WEB-BASED AND THINVNC REMOTE LABORATORY IMPLEMENTATION TO SUPPORT STUDENTS SKILLS IN MECHATRONICS COURSE TO FACE THE INDUSTRIAL REVOLUTION 4.0

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Abstract

Engineering or science courses require the use of laboratories during a pandemic outbreak and normal days. A practicum method is designed to address the constraints of the COVID-19 pandemic and the disparity between the number of students to the number of accessible laboratory facilities, which could be accessed by users from their current location by the Internet. A remote laboratory is one of the solutions being considered. The re-laboratory design is a laboratory to run mechatronic practicum (pneumatic, electro-pneumatic, PLC). Users can be accessed by users using a laptop remotely based on an internet network and can be an online practicum solution during the Covid-19 pandemic and can more freely manage practicum schedules. However, re-laboratory has problems such as the need for an internet network to access it. The hardware consists of 3 main parts, namely the server connected to laboratory equipment and cameras, the internet network, and the user's equipment. In contrast, the software used is the ThinVNC Server. The remote laboratory consists of three key components including the server, the internet network, and the consumer. The server consists of a computer server, a camera, and a practicum module. The ThinVNC server is installed on the computer server functions to manage user, password, and port. ThinVNC is used to make it convenient for users to access the laboratory by only having a web browser that supports HTML 5. The camera works to provide the user with details about the program execution that the user sends while the program is running. The issue that lectures encounters during the COVID-19 pandemic can be solved by applying remote laboratories in mechatronics course at the Department of Electrical Engineering, Faculty of Education and Vocational Engineering, Universitas Pendidikan Indonesia (DPTE FPTK UPI). Also, due to the policy where gatherings should be avoided to reduce virus transmission. It can also resolve the disparity in the number of students and the available practicum equipment, it can be accessed from the current location of the user and the schedule can be arranged in turns.

Keywords: COVID-19, Mechatronics, Re-laboratory, ThinVNC.

1. Introduction

Knowledge, skills, and professional attitudes that are strongly supported by the presence of a laboratory are the three key things that establish the expertise in the field of science and engineering. In order to improve skills that are not only theoretical but also promote practical capacity, the laboratory role is necessary for students to experience using practicum equipment [1]. To avoid the transmission of COVID-19, practicum cannot be conducted as usual where students do the practicum together in the laboratory during the COVID-19 pandemic. Another issue that occurs in the practicum implementation is the imbalance number between the equipment and students who want to do an internship, specifically on practicum material due to the expensive equipment needed in mechatronics course [2, 3]. Mechatronics course is a control based on a combination of mechanics and electronics such as pneumatic, electro-pneumatic and PLC-based controls, to run pneumatic and electro-pneumatic practicums, simulations can be assisted using the Fluidsim software, to run Fluidsim-based control programs it can be done by the user on their respective laptops than to run the program it is sent to a server connected to the practicum equipment, while for PLC the method is almost the same but uses different software, including based on ladder diagrams [4, 5].

The remote laboratory consists of three key components including the server, the internet network, and the consumer. The ThinVNC server is installed on the computer server, which functions to manage user, password, and port. ThinVNC is used to make it convenient for users to access the laboratory by only having a web browser that supports HTML 5 [5, 6]. The advantage of ThinVNC is that users do not have to install any browser plugins because ThinVNC is a remote desktop program based on HTML 5 or a website. Apart from that, ThinVNC also supports various web browsers such as Firefox, Microsoft Edge, Safari, Chrome, etc. In this tool, ThinVNC web is inserted on the website created after going through the login page, scheduling, and remote lab access. The process of activating the server uses Ngrok and ThinVNC to have a public IP and is quickly started by the laboratory assistant [2]. The camera works to provide the user with details about the program execution that the user sends while the program is running [1].

The use of a remote laboratory is one solution to the issue since the remote laboratory device will provide practice or tests from where the user is, as long as the user has an internet network. The remote laboratory could be used to replace real laboratories [7].

Many reports showed the effectiveness of the remote laboratory [8-17]. On April 2020, research conducted (for example Mulyanti et al. [18]) on distance learning related to remote practicum at vocational schools during the COVID-19 pandemic in West Java Province [18]. The COVID-19 pandemic condition has changed the way of teaching strategies especially in online learning [19-23], assessment [24], and life condition [25-27]. The results from Mulyanti et al. [18] showed that 4.6% of the respondents stated that the online practicum materials and virtual laboratory facilities at the school were extremely good, and 22.2% said they were good. Being based on the policy of Indonesian Ministry of Education and Culture on the learning process during the COVID-19 pandemic, and the results of the survey conducted by Mulyanti et al. [18] on the shortage of vocational schools that have sufficient online practicum materials and virtual laboratory facilities to support practicum learning, therefore, it is necessary to establish a practicum-based

practicum. One of the solutions to this problem is the establishment of a remote laboratory [6]. This research was conducted as a practical solution in the COVID-19 pandemic condition that cannot carry out offline learning because of concerns about the transmission of the COVID-19 disease and as a solution to the imbalance between the number of tools and the number of users. The expected output is a practical tool designed and tested for its feasibility both technically and in its implementation in learning [7].

2. Literature Review

The implementation of the practicum under the COVID-19 pandemic outbreak and the limited number of installations involve distinctive management. One of the efforts to conduct practicum on the subject that do not require hands-on skills can be overcome by the remote laboratory, which aims to avoid crowds and flexible timing. The remote laboratory is a laboratory that uses internet technology to access the two types of remote laboratories, namely remote laboratory, and virtual laboratory [1]. The remote laboratory has certain advantages compared to the virtual laboratory because on remote laboratory users can interact directly with the laboratory equipment when the user is running the program and the program can be observed in the laboratory via a camera [3]. Meanwhile, the virtual laboratory user cannot interact directly with the equipment in the laboratory but only observes practicum simulations in the laboratory [4].

The comparison between the advantages and disadvantages of real laboratory, remote laboratory, and virtual laboratory [2] are the genuine research facility has practical information interaction with genuine gear, be that as it may, it has time and places limitation because it requires scheduling. As for virtual research facility, it permits collaborative work and interaction with boss, is nice for concept clarification, does not have time and put limitations, is intelligently and incorporates a medium moo fetched. In any case, it has costly supervision, requires idealized information, needs collaboration, and no interaction with real equipment. The farther research facility permits interaction with genuine gear, practical data, no time and put limitations, and encompasses a medium taken a toll. Its shortcoming is as it were "virtual nearness" within the lab.

The advantages of remote laboratory usage are students may conduct practicum activities with flexible time, students may perform practicum without having to go to the laboratory, increase the effectiveness of the time spent in the laboratory with the practice, and improve safety and security as there is no risk of failure caused by physical contact during the experiment [5].

3. Overall System Description

3.1. Design results

The most components of the virtual lab are farther clients, server settings, web, and research facility settings specifically farther research facility design as shown in Fig. 1.

The virtual research facility framework employments an inaccessible desktop framework to permit clients to control the computer lab that is as of now associated to the lab hardware. This may be seen from the design of the inaccessible lab framework.

Not at all like inaccessible desktop frameworks in common, which utilize the default RDP of the working framework, as shown in Fig. 2. this instrument

employments Virtual Arrange Computing (VNC) as a implies of communication between clients or clients and the server computer [6]. As for the sort of VNC utilized, ThinVNC is based on HTML 5.
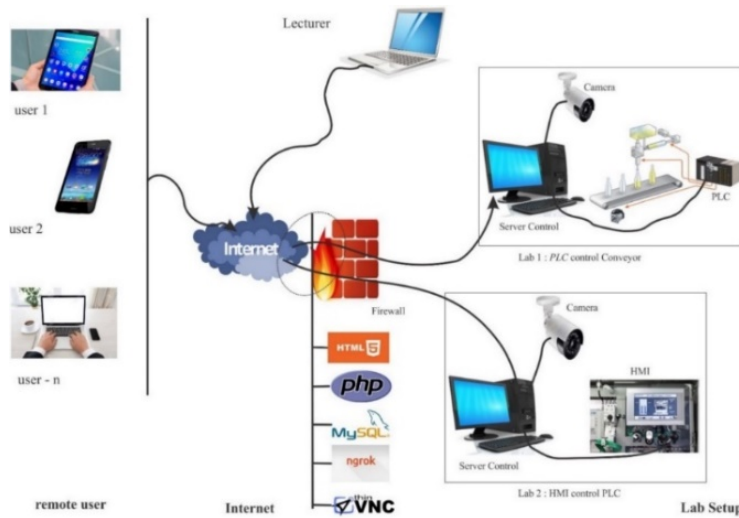

Fig. 1. Remote laboratory architecture.

Fig. 2. Remote desktop system.

ThinVNC is used on the appliance because it is a remote web access client (browser-based, HTML 5). It is an expanded shape of the standard VNC tradition and covers all the same scenarios, but with much prevalent execution and without the have to be present any personal computer (PC) client or browser plugins.

After introducing ThinVNC on a PC or tablet that works as a server, clients as it were ought to give a web browser to associate to the client server and have farther get to desktops and records (indeed from a versatile gadget), at that point work as in the event that they have as of now logged into a computer [7]. Lean VNC may be a perfect web-based blocked off get to execution (based on HTML5 & AJAX). The web client works on HTML5-supported browsers such as Chrome, Firefox, Safari, IE, or Edge.

As said over, ThinVNC is an RDP-based site, numerous changes are made to the webserver where understudies seem specifically select the computer, they need to get to without having to enter the IP address of the server. The process of selecting a computer and entering a server computer is shown in Fig. 3. Meanwhile, to make a local server accessible via the Internet, the user needs to have a public IP address. Steps to activate the server computer start with open the ThinVNC server, followed by set up the username, password and port and run

the server. Open a command prompt and locate the Ngrok directory. Open Ngrok and enter ""HTTPS: server IP address" once public IP is reached and can be accessed through the website.

Fig. 3. Server access.

3.2. Lab remote access flow

A client who gets to the farther research facility must pass a default way. This stream can be seen within the stream chart appeared in Fig. 4. This step begins when an account is given to the client by the teacher. As it were understudies who have accounts are permitted to get to the inaccessible lab site.
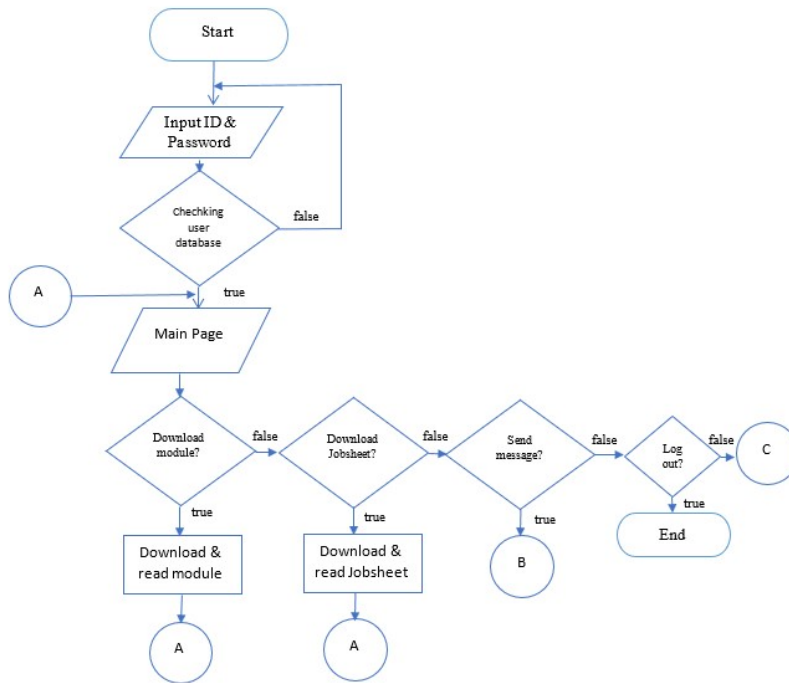

Fig. 4. Website flowchart.

Every account that attempts to log in to the website will be checked in the availability database first. All the database accounts have been encrypted to enhance the security system. When the account works, the user will immediately go to the website main page where four main options are provided, namely opening module, jobsheet, send a message or the selection of the lab computer to be accessed. There is no time limit for access at this stage, so users can enter this stage

at any time. However, if users have selected a computer server, the access time has been predetermined at this stage, and the message sending process shown in Fig. 5.
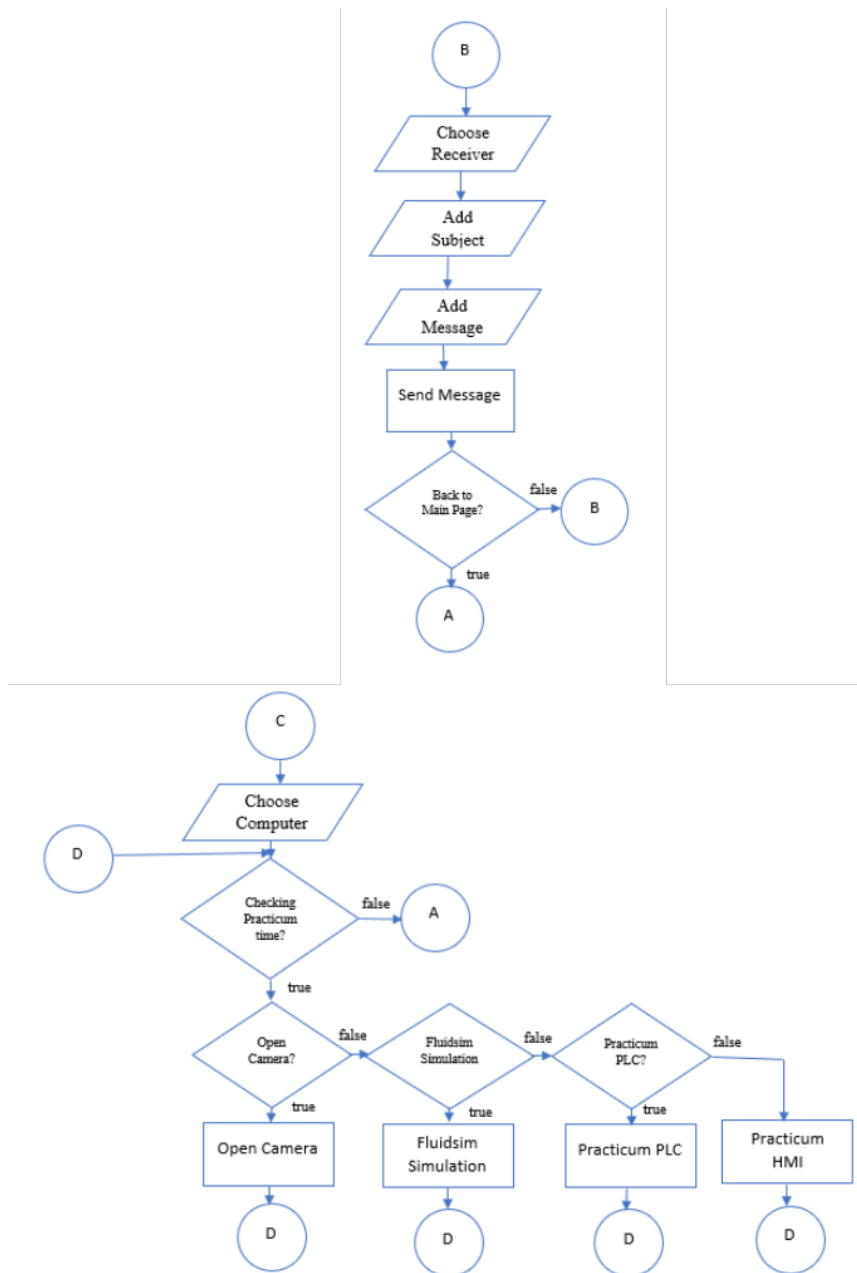

Fig. 5. Message and remote lab access flowchart.

Within the message send menu, clients are welcome to begin with select beneficiaries, then determine the subject, and after that fill within the message. This organize can too be made anytime and is not restricted to the number of messages

sent. The practicum plan will be checked at first at the arrange of selecting a computer. Additionally, clients cannot get to the computer server in case they have not entered the required practicum time. On the off chance that the client has entered the practicum time, the client as it must press the interface button and the user's gadget can be associated straightforwardly to the computer server. The gadget utilized can be a PC, portable workstation, or smartphone as long as the gadget is associated to the web [8].

A Graphic User Interface (GUI) is also provided on a computer server that gives users convenience when using it. Clients will be given four choices when getting to the computer server begins from opening the camera, opening the FluidSim, opening the Cx-Designer, to opening the Cx-Programmer. Other than, in this inaccessible research facility framework, clients can do a few hones at once and see the comes about through a camera introduced within the lab. When the practicum closes, the framework will consequently log out and go back to the most page of the site

3.3. Remote laboratory system settings

There are two main components for setting up a remote laboratory, namely management and personal use. The management works to mitigate the operation of the remote laboratory between the user and the tools. In the mechatronics practicum, besides hardware and systems, the most important thing is the involvement of lecturers, technicians, and students. Their roles are described below.

3.3.1. Lecturer

The role of lecturers in managing the practicum using remote laboratory includes explaining the use and how to access a remote laboratory, setting a schedule and assign accounts to users, setting a schedule and assign accounts to users, uploading modules, uploading the jobsheet, supervising the practicum course and checking student assignments which are uploaded through the system.

3.3.2. Technician

The technician is the person who helps with the practicum and has the tasks of activating the server computer, checking the server connection, enabling public IP, and checking GUI activation. The activation schedule is built into the operating system for scheduling its activation.

3.3.3. User (student)

Students are users who have a strong interest in the implementation of practicum who have the tasks to download and study the modules on the website, download and study the jobsheets that are available on the website, conduct the practicum according to module guidelines and jobsheets, record the program results that have been made through the camera available in the laboratory and upload assignments based on practicum results in the form of files and videos [9].

4. Research methodology

The first stage is conducting literature studies related to mechatronic content, equipment needed for practicum, practicum activities in normal conditions, virtual

laboratory, remote laboratory, and choosing the most appropriate practicum method during the COVID-19 pandemic the imbalance between the number of tools and the number users [9]. The second stage is creating tools and designing lecture management. The third stage is testing the feasibility of devices designed and made based on technical testing and user interviews. The fourth stage is to improve the tool's making by using trials and suggestions from users and the fifth stage of application in learning to evaluate learning outcomes [10].

At the tool-making stage, the test process for each progress is carried out. Each part is evaluated, and many modifications are made. Once the tool has been made, it will be fully tested as well as applied to the mechatronics subject with the electrical engineering students who are the respondents of this research. This stage starts with a demonstration of the tool, and then students are asked to give their viewpoint on the remote laboratory system that has been created. Decent suggestions and input from students are used as evaluation materials in the development of this remote laboratory system, as students will work as users of this remote laboratory. The application of real learning continues after the modification stage is completed. In order to find out the results of learning mechatronics using a remote laboratory, an evaluation of the learning outcomes is conducted as well as interviews with users on the advantages and disadvantages of learning using a remote laboratory. The stages of this research are shown in the diagram flow in Fig. 6.
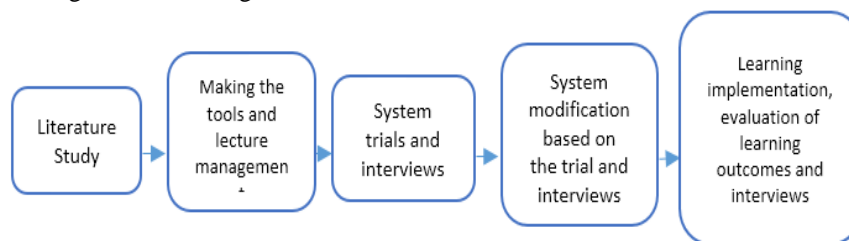

Fig. 6. The method used in this research

To evaluate the use of a remote laboratory as a medium for remote practicum learning, the researchers distribute questionnaires to 28 respondents and invite the respondents to do the practicum in a remote laboratory. The questionnaire consists of eight questions measured on a scale of 1 to 5; where 5 is strongly agree, 4 agree, 3 sufficient, 2 disagree, and 1 strongly disagree. The questionnaire used can be seen in Table 1.

Total amount of the student from electronics industry are 28 people, so this research used total sample methods. This questionnaire is completed by 28 respondents who are electronics industry students from DPTE FPTK UPI

5. Results and Discussions

The following are the design results that have been created on the server and accessed by the users.

5.1. Trial

The following are the design results that have been created on the server and accessed by the users.

Table 1. Remote laboratory evaluation questionnaire

Q#	Questionnaire	Score				
		5	4	3	2	1
Q1	A remote laboratory can be used in remote practicum.	22	1	1	2	2
Q2	I can do my practicum outside the practicum hours using a remote laboratory.	20	6	2	0	0
Q3	Using a remote laboratory makes it easier for me in the distance learning process.	24	1	1	2	1
Q4	The remote laboratory web display is interesting and easy to understand.	17	8	1	0	1
Q5	I have no difficulty in operating a remote laboratory.	21	2	3	2	0
Q6	I can easily fix or modify the program in a remote laboratory.	20	3	2	1	2
Q7	I would encourage other students to use a remote laboratory.	19	7	1	1	0
Q8	Overall, I am satisfied with distance learning using a remote laboratory.	25	3	0	0	0

5.2. Delay calculation

The creation of a remote laboratory cannot be separated from the delays that will occur within the system. The length of time delay depends on the speed of the internet, based on the trial, the delay data is obtained in Table 2. Furthermore, any computer, tablet or mobile device with an internet connection can be connected remotely. The following are the recommended specifications for optimum performance.

- 5 Mbps or higher to download and upload bandwidth is required.
- 500 kbps of bandwidth to download and upload is recommended for this system [1].

Table 2. Delay calculation

| Internet server speed (MBPS)	User internet speed (MBPS)	Delay (s)
5	5	1
5	20	0.7
20	5	0.7
20	20	0.3

5.2.1. Practicum trial

HMI (Human Machine Interface) aims to display the program PLC as an interface that displays PLC data, whether it is input, output, or sensor data [11, 12]. Besides, the HMI can also be used as a replacement button [13]. As an example, when using an emergency button.

Furthermore, students practice designing the HMI by adjusting the address on the HMI with the address used by the PLC [14, 15]. After that, understudies can exchange the program that has been made to the PLC and see the input and yield through the HMI that has been made [7].

At the same time, understudies can to see the apparatuses that run through the introduced camera [11]. Figure 7(a) could be a show of the HMI practicum utilizing the Cx-Designer or Sysmac Studio application on the user's gadget. Figure 7(b) may be a show of PLC programming on Cx-Programmer or Sysmac Studio PLC [6].
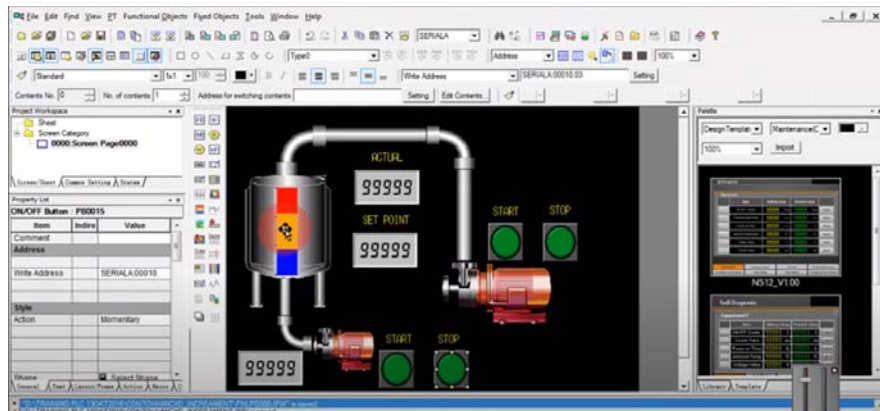
(a)
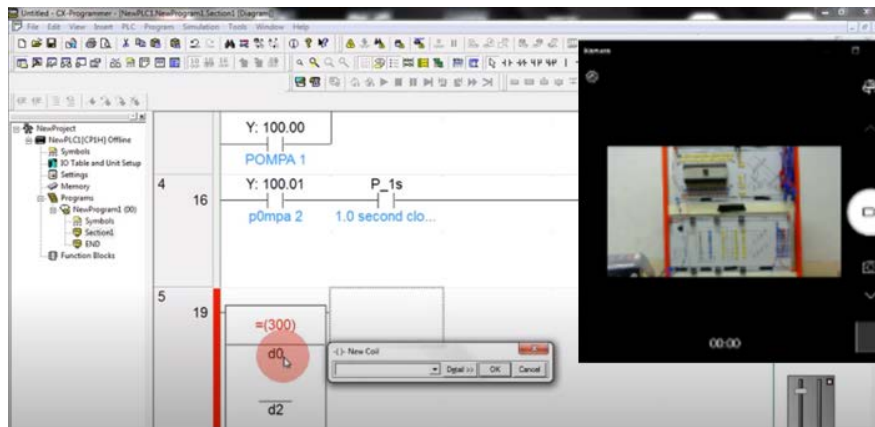
(b)

Fig. 7. Display of HMI (a) and Display of PC practicum (b).

The trial for the inaccessible research facility is conducted in a mechatronics subject with mechanical hardware understudies of Universitas Pendidikan Indonesia. The trial handle happens for two weeks and the practicum information can be seen in Table 3.

Table 3. Calculation of practicum time.

Lab Access	Conventional (minutes)	Remote laboratory (minutes)
Per Semester credit system	5 minutes/student	2 hours/student
Per week	150 minutes	50　hours

Being based on the comes about of the practicum trial, it can be seen that inaccessible research facility has appeared critical focal points. Typically based on practicum time from 5 minutes per understudy per week to 2 hours per week. A few respondents make great comments almost the farther research facility framework. At this organize, understudies are inquired to share their supposition on the comparison of routine farther lab frameworks as well.

5.3. Application in learning and evaluation

The mechatronics course may be an expertise that does not require hands-on abilities. Hence, in this case, materials around PLC stepping stool charts, HMI, and pneumatic recreations are chosen. Taking after the execution of the learning prepare, the assessment conducted based on the tests and ventures given on the site. The comes about of the test appear great grades as shown in Table 4. The results of the evaluation of remote laboratory use as a learning medium for remote practicum is illustrated in Fig. 8.

Table 4. Student grades.

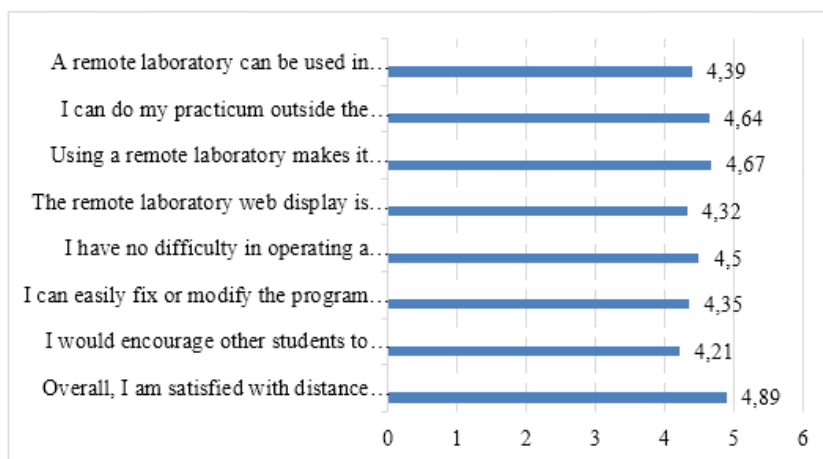| Number of students	Grades							
	A	A-	B+	B-	C+	C-	D	E
28	22	4	2	-	-	-	-	-

Fig. 8. The evaluation graphic

Based on the results of the calculation of each indicator, it can be seen that generally the respondents strongly supported the use of the remote laboratory as a medium for remote practicum learning. From the results of the data analysis, it can be seen that more than half of the respondents (4,39%) agree that remote laboratories function as distance learning media, and more than half of the respondents (4,64%) strongly agree that remote laboratories should be used to facilitate distance learning. More than half of the respondents (4,67%) agree that remote laboratory can be used in remote practicum learning, while (4,32%) of respondents strongly agree that they do not experience difficulties in operating remote laboratories.

Furthermore, 4,35% of respondents strongly agree that practicum implementation can be performed outside practicum hours by using a remote laboratory and can fix or modify the program in the remote laboratory easily. 4,21% of respondents strongly agree that they will encourage other students to use the remote laboratory, and 4,89% of respondents strongly agree that the remote laboratory web display is interesting and easy to understand. Needless to say, the use of a remote laboratory makes it convenient for students to learn, [12] concerning Industry 4.0 where learning integrates technology or digitalization into the learning process [13, 16, 17].

6. Conclusion

Based on the comes about and dialogs, it can be concluded that the application of the web-based farther research facility and ThinVNC to back understudy abilities in mechatronics course to bargain with the COVID-19 widespread has been effectively executed as arranged. The results of the trial show that each section works well, and the lab computer can be accessed from anywhere, on condition the access rules are set, and the ultimate goal of the tool design is fulfilled. All systems which have been modified such as Ngrok and ThinVNC work well and can communicate excellently. Other than, this framework too sets out specifications that are not as well overwhelming given that clients as it were got to give 5 Mbps of web speed to induce ideal get the 0.7s delay calculation. The comes about of the learning application moreover appear great comes about, as can be seen from the securing of understudy scores, where most of the understudies get great comes about and as it were a critical division get palatable scores. Based on the results of the meet, the farther research facility appears great comes about where understudies appreciate employing an inaccessible research facility more than ordinary practicum since each understudy can hone for a longer period and concurring to the time planned.

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