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Project-Based Learning with Simulation Approach for Digital Control System Vocational Practicum

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ABSTRACT
The Project-based learning approach utilizing simulation for vocational techniques in the field of automation is proposed in this paper. Practicum of automation engineering technology students at the applied undergraduate level is contained in courses such as sensors, microcontrollers, digital controls, IoT, embedded systems or the like. Learning is carried out with practicum methodology using Wokwi simulation applications for simple system control such as leds, switches, and motors. This paper discusses Wokwi devices and simulation implementation to improve students learning ability in the Digital Control System course.

Keywords: *Project-based simulation learning, Digital Control, Course Evaluation.*

1. INTRODUCTION

Restrictions on human social activities during the Covid-19 pandemic around the world have caused the closure of learning activities in schools from elementary to tertiary education [1-4]. According to UNESCO, during the Pandemic, more than 90% of enrolled students (1,5 billion young people) in 188 countries lost their education due to school closures [5]. Indonesia is also one of the countries that implemented a school closure policy and replaced it with learning from home. This policy changed the habits of educators from face-to-face at school to distance learning [6].

Distance learning is an alternative as a response to overcome the crisis. With all the benefits provided by distance learning, there are challenges that need to be researched, especially related to distance learning in the fields of Science, Engineering Technology and Mathematics (STEM) including vocations that prioritize laboratories or practice in learning. During the pandemic, many researchers have conducted studies on the use of virtual laboratories to support STEM learning. The use of Online Project Based Learning in biology lessons has been tested and concluded that Blended Learning and Project-Based Learning are quite influential in improving creative thinking skills [7]. The implementation of virtual laboratories in chemistry subjects has been researched with the result that the use of virtual laboratories can be used to achieve learning objectives [8].

Virtual laboratory or better known as simulation technique is an alternative for students who due to conditions cannot physically attend the laboratory and do practicum in the vocational field. Practicums using simulation techniques generally have the aim of helping learners acquire certain skills, such as aircraft pilots, surgeons, or electricians. The use of simulation techniques has also changed the paradigm of engineering expert work from numerous, dangerous, expensive and tedious calculations, to simple, safe, cheap and better understanding [9-10].

Simulation is cheap and safe because it is basically a model of physical phenomena using mathematical formulas. Users can observe an operation without actually performing the operation but only by using simulation software. This operation is developed using models designed to be as close to the original as possible at no cost when modifications are required to be made. Understanding using simulations will also be better because real-time response support and the variety of operations supported vary greatly. Simulation has become a great teaching aid or instructional tool for basic electronics courses and has improved students' ability to understand the behavior of multiple electronic circuits, providing a valuable training experience to achieve learning objectives [11].

Referring to the covid policy during the pandemic, direct practicum in the vocational study program faces many obstacles. Meanwhile, if practical tools are sent to

each student for practicum individually, it costs money. Therefore, researchers conducted research on digital control system courses that have practicum components using embedded systems as controllers of a process using the Wokwi application, an online simulation application so that students can practice anytime, anywhere, and can be applied directly to real applications in real embedded system modules.

2. METHOD

2.1. Project-Based Learning

Methodologically, project-based learning (PBL) is to reinforce students' natural desire to learn by prioritizing learning based on student issues or needs and helping to integrate knowledge in practical ways and produce relevant and meaningful learning [12].

Still according to [12], Project-based work is a more flexible way of organizing the teaching and learning process and emphasizes the relationship of different curricular content around a topic center that serves to organize and connect the different aspects and disciplines that make up the project.

Meanwhile, project-based work is a real and authentic instruction strategy, where students can solve problems, make decisions and perform complex and challenging tasks [13]. It also offers students the possibility of working relatively independently for long periods of time and culminates in the preparation of presentations and final products.

2.2. Simulation

Simulations represent real activities with a mathematical modeling approach. Simulation applications for example are for weather forecasting, analyzing, and designing actuators or sensors in control systems, as well as visualization virtually for educational purposes [14].

There are two mathematical models used, stochastic and deterministic. Stochastics are dominant at a certain degree of randomness and are used on complex activities with difficult predictability. While deterministic models are static approaches using algebraic or dynamic equations using differential equations or difference equations.

2.3. Wokwi

Wokwi is an online electronic simulator that can be used to simulate devices without a real device. Wokwi supports several types of devices such as ESP32, STM32, Arduino, Raspberry Pi Pico, screen, sensor, motor and WiFi simulation [15]. In addition, Wokwi can also be used to simulate Motor, DHT22 sensors to measure temperature and humidity. Wokwi is free, web-based and can be accessed on the https://wokwi.com/

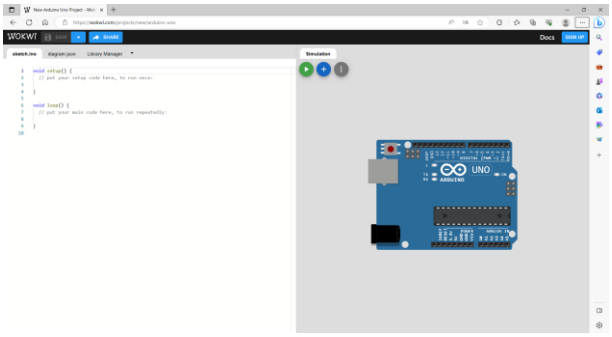

Figure 1 Wokwi interface.

2.4. Sampling and Analysis

There were 42 students participating and were divided into two groups. The first group of 20 students used Simulated PBL-based learning and the other group used PBL with real tools. The division of groups is based on the normalization of the results of the required courses, namely the Continuous Control System. Early before PBL, students were taught theory and introduction using Wokwi simulation and Arduino microcontroller through online learning (Zoom meeting). Furthermore, students are assigned to determine the project to be created and given time to complete the project. At the end of the session, students are asked to present a project and

Table 1. Questionnaire for evaluation of the Project-Based Learning with Simulation Approach.

No	QUESTIONAIRE	1	5
1	How is Wokwi's interface	Less User Friendly	Very User Friendly
2	How complete are Wokwi's tools	Less Complete	Very Complete
3	How to use Wokwi	Very Difficult	Very Easy
4	How Wokwi supports understanding control systems	Less Support	Very Supportive
5	How design a control simulation with Wokwi	Very Difficult	Very Easy
6	How satisfied you are using Wokwi	No. Comment	Very Satisfied
7	How actively you expose Wokwi	Never	Very Often
Head 1	Ctl+1	Reference title	Alt+T
Reference item	Alt+R		

run an Online simulation for the PBL Simulation class and run the final project with a real system or arduino. Simulated PBL participants filled out a feedback form and a set of questionnaires to answer. This form is designed to get student feedback regarding simulated PBL evaluations. Meanwhile, the results of PBL achievements in each group were also compared.

The questionnaire is presented in **Table 1** given at the end of the digital control systems course. The assessment is conducted using a qualitative evaluation of the PBL conducted and measures the level of comfort and understanding. The questionnaire consisted of seven questions that sought to obtain anonymous opinions from learners about the ease and effectiveness of various Wokwi features using a five-point Likert scale ranging from 1 to 5.

4. RESULTS AND DISCUSSION

Figure 2 displays the final grade results of each group. The first group to use PBL with real tools had an average of 74.76 with a yellow chart-like spread. While group 2 with an average of 76.42 with a distribution like a red picture. Group 2 using simulation-based PBL was 2.23% superior. This figure, although not too significant, is quite encouraging with no additional costs to buy practicum equipment, but it is able to increase final results and understanding. In addition, the use of simulation-based PBL makes it easier for students to conduct various kinds of experiments. The use of simulation-based PBL shifts the distribution leaning to the right or towards higher in practice and understanding.

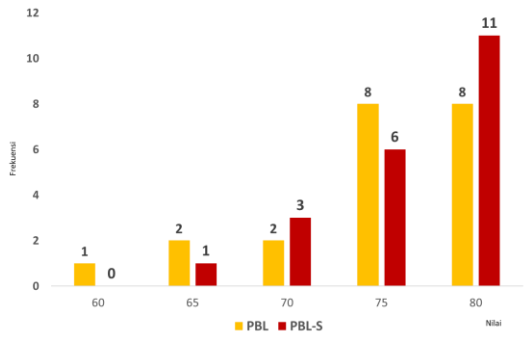

Figure 2 Students' general score.

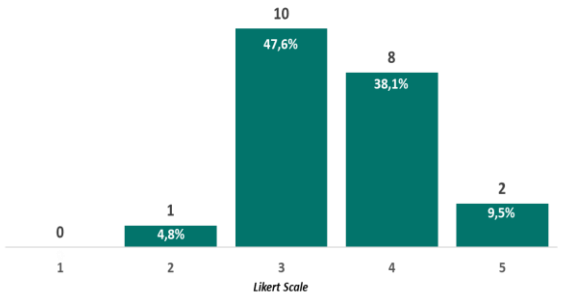

Figure 3 Feedback on Wokwi interface.

Broadly speaking, Wokwi's interface is quite user friendly. Of the 21 respondents, 95.2% of respondents answered the easy to very easy interface (47.6% scale 3, 38.1% scale 4 and 9.5% scale 5) while only 1 respondent answered less easily (**Figure 3**).

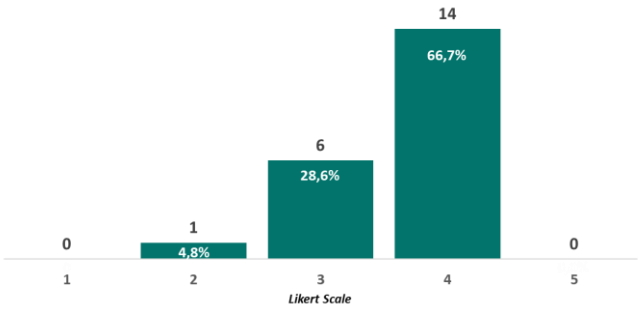

Figure 4 Feedback on the completeness of Wokwi tools.

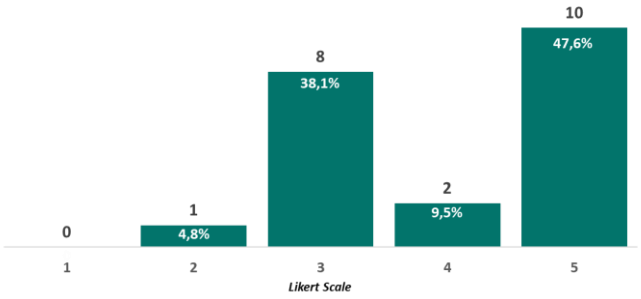

Figure 5 Feedback on Wokwi's ease of use.

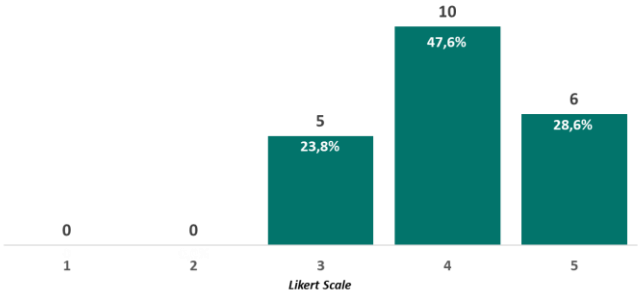

Figure 6 Feedback on Wokwi's support in understanding control systems.

Meanwhile, 95.2% of respondents also agreed that the tools provided by Wokwi were complete (**Figure 4**), 28.6% of respondents chose scale 3 (complete) and 66.7% of respondents answered scale 4 (quite complete).

As shown in figure 3 and figure 4, **Figure 5** shows the distribution of respondents who chose ease of use of Wokwi. More than 95% of respondents agree with the ease of using Wokwi.

The interesting thing is the use of Wokwi to support the Digital Control System course. One hundred percent of respondents agreed that Wokwi supported their understanding of control systems. **Figure 6** shows that

23.8% of respondents answered a scale of 3, 47.6% answered a scale of 4, and 28.6% answered a scale of 5.

5. CONCLUSION

In this paper the effectiveness of project-based learning using Wokwi simulation software is described in the subject of digital control systems. With project-based learning using simulations, students can better understand control systems, be more diverse in doing various practicums and be cheaper. This makes students more flexible in doing practicum and this methodology has improved learning outcomes. The survey conducted shows that Wokwi's simulation tools are user friendly, complete tools, and easy to use to support project-based learning in practicum in the Digital Control Systems course.

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