

## Hybrid Learning Integrated Remote Laboratory: A Pedagogical Strategy for Future Practicum Learning

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**Abstract**—The hybrid learning integrated remote laboratory, an innovation in educational technology, is a practical and real-time solution that allows students to access and interact with laboratory equipment remotely via the internet network. This research aims to analyze the implementation and effectiveness of this model in an embedded systems practicum course. The study, conducted using a quasi-experimental method, involved 35 students in the experimental group and 36 in the control group. The learning model in the experimental group was implemented with a differentiated approach, allowing students to participate in face-to-face learning in the laboratory or attend online. The technology in this research was built with an interactive user interface in the form of an e-learning integrated remote laboratory application, providing online students with access to learning materials, discussion forums, assignments, chat, video conference, and an online microcontroller coding editor. The use of the online microcontroller coding editor empowers students to create programs and control physical equipment in the laboratory, such as Arduino modules, several sensors, and output devices, remotely and in real-time. Descriptive analysis and t-tests were used to analyze students' comprehension of the embedded systems course. The test results showed a difference in the average academic achievement of students, with the learning outcomes of the experimental group students being higher than those of the control group. This model, therefore, demonstrates its impact on optimal and practical learning in the embedded system course.

**Keywords**— Hybrid learning; remote laboratory; embedded system; flexible learning.

Manuscript received 30 Nov. 2023; revised 15 Dec. 2023; accepted 9 May 2024. Date of publication 30 Jun. 2024.  
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### I. INTRODUCTION

Hybrid learning is a popular topic and continues to develop in the world of education today. This is due to digitalization in the education world which forces the transformation of traditional learning into technology-based learning, thereby allowing flexible learning in terms of space and time [1]. Hybrid learning is suitable for the current and future digitalization of the world of education [2], [3], hybrid learning aims to combine face-to-face benefits with distance learning to overcome the approved challenges and ensure an effective learning process [4], where the results of bibliometric studies showed that there has been very significant growth in the use of hybrid learning in higher education, especially during the last 2 years, even exceeding the development of online learning [5] and this growth will continue to increase since hybrid learning has a considerable impact on the future of higher education [6], where hybrid learning will no longer be an option but will become a

necessity that every educational organization must have [7], so that hybrid learning has become a new direction for educational reform in higher education and even in vocational education [5], [8], [9].

Researchers continue to carry out the design and development of hybrid learning. According to [5], there has been an increase in research interest in fields related to hybrid learning, technology acceptance models, and interactive learning environments. Several previous studies related to the design, development, and implementation of hybrid learning have been carried out and have had a positive impact, such as Jia and Zhang[10], who stated that the hybrid learning model could improve students' abilities, independent learning abilities, and also make it easy for teachers to analyze and adjust teaching methods, hybrid learning also has a significant effect on spatial thinking abilities [11]. The other related research results of Douglas de Matos Magnus showed that the hybrid learning model has a positive impact on students, including factors that include increasing students' critical

sense and problem-solving skills, providing more opportunities for peer-to-peer discussions, as well as improving students' interest and motivation to learn practical work in the laboratory for students even in engineering majors [12]. Other findings research affirms that practical learning is possible in hybrid contexts and is no less real than on campus [13].

Based on research trends related to the design, development, and application of hybrid learning in higher education, limited research exists regarding the development and effectiveness of hybrid learning in practical learning. Therefore, it is very important to continue to develop hybrid practical learning so that it can provide an in-depth learning experience.

In this research, we analyzed the development and effectiveness of implementing hybrid learning, which is integrated with one of the technologies in IR4.0, namely Remote Laboratory. IR4.0 technologies have an essential role in the development of current knowledge, such as Remote Laboratories, Virtual Laboratories, Augmented Reality, Robotics, IoT, and others [14], [15]. The use of remote laboratory aims to answer the opportunities and challenges in developing hybrid learning, which is to create hybrid learning in a more interactive practical course [5], [16]–[18]. Utilization of remote laboratories allows students to interact with practical equipment online because remote laboratory has certain advantages, such as users can control, get accurate visualization of information, and interact directly with laboratory equipment [19]–[21], students can define, start, stop, pause, and repeat the experiment just as if they were close to the equipment [22]. This remote laboratory integrated hybrid learning is appropriate to the subject area or course with dominant practical material.

The novelty of this research is how to implement hybrid learning integrated remote laboratory model activities with a differentiated model arrangement in embedded system courses and what the effect is on students' academic achievement.

## II. MATERIALS AND METHOD

This research used a quasi-experimental design. The quasi-experiment design focuses on the treatment and outcome; the data were taken from pre-test and post-test to examine whether hybrid learning integrated remote laboratory model can improve student's achievement in embedded system courses. The subjects of this research were students in the fifth semester of the computer engineering department at Universitas Putra Indonesia YPTK Padang. They were divided into two groups (experimental group and control group). The experimental group comprised 35 students, and the control group comprised 36. The experiment group pursued all the hybrid learning integrated remote laboratory model activities for 12 weeks, while the control group was taught in a traditional lecture-based learning manner. The numerical data from the pre-test and post-test were analyzed using descriptive analysis and t-test techniques using SPSS software.

The hybrid learning integrated remote laboratory being built consists of the following:

1) *Infrastructure*: a server connected to the internet and cameras.

2) *Physical equipment* used in experiments placed in the laboratory, namely the Arduino module with several input and output devices, including infrared sensors, TCR5000 sensors, DHT11 sensors, RTC, LCD, LED, Buzzer, etc.

3) *e-learning integrated remote laboratory application* as a user interface that provides an interactive interface with student management features, learning material management, discussion forums, assignments, chat, video conference, and online microcontroller coding editor.

4) *Real-time data*: data generated during the experiment is returned to students in real-time.

## III. RESULTS AND DISCUSSION

### A. The Implementation of Hybrid Learning Integrated Remote Laboratory Model on Embedded System Course with the Differentiated Model

Hybrid learning has several different models for structuring its implementation [7], [23], [24], as follows:

1) *The differentiated model*: in this model, every student attends class simultaneously at the same time, whether online or face-to-face students.

2) *The multi-track model*: Students register for the online or face-to-face track at the beginning of learning. This multi-track model provides a different track between the online and face-to-face, so it is as if they have two separate classes.

3) *The split A/B Model*: In this A/B split model, a lecturer can have face-to-face meetings by maximizing students' interaction when they meet in the classroom. At the same time, activities outside the school can take the form of learning videos with the flipped classroom concept, rotating stations, engaging in meaningful independent practice, or doing independent projects. In other words, synchronous learning is done face-to-face, and asynchronous learning is done at home so students can work at their own pace. In this research, the hybrid learning integrated remote laboratory application uses the differentiated model to allow students who take part in the teaching and learning process online or face-to-face to carry out learning activities simultaneously; this design can be seen in Figure 1.

The implementation of hybrid learning has four learning dimensions [2], [25], namely: Live Synchronous is held in the form of learning activities in the classroom, practical activities in the laboratory, mentoring or job training, delivering material, presentation discussions, exercises, and exams. Synchronous Virtual Collaboration is a collaborative teaching format that involves simultaneous interaction between lecturer and students. This collaborative activity is carried out using e-learning. This facility will be used to communicate between lecturers and students during class hours. Asynchronous Virtual Collaboration is a collaborative teaching format that involves interaction between lecturer and students which is delivered at different times. The facilities used in this learning activity are online discussion boards or discussion forums and e-mail. Self-paced asynchronous is an independent learning format at different times where students can study material provided by the lecturer in the form of teaching material modules or do assignments and exercises

online. Besides, in self-paced asynchronous, the lecturer can study the lesson or materials by linking to other teaching resources.

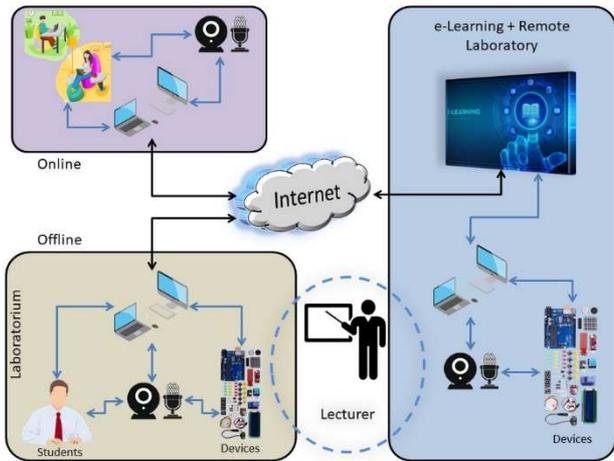


Fig. 1 The Design of Hybrid Learning Class Integrated Remote Laboratory on Embedded System Course

Based on Figure 1, the students were divided into two groups: the first group of students who took face-to-face learning and the second group of students who took part in online learning. Face-to-face students take part in embedded systems courses in the laboratory. The laboratory facilitates practical materials and equipment that will be used by students. Online students can learn from anywhere via their computers connected to the internet. Each online student has an account to access learning materials, discussion forums, assignments, chat, video conferences, and online microcontroller coding editors, and of course, they can access several practical materials and equipment too (infrared sensors, TCR5000 sensors, DHT11 sensors, RTC, LCD, LED, Buzzer, etc.). Cameras in the laboratory allow online students to observe practical materials and equipment in real time; apart from that, the video conference and chat features enable online students to discuss and collaborate with offline students.

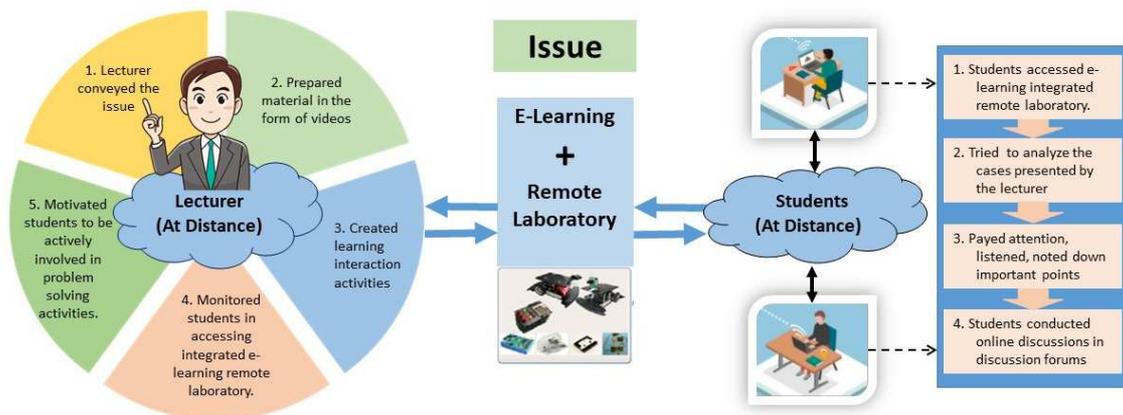


Fig. 3 Lecturer and students' activities in the issue syntax

### B. Hybrid Learning Integrated Remote Laboratory Models Activities on Embedded Systems Course

Hybrid Learning integrated remote laboratory models' activities on embedded systems courses are divided into 3 phases: pre-class, in-hybrid, and post-class. Experimental group students will follow these 3 phases for 12 weeks in the learning process (Figure 2).

1) *Pre-Class*: Pre-class activities are in the learning dimension of Asynchronous Virtual Collaboration and Self-Pace Asynchronous, which includes 2 syntaxes, namely (1) issue and (2) investigation. Pre-class activities are flexible, where students study outside of class according to the place and time they want; students follow the lecturer's instructions via the remote laboratory-integrated e-learning platform.

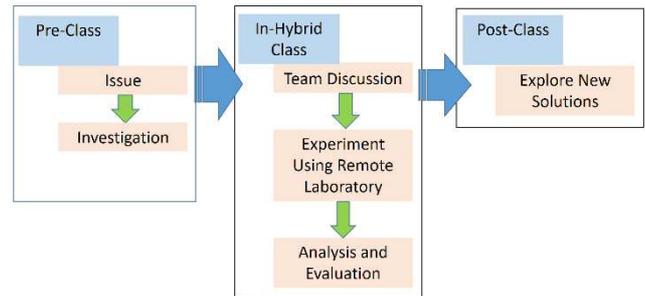


Fig. 2 Hybrid learning activity phase integrated with remote laboratory

In the issue syntax, the activity begins with presenting a problem based on current phenomena presented by the lecturer on the e-learning integrated remote laboratory platform. Then students will analyze the problem presented and conduct an online discussion in the discussion forum. In the investigation syntax, students must carry out investigations by collecting data or information via the internet, books, observations, and interviews with lecturers or tutors to support their analysis and predict several solutions that can solve the problems presented individually. However, at this stage, students can still access e-learning to discuss with each other in forums (Asynchronous virtual collaboration). The lecturers and students' activities can be seen in Figures 3 and 4.

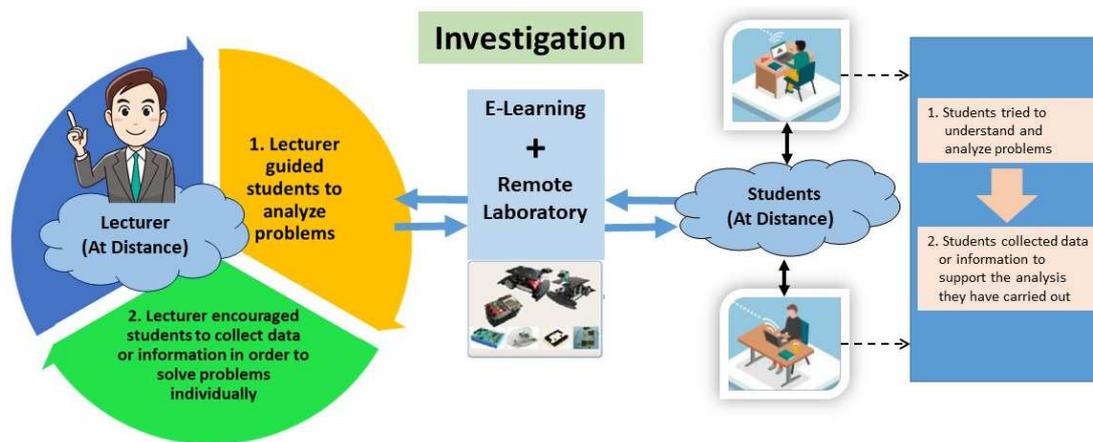


Fig. 4 Lecturer and students' activities in the investigation of syntax

2) *In-Hybrid-Class*: In-hybrid class activities are based on Live Synchronous dimensions and Synchronous Virtual Collaboration, which includes 3 syntaxes, namely (1) team discussion, (2) experiment using remote laboratory, and (3) analysis and evaluation. Entering this phase, students can attend directly in class (face-to-face) or participate via video conference (Synchronous virtual collaboration).

In this team discussion syntax, students are divided into 7 groups consisting of 4-5 people in each group. This syntax provided more opportunities for students to interact directly with the lecturer in the classroom face-to-face. They can interact directly with the lecturer outside the classroom via video conference. Apart from interacting with the lecturer, students can also collaborate, both students present in class and online students; this is the main advantage of implementing hybrid learning with a differentiated model. In

the experiment using remote laboratory syntax, students who attend class or attend online can access practical equipment available in the laboratory. The students who attend class can access practical equipment available in the laboratory, such as Arduino modules, several types of sensors such as infrared sensors, TCR5000 sensors, DHT11 sensors, and several other devices such as RTC, Liquid Crystal Display, Light Emitting Diode, Buzzer, etc. The students who attend online can access this practical equipment too via the remote laboratory system. They can see the results of practical equipment control via video meetings on their monitor screens. In addition, the students who attend class can collaborate with online students, making the learning process more interactive. Next, in the analysis and evaluation syntax, students analyze and evaluate the experiments carried out and can convey the obstacles the lecturer faces. The lecturer and students' activities in the in-hybrid class phase can be seen in Table 1.

TABLE I

LECTURER AND STUDENTS' ACTIVITIES IN THE HYBRID-CLASS PHASE OF THE REMOTE LABORATORY INTEGRATED HYBRID LEARNING MODEL IN THE EMBEDDED SYSTEMS COURSE

Learning Dimensions	Syntax	Lecturer activities	Students' face-to-face activities	Students' online activities
Face-to-face and Synchronous virtual collaboration	Team discussion to solve problems (Collaboration)	<ol style="list-style-type: none"> <li>The lecturer conducted video conferences for online students through an integrated e-learning remote laboratory.</li> <li>Formed a team of students face-to-face and online</li> <li>Guided students in discussions to determine the best solution used by the team.</li> <li>The lecturer monitored the progress of the synchronous discussion between students in face-to-face classes and online hybrid courses.</li> <li>The lecturer responded to questions from students both online and face-to-face.</li> </ol>	<ol style="list-style-type: none"> <li>Students sat in groups.</li> <li>At this stage, students collaborated with other students, either those who came to the class or those who presented virtually, to build a better understanding and find the best solution to the problem that had been presented based on their existing knowledge.</li> <li>Students consulted and discussed hypotheses (solutions) with the lecturer, who, as facilitator and mentor, guided them.</li> </ol>	<ol style="list-style-type: none"> <li>Students joined video conferences through integrated e-learning remote laboratory.</li> <li>Students knew their respective teams.</li> <li>At this stage, students collaborate with other students, either those who come to the class or those who present virtually, to build a better understanding and find the best solution to the problem that has been given.</li> <li>Students consulted and discussed the hypothesis (solution) with the lecturer, who, as a facilitator and mentor, guided them.</li> </ol>

Learning Dimensions	Syntax	Lecturer activities	Students' face-to-face activities	Students' online activities
Face-to-face and Synchronous virtual collaboration	Experiment using remote laboratory	<ol style="list-style-type: none"> <li>1. Explained the project that was completed by the students face-to-face and online.</li> <li>2. Monitored and oversaw the progress of the experiment face-to-face and online</li> <li>3. Guiding experiments carried out by students face-to-face and online.</li> <li>4. Testing student project results face-to-face and online</li> </ol>	<ol style="list-style-type: none"> <li>1. Students implemented the solutions that have been discussed into project form.</li> <li>2. Work on project tasks creatively.</li> <li>3. Working on project tasks together with groups, either face-to-face or online.</li> </ol>	<ol style="list-style-type: none"> <li>1. Student implemented the solutions that have been discussed into project form through integrated remote laboratory e-learning</li> <li>2. Work on project tasks creatively.</li> <li>3. Working on project tasks together with groups, either face-to-face or online.</li> </ol>
Face-to-face and Synchronous virtual collaboration	Analysis and Evaluation	<ol style="list-style-type: none"> <li>1. Prepare group work assessments</li> <li>2. Evaluate student projects</li> <li>3. Give feedback</li> <li>4. Measuring the achievement of student learning outcomes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Follow up and receive assessment of group work projects.</li> <li>2. Convey the obstacles faced in group work.</li> <li>3. Understand the conclusions about the project made.</li> </ol>	

3) *Post-Class*: The post-class phase implements a new solution syntax. In this syntax, students can explore the knowledge and skills they acquired in the in-hybrid class

phase by accessing practical equipment using a remote laboratory independently and, of course, with time and a flexible place (Figure 5).

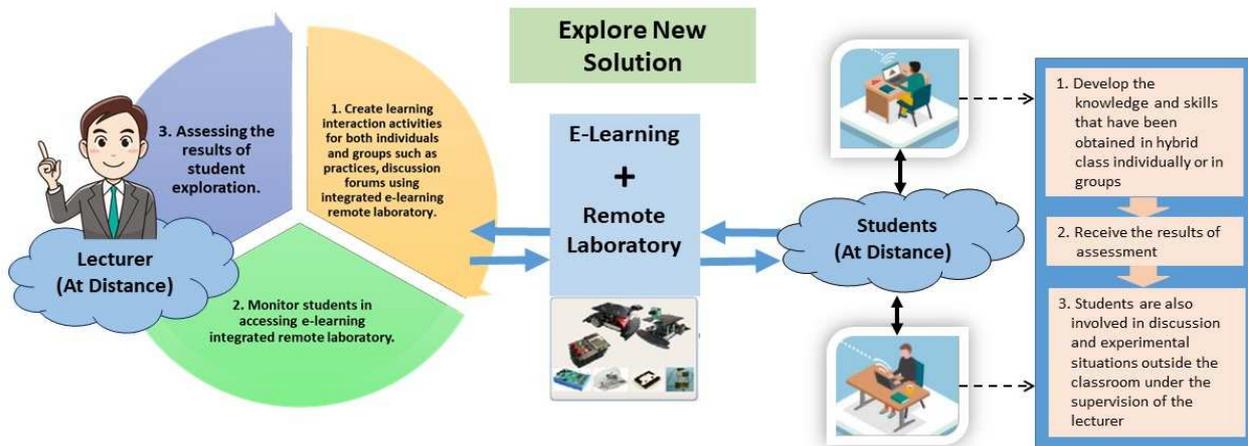


Fig. 5 Lecturer and students' activities in the explore new solution syntax

### B. The Effectiveness of Implementing a Hybrid Learning Integrated Remote Laboratory Model on Students' Abilities in Embedded Systems Course

To assess students' abilities in embedded system courses, students are given two stages of tests, namely pre-test and post-test, in the form of objective questions and essays validated by experts. The tests were given to the experimental group and control group. Students' learning outcomes in the experimental group can be seen in Figure 6, and students' learning outcomes in the control group can be seen in Figure 7.

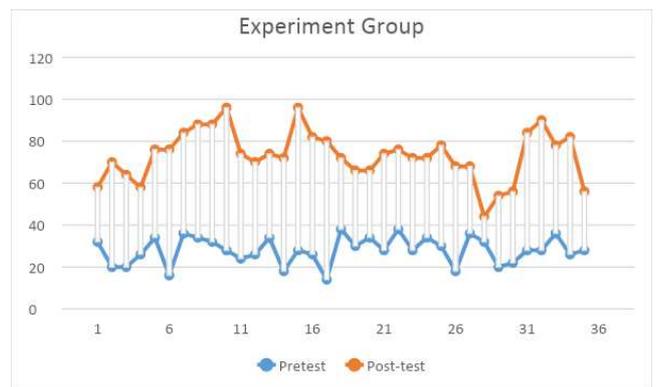


Fig. 6 Students learning outcomes in the experiment group

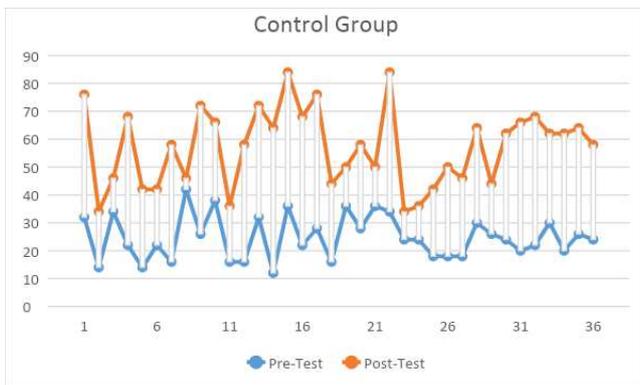


Fig. 7 Students learning outcomes in the control group

Table 2 shows descriptive data of the experimental and control groups. In the experimental group, the mean value of the pre-test = was 28.06, post-test = 73.20. In contrast, in the control group, the mean value of the pre-test = 24.89, post-

test = 57.00, so it can be stated that the average value in the experimental group was higher than the control group.

TABLE II  
DESCRIPTIVE DATA OF EXPERIMENTAL AND CONTROL GROUP

Sample Group	Test	Min	Max	Mean	Std. Deviation
Experimental Group	Pre-test	4	38	28.06	6.480
	Post-test	4	96	73.20	11.894
Control Group	Pre-test	2	42	24.89	7.789
	Post-test	4	84	57.00	13.984

The normality test of the data showed a sig value above 0.05, so the data is declared normally distributed. The homogeneity test of the data showed a significant value of 0.116, so the data can be declared homogeneous and continued at the t-test analysis stage. Next, an independent sample t-test analysis was carried out to see differences in students' learning abilities.

TABLE III  
INDEPENDENT SAMPLE T-TEST RESULT

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper	
Students' Academic Achievement	Equal variances assumed	2.530	.116	5.251	69	.000	16.200	3.085	10.046	22.354
	Equal variances not assumed			5.263	67.814	.000	16.200	3.078	10.058	22.342

The results of the data analysis showed a difference between the experimental group and the control group. This is indicated by the value of Sig. (2-tailed) = 0.000, so it can be stated that the hybrid learning integrated remote laboratory model is effective and can improve students' learning outcomes (students' embedded system programming abilities).

The advantages of implementing the hybrid learning model integrated remote laboratory in this research are (1) students can use the available chat feature so that online and face-to-face students can discuss in writing while learning takes place in the laboratory; (2) students can use the video conference feature to discuss directly during learning, either with students face-to-face or with lecturers; (3) online students can program the Arduino module directly in the laboratory and see the results of the controlled hardware on their monitor wherever they are, this display comes from camera footage in the laboratory; (4) students can access practical equipment whenever they want so that learning flexibility occurs in terms of time and place.

In the pre-class phase, activities have been designed to stimulate students to conduct investigations and search for information related to the new knowledge and problems based on current phenomena they have acquired, thus supporting students to develop higher-level thinking and student analysis. This aligns with previous studies that case-based teaching in hybrid learning makes students better understand the

application of theory knowledge. It can introduce multiple perspectives, promote understanding and reflection on problems, and help students develop analysis and synthesis skills [26], [27]. Case studies are suitable for use in embedded systems learning [28]. In the in-hybrid-class phase, students interact actively and collaborate with students present in the class or students who attend via video conference, thus supporting students' collaboration and communication skills within the team. These findings were also shown in similar studies; the application of hybrid learning increases student's collaborative interactions [4], even when collaborating, students show their critical thinking, problem-solving, and communication skills in completing the tasks given [29], [30], [31]. The post-class phase provides exploration space for students to access practical equipment online with flexible time and space. This phase increases student activity and interest in the learning process to develop their understanding and abilities. This is in line with Jia & Zhang's research, which stated that hybrid learning is conducive to improving students' interests and cultivating their comprehensive abilities [10], [32], [33], and also improve their discipline [34], in addition, hybrid learning increases students' involvement in the learning process individually [4], and hybrid learning is suitable and acceptable for students with different levels of self-regulation (high, medium, and low) [35].

Furthermore, the hybrid learning integrated remote laboratory application supports embedded system

programming practices so it can be carried out flexibly. This is in line with a previous study which stated that hybrid learning is suitable for online coding learning [35]; the implementation of remote laboratories increases individual student interaction with practical equipment; besides that, the availability of class recordings and other digital resources enhances flexibility without detrimentally affecting student performance. Students could choose how to access the course content based on their personal preferences and circumstances, which likely leads to increased engagement and satisfaction with the learning experience [36], [37]. This shows the suitability of hybrid learning with flexible learning. The demand for flexible learning continues to grow due to the lifestyle of the Z Generation, which is closely intertwined with technology [38] It allows lecturers and students to save time by attending classes online from anywhere.

#### IV. CONCLUSION

This research analyzes the implementation and effectiveness of hybrid learning integrated remote laboratory model activities in embedded systems courses. This research used a quasi-experimental design. The research subject consisted of 35 students in the experimental group and 36 students in the control group. Hybrid learning integrated remote laboratory is implemented with a differentiated model arrangement. The implementation of this model has 3 activity phases, namely pre-class, in-hybrid-class, and post-class. In the pre-class and post-class phases, students completed online learning through integrated remote laboratory e-learning according to the time and place they wanted. In contrast, in the in-hybrid-class phase, learning is carried out simultaneously, where some students come to the classroom and some attend meetings via video conference so they can do practicum together. The descriptive data showed that in the experimental group, the mean value of the pre-test = was 28.06 and the post-test = 73.20, while in the control group, the mean value of the pre-test = was 24.89, the post-test = was 57.00, the average value in the experimental group was higher than the control group. The independent sample t-test analysis showed that the value of Sig. (2-tailed) = 0.000, so it can be stated that the hybrid learning integrated remote laboratory model is effective in improving student learning outcomes in embedded systems practice so it can be the choice of flexible, practical learning model in the future. Furthermore, this research contributes to the innovation of distance learning technology and the development of flexible learning models.

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