Development of Internet of Things (IoT) based learning media in efforts to improve student skills at the industrial revolution era 4.0

J Kustija*, D L Hakim and H Hasbullah
Departemen Pendidikan Teknik Elektro, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi 207, Bandung 40154, Indonesia.

*jaja.kustija@upi.edu

Abstract. Practicum is an essential component in the learning process at universities, especially in the fields of science and technology. Realizing quality practicum requires a balanced amount of equipment that supports the process, but practicum participants often exceed practicum equipment. The solution is to create a remote laboratory that can be accessed from anywhere while connected to the internet. The remote laboratory consists of three essential parts, namely a server that includes a computer or laptop connected to the data processor sent by the user and then connected to the actuator, a server is also connected to the camera that the user can observe the practical work. The second part is an internet connection, and the third part is the user. All that is controlled by ThinVNC software, Ngrok, and GUI that has been provided. On the server computer, GUI, ThinVNC, and Ngrok are installed as controllers for the practical work, while the user can open the website to access the lab computer. Based on theory and experience, this technique is very suitable if used in PLC and pneumatic practicum. The use of remote labs makes students more skilled in facing the era of the industrial revolution 4.0.

1. Introduction
The era of the industrial revolution 4.0 must be faced by all existing institutions, including educational institutions. This must be taken seriously so that students who will enter the industrial world can compete well. Equipment available at educational institutions must have industry standards to get students accustomed to using industrial equipment [1]. Internet of Things (IoT) is a significant component in the 4.0 revolution era, where each part uses wireless devices and is controlled via the internet [2].

The industry-standard equipment that is widely used for control today is a programmable logic controller (PLC) [3]. This can be used as a reference that educational institutions must have a PLC as a practical tool. In fact, the number of PLCs available at educational institutions is often out of balance with the number of students who use them. The relatively high PLC price is a significant factor in the lack of PLCs in educational institutions [4].

Another solution is to engineer the equipment available using a remote lab system. Remote Lab is a system that allows access to lab equipment from anywhere with the agreed time [5]. With the remote lab, a reasonable time is longer, even with a small number of tools. The remote lab system must be equipped with an organized scheduling system and complete features. The intended features include a message delivery system, practical guides, and job sheets that must be worked on.
Not all practicums are suitable for using remote labs, and practicum means labs that require hands-on skills such as welding and soldering. PLC practicum is a type of practicum that is suitable if using a remote lab because the user only has to do the coding and transfer the program that has been made. In the lab, the computer is also provided a camera that oversees the course of the practicum so that users can see the results of programs created [5]. Based on this, the remote laboratory might be the right solution to overcome the problem.

2. Methods
The design of this tool uses an experimental method that includes literature study, tool making, analysis, and implementation. At the literature study stage, a reference search is made in some of the latest journals about the development of remote laboratories, this stage is at the same time searching for remote laboratory models to be made. The next stage is the stage of making tools, at this stage the selection of connection options and components to be used.

During the tool manufacturing stage, the testing process is also carried out each on the progress that is obtained, each part is evaluated and gets many modifications. After the tool is finished, a complete test will be carried out as well as the application of the mechatronics course with the DPE FPTK UPI 2017. Electronic student respondents in this phase begin with a demonstration of the tool first, then students are asked for their opinions on the remote lab system that has been made. Every input given by students becomes an evaluation material in the development of this remote laboratory system. This is certainly very important because students will act as users, so they must provide input to the development of the remote lab system.

3. Results and discussion

3.1. Design results
The main components of the remote laboratory consist of the internet, server computers, and websites. The three components are integrated to produce a complete remote laboratory system. In each of these main components, many sub-components make the remote laboratory system made more comprehensive and easy to use, as seen in Figure 1.

![Figure 1. Remote lab architecture.](image-url)
3.1.1. Server and Ngrok. A computer lab connected to the lab equipment (PLC) is used as a server. The computer lab installed Ngrok software that provides public IP so that it can be accessed from anywhere [6]. Activation of public IP begins with activating the ThinVNC server first on the server computer and continues with activation of the public IP and provides domain.

3.1.2. Website and ThinVNC. The website provided is a versatile website. In addition to providing features for remote lab access, it also provides features for sending messages, storage modules, worksheets, and uploading assignments for students [7]. The feature of sending work messages as a means of discussion between users, during the work module and job sheet as a guide for students in remote lab access.

3.1.3. Additional features of remote lab. Additional features intended are conveyer trainer features and pneumatic object thrust systems. This feature aims to make the lab feel more real with the presence of a moving actuator as a controlled medium, as seen in Figure 2 (b). There are four choices of practical combinations for this trainer, including:

- Traffic light Trainer
- Object pusher machine
- Relay control practicum
- LED output trainer

From the four types of practicums above, it can be developed into many variations of the program provided in the job sheet in accordance with the material of the program created.

3.2. Flow of remote laboratory access

Every user accessing a remote laboratory must pass through a predetermined path. This flow can be seen in the flowchart that has been provided. This step starts when the user is given an account by the lecturer. Only students who have an account can only access the remote lab's website.
Every account that tries to enter the remote lab's website will be checked first in its availability database. All statements in the database are encrypted, making system security stronger. If successful, the user will go directly to the main page of the website which has been provided 4 main choices, namely opening modules, job sheets, sending messages or choosing the lab computer to access. At this stage access time limits are not given, so users can enter this stage at any time. This will be different if you have chosen a server computer, at this stage, the access time is predetermined.

**Figure 3.** Websites flowchart.

**Figure 4.** Message and remote lab access flowchart.
On the message sending menu, the user is welcome to select the recipient first, then determine the subject, then fill in the message. This stage can also be done at any time and is not limited by the number of messages sent. At the stage of choosing a computer, the practicum schedule will be checked first. The user cannot access the server computer if it has not entered the specified practicum time. If you have entered the practicum, the user only needs to press the connect button, and the user's device can directly connect to the server computer. The user's device can be a PC, laptop, or smartphone as long as the device is connected to the internet, as seen in Figure 3.

The server computer also provided a Graphical User Interface (GUI) that makes it easy for users. Users will be given four choices in accessing the server computer, namely opening the camera, opening Fluidsim, opening Cx-Designer, opening Cx-Programmer. In this remote laboratory system, users can do several labs at once and see the results through the camera installed in the lab. If the practicum time is up, the system will automatically log out and return to the main page of the website. The testing of the features above is done on mechatronics courses where students are asked to access the web and work on the available worksheets.

3.3. Remote laboratory system settings
To access the remote lab, in addition to the main components in terms of equipment and systems, also required arrangements made by the parties involved, namely lecturers, laboratory assistants, and users (students) [8].

3.3.1. Lecturer. The lecturer as the lecturer of the course has several assignments on the remote lab system including Give a short tutorial on how to access remote laboratories, Give user accounts to students, Uploading modules, Uploading the job sheet, Monitor the running of the practicum, and Check video assignments and files uploaded by students.

3.3.2. Users (students). Students as people who will do the practicum have the following tasks:
   - Download the module provided on the website
   - Read the modules that have been downloaded
   - Download the job sheet that has been provided on the website
   - Read the downloaded job sheet
   - Do the practicum according to the module and job sheet guidelines
   - Record the results of programs that have been made through the camera available in the lab
   - Uploading assignments in the form of video evidence and program files that have been created

In addition to the main tasks above, students can also use the feature of sending messages if they have difficulty in accessing the remote lab.

4. Conclusions
Based on the results and discussion, the creation of a remote laboratory for learning mechatronics in improving the ability of students to face the era of the industrial revolution 4.0 was successfully made according to plan. This can be seen from the time the student practicum is longer. At the testing stage, it can be seen that lab equipment can be accessed from anywhere with a more organized time. The use of remote labs is also a solution to overcome the imbalance between the number of students and the number of trainers available without spending a fortune. The remote lab can also improve student abilities. In addition to increasing the duration of the practicum, it is also the application of the IoT system, which is the student's capital in facing the era of the industrial revolution 4.0.

Acknowledgments
The author would like to thank reviewers for the suggestions that helped improve the quality of this paper. In addition, the authors are also very grateful to the Basic Electronics Laboratory of the
Department of Electrical Engineering Education, Faculty of Technology and Vocational Education, Indonesia University of Education for providing resources.

References

[1] Grodotzki J, Ortelt T R and Tekkaya A E 2018 Remote and Virtual Labs for Engineering Education 4.0: Achievements of the ELLI project at the TU Dortmund University Procedia Manuf. 26 1349–1360

[2] Tsiatsos T, Douka S, Mavridis A, Tegos S, Naddami A, Zimmer T and Geoffroy D 2014 Evaluation plan and preliminary evaluation of a network of remote labs in the maghrebian countries Int. J. Interact. Mob. Technol. 10(5) 15–20

[3] Fiala O, Fencl T, Moc L and Burget P 2008 Remote Labs and Resource Sharing in Control Systems Education IFAC Proc. Vol. 41(2) 13640–13645

[4] Heradio R, de la Torre L and Dormido S 2016 Virtual and remote labs in control education: A survey Annu. Rev. Control 42 1–10

[5] Locherer M, Hausamann D and Schüttler T 2012 Practical science education in remote sensing at the DLR School_Lab Oberpfaffenhofen 2012 IEEE International Geoscience and Remote Sensing Symposium pp 7389-7392

[6] Fayolle J, Gravier C, Yankelovich N and Kim E 2011 Remote lab in virtual world for remote control of industrial processes 2011 IEEE International Conference on Multimedia and Expo pp 1-4

[7] Lustig F 2016 Simple modular system ‘iSES Remote Lab SDK’ for creation of remote experiments accessible from PC, tablets and mobile phones Demonstration Proc. 2016 13th Int. Conf. Remote Eng. Virtual Instrumentation, REV 2016 pp 403–405

[8] Post L S, Guo P, Saab N and Admiraal W 2019 Effects of remote labs on cognitive, behavioral, and affective learning outcomes in higher education Comput. Educ. 140 103596