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Assessing the Performance of Remote Laboratory

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***Abstract*—Remote laboratory facilities have been accessible from the internet for more than a decade. Since the COVID-19 pandemic, remote laboratories have become an option for technical and vocational schools and high schools to continue the laboratory learning process. The biggest challenge in implementing remote laboratories is the physical equipment and assessment of the facility. Not only technical support but also usability and support for students should be considered. On the technical side, the physical equipment must be fully controlled independently by the student. The remote laboratory performance was tested using the Web Applications Performance Test (WAPT) tool. Questionnaires for students were used to determine the ease of use and accessibility of the application of this laboratory. This research found that the software and equipment were quite good in the remote laboratory that was being developed. Likewise, the control on the student side is also well accessible. There is a significant weakness that one user can only use this remote laboratory at a time. It cannot be multi-user at a time.**

Keywords—remote laboratory, WAPT tool, assessing the performance

I. INTRODUCTION

Education related to science and technology is closely related to hands-on learning and trouble-shooting skills in a laboratory [1,2]. Learning activities in the laboratory are a very important part of the educational experience [2]. The implementation of the practicum requires workshops and laboratories with minimum service standards of industrial competence [1]. In vocational education, practicum learning is very dependent on the conditions and completeness of the laboratory it uses. If the laboratory conditions are good enough and complete, then the practical study can be carried out accordingly and vice versa. However, currently, the on-site in-class laboratory learning process is a difficult thing to do, due to the COVID19 pandemic, so classroom learning has to switch to online learning. To face the limitation of the situation, one possible solution is to conduct a laboratory learning process that is controlled and can be accessed remotely [3].

Learning process using remote laboratory have many challenges, including remote laboratory development and assessment of remote laboratory implementation [2]. Learning process using remote laboratory, allow student to perform direct interaction with the distant system as close as to actual work on the real equipment [4]. Learning process using remote laboratory not only allow greater accessibility, but have potential to bridge the gaps in development of laboratory skills by allowing students to work with physical laboratory equipment remotely [3]. This model will improve teaching efficiency, providing considerable time and money savings. Therefore, the success and effectiveness of students in achieving specific competencies also increases [5].

II. THEORETICAL OF LABORATORY

One of the most important things to produce students who have excellent psychomotor skills is to provide a learning process that is carried out in the laboratory. Various technology and engineering laboratories are created to obtain laboratories that can change the economic costs of educational technology, and also change the paradigm of educational effectiveness at the same time [6-8]. This topic is often debated in comparing different types of laboratories, namely laboratories with traditional practice approaches versus remote access laboratories and simulated versions.

The traditional physical laboratory pro group immediately thought that an engineer needed to be in direct contact with the equipment. Real-world conditions of physical laboratories will have many unexpected data possibilities that occur as a result of equipment problems, noise, or other uncontrolled variables. While on the other hand, the simulation group shows the high monetary, space, and time requirements of laboratory practice as the main considerations. The setup and unloading time may be longer than the actual experiment performance time. They claim that simulation is not only cheaper but also better because more labs can be done than with physical labs. However, there is a third alternative to consider, namely a remotely operated laboratory called a remote laboratory [9,10]. Remote labs take up space but are much less than the physical lab space needs. Operating real data using a web interface is much cheaper and easier to operate.

Laboratories are classified into 3 types [11], namely: (a) Hands-on Laboratory, (b) Simulated Laboratory and c) Remote Laboratory. Hands-on Laboratory has the concept of involving real physical laboratory equipment activities in carrying out the practicum process. There are 2 characteristics that distinguish

this type of laboratory, namely: (1) All the equipment needed to carry out the practicum is in the form of physical/equipment that is set in such a way; (2) students who do physical practicum must be present in the laboratory directly and require a large enough room, instructor, time, and other infrastructure and support, all of which require high costs. A Simulated Laboratory is a simulation process as a duplication of experiments in the real laboratory. All the infrastructure needed for this laboratory is not actual but is simulated on a computer. Simulation costs are not necessarily lower than hands-on laboratories [12]. Meanwhile, the remote laboratory has characteristics similar to the hands-on lab. The clear difference between a hands-on lab and a remote lab is the distance between the experiment and the person doing it. In the hands-on lab, the equipment is mediated through computer control, but in contrast, in the remote lab, the researcher obtains data by controlling the equipment remotely.

III. Remote Laboratory Development

The developed remote laboratory can be accessed remotely via wired or wireless telecommunications media and can even be accessed via the internet. This laboratory can be used for practicum with the following learning scenarios: (a) Experiments are carried out during lectures (b) Distance lectures (students are at home) (c). End to End Scenario (students can conduct experiments in other university laboratories by accessing these laboratories for a fee). In higher education, students can carry out various simulation activities that are needed as a sophisticated learning resource. However, technically, quality practicum learning must be carried out with real laboratory equipment [13,14]. Therefore, remote laboratories, which also provide laboratory facilities for interfaces to students such as simulation software, are sufficient to meet the demands of real laboratories [15]. On a certain scale, it becomes a better substitute when hands-on practicum activities cannot be carried out.

The development of a remote laboratory is one of the laboratory development innovations that can provide students with real simulations of experiments that can be carried out anywhere. Each student can learn hands-on and can gain practical experience according to their study schedule. In addition, expensive equipment on one workstation can be shared in different programs and with different schedules and knowledge levels. Remote laboratory development can be seen in Figure 1.

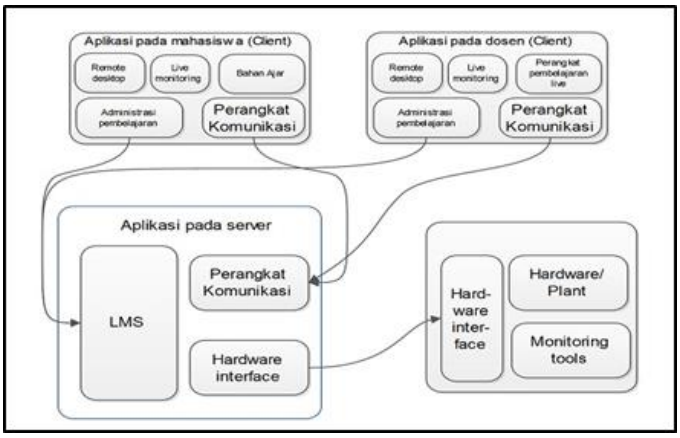

Fig. 1. Remote laboratory development.

The physical equipment considered for remote experimentation is an industrial automation system with controlling the objects using Programmable Logic Controller (PLC). The used of PLC generally in industrial environment. In education, PLC used as one practicing in the laboratories for increasing the skill of the students in this subject. PLC is a micro computer which has communication protocols, input and output ports to control and manage the processes or systems [5]. The physical equipments must be fully observable remotely. Not only the state of the physical equipment of interest but also the surrounding environment should be observable [4].

IV. Assessment for Remote Laboratory

laboratory is conducting an accurate evaluation and assessment of the learning success of students in running remote practicum. The main obstacle in addition to infrastructure that must be complete also requires efforts to develop an authentic, accurate, accurate assessment or evaluation model that can clearly describe the processes and competencies of students that have been achieved. Remote laboratory assessment models need to be carried out in real-time because experiments can be configured quickly and run using the internet. Monitoring and observation are carried out with various devices that can access the activities of students who carry out practical activities directly. Remote laboratory procedures and assessments utilize actual hands-on laboratory data and numerous data during practicum. The effectiveness of the assessment is relatively complex because the technology underlying the laboratory is only one of many possible factors that can affect competency achievement [12].

The remote laboratory can be applied as a software-related technology instead of other laboratory technologies. To guide decision-making in choosing this technology requires a model of how these technologies can be compared with each other. The proposed model has a cognitive component, which assumes that many different factors will affect student cognition, which in turn will lead to different learning outcomes. Three types of easily measurable results: student test

scores provide a strong indication of what has been done and then responses to questions built to test hands-on knowledge next skills taught in laboratory assignments [12,16].

The instructional assessment model development cycle includes the analysis, planning, development, implementation, evaluation, and revision phases. The evaluation and revision phases are continuous activities carried out at each phase throughout the development cycle. After each phase, an evaluation of the results of the activity should be carried out, make revisions, and proceed to the next phase [17].

V. DATA ANALYSIS AND DISCUSSON

The developed remote lab model underwent several revisions based on the results of discussions with the team and experts. The remote model made is equipped with a laboratory management system (RLMS). RLMS manages users who can use this remote laboratory, only users who have been enrolled by the teacher or admin can use or access this remote laboratory.

The use of remote laboratories is also managed by way of reservation/booking time slots, so there is no use of remote laboratories that clash with one another's schedules. High-resolution cameras are installed to allow remote viewing of the physical laboratory. Users can access the physical laboratory via remote desktop software. A controller is installed to adjust the lighting or lamps. When the user accesses the remote laboratory at night, the user can turn on the lights remotely and turn them off if not needed, besides that this controller is also used to reset the physical laboratory if an error occurs in the PLC.

After the feature has been designed, testing or feedback from users is carried out on the interaction of these features. A total of five users as testers of features in use via the internet. Based on the results of feature testing by the user, there is only one feature that is still problematic, namely the feature of turning on and off the lights, when the Lamp On or Lamp Off button is clicked, it connects to the controller (relay) but the lamp does not give any action. However, what is more, emphasized in designing this GUI are the main features and display design to make it more responsive and easier for users. Because the color aspect has a main role in the display design. The success of a display design is determined, among other things, by how to include elements of color that can create a strong impression and be pleasing to the eye. Bright colors are not dazzling they don't cause eyestrain, headaches, and tension.

For the experiment, the performance of students who took the Industrial Automation Practicum course was divided into two groups: 1) On-site students, 2) Online students. All courses, assignments, tests, and laboratories are delivered equally to both groups of students. The only difference between the two groups is that on-site students are students who are physically present on the main university campus. On-site students can do practicum using the physical equipment in the lab. Distance students do not live on the main campus. Meanwhile, online students are those who conduct laboratory experiments using a remote laboratory via the internet. They have to use a client-side software application that has been developed to observe their movements via a web camera. To complete the laboratory experiment, both groups of students were given the same adequate amount of time. Table 1 shows the questionnaire used for student picking tests on a remote laboratory that is being developed.

TABLE I. TEST QUESTIONS FOR REMOTE LABORATORY DEVELOPMENT

Questions
Practical activities in the laboratory, motivated me to learn more about industrial automation systems
Learning methods in the laboratory help me visualize and understand industrial automation
I am familiar with the hands-on practice of industrial automation with experience in the lab
Remote Laboratory helps me learn the basics of industrial robot control and programming
Overall, I really enjoy and it helps with learning like this

An interesting conclusion can be drawn about the comparative assessment between the two surveyed groups. The results of the direct assessment based on grades showed that both groups of students got the same learning experience from the robot programming lab. There was no significant difference in performance between the two groups. In addition, the relatively close assessment results from laboratory tests and reports are valid indicators that both groups understand the subject matter. For the initial study, the results were satisfactory enough to prove that there was no significant difference in students' responses to working with remote and local equipment. From the results of the qualitative survey, it is also known that remote laboratory practice has a positive influence on students' motivation to learn remotely.

VI. CONCLUSION

Based on the experience gained with the systems presented in remote engineering technology education, it is very convenient and cost-effective to utilize remote laboratory technology in online education. This system allows providing direct learning experiences to various students who study online, who do not have direct access to university laboratory facilities due to pandemic restriction.

The overall qualitative and quantitative results from the initial assessment show that the remote laboratory system is very effective in online education because online learning students get the same experience as on-site students. The remote laboratory system also contributes to increasing online student motivation.

It should be noted that many other factors that influence student learning outcomes were not measured in this preliminary study. A larger-scale study will be carried out in the future by researchers to capture some of the influencing factors and investigate the effectiveness of remote laboratories in more depth.

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