemented a Mobile Virtual Laboratory grounded in Project-Based Learning (PjBL) using a previously established framework. Subsequently, the PjBL-based Mobile Virtual Laboratory underwent testing with a predetermined group of students. The objective is to gather data and insights regarding the feasibility of the PjBL-based Mobile Virtual Laboratory in enhancing students' proficiency in electrical measurement practical exercises. The obtained data and feedback will serve as the basis for evaluating the ongoing development of the PjBL-based Mobile Virtual Laboratory and identifying potential enhancements for the subsequent phase. Through this Develop stage, researchers can generate a PjBL-based Mobile Virtual Laboratory that is both pertinent and efficacious, ultimately contributing to improved student learning outcomes in electrical measurement practical courses. Therefore, the Develop stage is a pivotal step in crafting learning solutions that cater to the practical needs of students.

Disseminate, In the Dissemination phase, diverse actions are undertaken to efficiently communicate research outcomes to pertinent stakeholders. Initially, data was gathered through questionnaires distributed to a select group of students. Subsequently, the acquired data undergoes descriptive analysis to derive meaningful insights. Following this, the analysis results are interpreted and presented in a comprehensive research report. Furthermore, researchers draft scientific articles intended for publication in international journals. The primary aim of this stage is to widely distribute and convey research findings within the scientific community and among practitioners in the field of engineering education.

3.1 Population and sample

The population in this study were students of the electrical engineering education study program, Faculty of Engineering, Padang State University, totaling 42 people. This research uses a total sampling technique, where the entire population is sampled.

3.2 Instrument and data analisi

The instruments used in this research consisted of validity instruments and constructivism instruments. The validity instrument indicators can be seen in Table 1. The following:

Table 1. Validity instrument indicators

Indicator	No. Item
Curriculum Coherence	1,2,3
Operational	4,5,6,7
Performance	8,9,10,11,12
Security	13,14,15,16
Design	17,18,19,20

This questionnaire was given to experts in the field of electrical installation and educational media to obtain input and assess validity. The validity assessment given by the expert is analyzed using the Aiken's V validity coefficient formula:

$$v = \sum s/[n(c-1)] \tag{1}$$

The PjBL-based Mobile Virtual Laboratory is declared valid if the assessments from all experts have met the following criteria:

Table 2. Validity criteria

Criteria	Category
>0.6	Valid
<0.6	Invalid

Next, constructivist instruments were used to evaluate the impact of using the PjBL-based Mobile Virtual Laboratory. This questionnaire was designed by considering several factors which can be seen in Table 3:

Table 3. Constructivism instrument indicators

Indicator	No. Item
Active Participation	1,2,3,4,5
Contextual Understanding	6,7,8,9,10
Independent Problem Solving	11,12,13,14,15
Creativity and Flexibility of Thinking	16,17,18,19,20
Acceptance of Disadvantages	20,21,22,23,24,25

Students involved in research will be asked to fill out a constructivism questionnaire after using the PjBL-based Mobile Virtual Laboratory. Data from this questionnaire will be analyzed using the following formula.

$$NA = \frac{S}{M} \times 100\% \tag{2}$$

The level of effectiveness of the PjBL-based Mobile Virtual Laboratory in students' constructivist learning abilities is determined based on data analysis with the following criteria:

Table 4. Categories of constructivism effectiveness level

Indicator	No. Item
85–100	Very effective
75–84	Effective
60–74	Moderately effective
55–59	Less effective
0–54	Ineffective

Before giving the constructivist instrument to students, a validity examination is conducted using the product moment correlation. This involves comparing the calculated "r" value with the critical "r" value from the table for degrees of freedom (df) equal to n-2, where, in this instance, n represents the number of samples in this study, specifically n = 42. Therefore, the df can be computed as 42-2 = 40. Given df = 40 and alpha set at 0.05, the critical "r" value from the table is determined as 0.3932 (based on the two-sided test at df = 40). According to the rule, if the calculated "r" value surpasses the critical "r" value (0.3932), then the questions in the questionnaire can be deemed valid. The ensuing results were as follows:

Table 5. Validity test results of the constructivism instrument

No. Item	Rcount	Rtable	Category
1	0.348	0.3932	Valid
2	0.628	0.3932	Valid
3	0.676	0.3932	Valid
4	0.621	0.3932	Valid
5	0.645	0.3932	Valid
6	0.624	0.3932	Valid
7	0.592	0.3932	Valid
8	0.628	0.3932	Valid
9	0.655	0.3932	Valid
10	0.590	0.3932	Valid
11	0.681	0.3932	Valid
12	0.437	0.3932	Valid
13	0.603	0.3932	Valid
14	0.696	0.3932	Valid
15	0.593	0.3932	Valid

(Continued)

Table 5. Validity test results of the constructivism Instrument *(Continued)*

No. Item	Rcount	Rtable	Category
16	0.718	0.3932	Valid
17	0.613	0.3932	Valid
18	0.701	0.3932	Valid
19	0.534	0.3932	Valid
20	0.495	0.3932	Valid
21	0.534	0.3932	Valid
22	0.501	0.3932	Valid
23	0.465	0.3932	Valid
24	0.486	0.3932	Valid
25	0.482	0.3932	Valid

Based on the results of the validity test of the constructivist instrument, it was found that 25 statement items were valid so that they could be used to measure the effectiveness of the PjBL-based Mobile Virtual Laboratory in developing constructivist thinking. Next, the instrument was tested for reliability with Cronbach's Alpha, the results were 0.830 > 0.60, so the instrument was declared reliable. The results can be seen in Table 6 below:

Table 6. Validity test results of the constructivism instrument

Cronbach's Alpha	N of Item
0.830	25

4 RESULT

In the design phase of the PjBL-based Mobile Virtual Laboratory, we developed learning content specifically designed to combine the PjBL approach with mobile technology. This application is designed to include the six main steps of the PjBL learning model, which consist of Problem Orientation tailored to the learning topic, planning group activities, completing projects, making project reports, presenting reports, and evaluation.

4.1 Intro

Displays the main title of the learning material "Electrical Measurement Practicum", along with related icons that represent each sub-material contained in this educational media. The page includes two different buttons: a 'continue' button that takes the user to the Home Page to select the desired learning material, and an 'exit' button that allows the user to close the learning media interface. The initial view can be seen in Figure 2 below.

Fig. 2. Intro

4.2 Home page

Providing a variety of lecture materials allows students to select content based on their academic needs. Each material selection button is accompanied by an icon representing the corresponding sub-material, facilitating navigation of the chosen topic. Additionally, the page features a laboratory menu guiding students to the virtual laboratory for electrical installation practical exercises. The main page layout is illustrated in Figure 3 below.

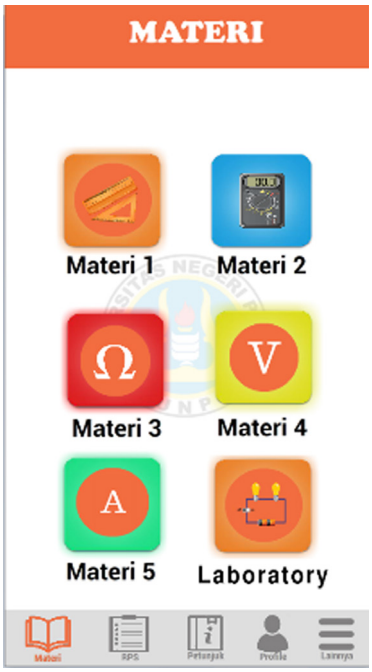

Fig. 3. Home page

4.3 Material page

The learning content is showcased through textual information along with instructional videos by professors. Additionally, animated videos are incorporated to capture students' interest and elucidate abstract concepts with more tangible examples. Students have the flexibility to replay the videos based on their individual learning pace, enabling them to comprehensively grasp the material. The visual representation of the material page is depicted in Figure 4 below.

Fig. 4. Material page

4.4 Dashboard project

When students log in to the "Project Dashboard", they will be greeted with a "Project Description". Here, students can deeply understand the goals, scope, and expectations of the projects they work on. Next, "Work Steps" guide students through each stage of working on a project. It's like a road map outlining the steps to take. Once the project is complete, students can easily upload their report via the "Upload Report" feature. In the Final menu, to give students the opportunity to present their work, there is a feature "Upload Presentation Project Video". Here, students can share videos of their presentations, showing teachers and classmates the process and results of their projects. The project dashboard display can be seen in Figure 5 below.

Fig. 5. Dashboard project

4.5 Virtual laboratory

The simulation practicum page is a virtual laboratory that gives students the opportunity to carry out interactive and practical electrical measurement simulations. In this environment, students can access a variety of accurately simulated electrical measurement equipment and tools. They can design experiments, set parameters, and view measurement results in real-time. The simulation lab page is designed to create a learning experience like a physical laboratory, with advantages in flexibility and accessibility. Students can run experiments without time constraints or physical equipment limitations, allowing them to repeat measurements and deepen their understanding of electrical measurement concepts.

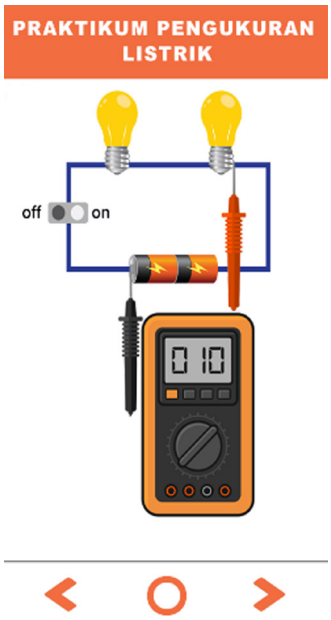

Fig. 6. Virtual laboratory

4.6 Discussion room

Specifically designed to make it easier for students to communicate and discuss various aspects of the project they are working on. If students encounter certain obstacles or problems while working on a project, they can open a new discussion topic in this room, allowing their friends to provide points of view, suggestions, or solutions. Apart from that, the Discussion Room also provides opportunities for students to respond and interact with existing topics, enriching discussions with various views and experiences. This creates a collaborative learning environment, where each student can benefit from the expertise and experience of his or her peers. Sometimes students need further guidance or clarification from the teacher. Therefore, this application has a chat feature that allows students to communicate directly with lecturers. Through this feature, students can get quick answers or additional guidance they may need. The appearance of the discussion room can be seen in Figure 7 below.

Fig. 7. Discussion room

4.7 Validity test

This development stage tests the validity of the product that has been created. The validity test was carried out with the validity test process starting with a usage test by 3 technology and education experts who are experienced in the field of electrical measurement practical learning. The experts were then asked to evaluate the content according to the questionnaire provided. During the evaluation process, experts provide valuable inputs regarding potential improvements and enhancements to the content. The assessments from the experts were analyzed to obtain the following results.

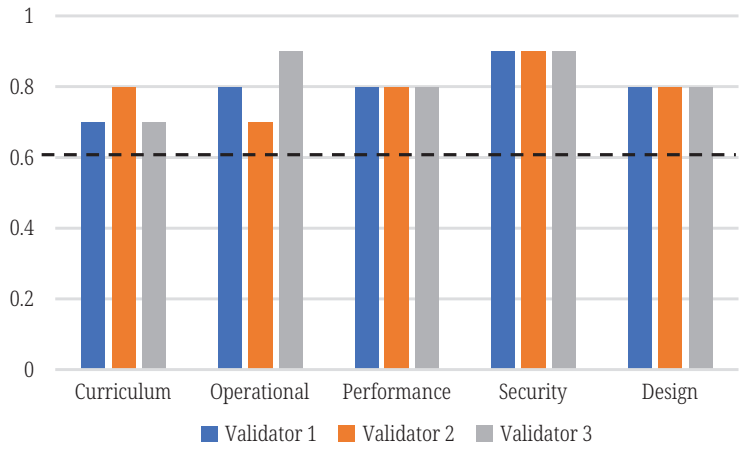

Fig. 8. Validity Result

The results of the validity test show that all aspects that are indicators in assessing the validity of learning media, namely Curriculum Coherence, Operations, Performance, Security and Design, were declared valid by the three validators involved in the evaluation process. Based on the value from these results, it can be concluded that the overall validity value of the indicators exceeds the minimum validity limit of ≥ 0.6. Therefore, based on the results of this validity test, the PjBL-based Mobile Virtual Laboratory is declared valid. This indicates that the learning content in this application has been declared valid and relevant by experts in the field.

4.8 Test the effectiveness of constructivism

The constructivism effectiveness test was given after students carried out learning using PjBL-based Mobile Virtual Laboratory by 48 electrical engineering students at Padang State University in the electrical measurement practicum. Respondents were asked to provide assessments and responses according to the questionnaire given. The collected data was then analyzed to obtain the following results.

Table 7. Constructivism effectiveness test results

Indicator	Scor	Category
Active Participation	85	Very effective
Contextual Understanding	78	Effective
Independent Problem Solving	82	Effective
Creativity and Flexibility of Thinking	80	Effective
Acceptance of Disadvantages	75	Effective

The results of the constructivism effectiveness test show that all aspects of the indicators to be declared effective. This shows that users feel that using the PjBL-based Mobile Virtual Laboratory can help them build understanding and creativity actively based on learning experiences, which are the goals of constructivist thinking.

This laboratory opens opportunities for further exploration in the development of innovative learning technology that can integrate artificial intelligence to increase the effectiveness of technology-based education.

5 DISCUSSION

The research results showing the validity of all aspects that are indicators provide a solid basis for believing that the research instruments used in measuring constructivism have high accuracy and precision. With guaranteed validity, it can be assumed that the instrument consistently measures the desired aspects and is related to constructivist thinking. This is an important first step in ensuring the reliability of research results. Furthermore, the results of the constructivism effectiveness test, which show that all aspects used as indicators are declared effective for developing constructivist thinking, provide confirmation that the use of these instruments in the context of constructivist learning has a positive impact. This effectiveness can be interpreted as the instrument's ability to achieve the main research objective, namely triggering, and developing constructivist thinking in respondents. In other words, these results provide empirical support for the concept and theory of constructivism as a philosophical and pedagogical foundation in education. The high validity and effectiveness of research instruments provide a strong basis for concluding that the implementation of constructivism in the context of this research is not just a concept but can be measured and produced effectively in learning practice.

The results of this research are in line with previous research findings, which show that the integration of Mobile Virtual Laboratory based on Project-Based Learning (PjBL) in the education sector can make a positive contribution to students' understanding of concepts and practical skills [15]. Like other research that emphasizes the effectiveness of the Mobile Virtual Laboratory in improving critical thinking, this research strengthens the argument that the approach can be applied successfully in Geography Practicum [8]. Some of these findings confirm that the integration of mobile technology in practical learning can facilitate constructivist learning experiences, where students not only receive information but also actively engage in exploration, collaboration, and practical application. The continuity of these results with previous research provides a strong basis for further development in designing electrical engineering learning approaches that are innovative and relevant to the development of technology-based learning.

6 CONCLUSION

The Virtual Laboratory based on Project-Based Learning (PjBL) can be effective as a medium for fostering students' active role in building their knowledge through interaction with learning materials and personal experiences, which are the basis for constructivist thinking applied to electrical installation practical learning. By applying this concept in the PjBL-based Mobile Virtual Laboratory, students can engage in exploratory, collaborative, and contextual activities that allow them to understand electrical installation practicum in depth. Constructivism emphasizes learning as a process of knowledge construction that is unique to everyone, where students not only receive information, but are also active in constructing their own

understanding. Based on the research results, the use of the PjBL-based Mobile Virtual Laboratory is not only a practical means for learning electrical engineering, but also as a forum that encourages constructivist thinking, creativity and active problem solving in the context of electrical measurement practicum.

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