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Integrated Knowledge and Skills with Multi-Material Learning for Engineering Students during COVID-19

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Abstract: Teaching and learning in engineering courses need to emphasize practicality to acquire integrated knowledge and skills. It is necessary to learn processes controlled by mathematical equations in mechatronic engineering to apply scientific principles to use automation control systems technology to support Industry 4.0, such as automatic control with a Programmable Logic Controller (PLC) control device. In addition, they are applying the data of engineering process control to real-time applications with Supervisory Control and Data Acquisition (SCADA) software and PLC Network. Due to the outbreak of Coronavirus (COVID-19), lack of practice face-to-face interaction, so the effectiveness of online learning practice is significantly reduced. This study presents the combination of remote-control technology and multi-material learning to promote engineering students' conceptual and practical experiments during online learning. The finding shows that this multi-material learning can operate and motivate engineering students in the distance learning situation.

Keywords: Automation, engineering education, PLC, SCADA, STEM

1. Introduction

In engineering education, the learning activity focuses on knowledge and principles to the professional practice of engineering. Significantly, the course of mechatronics engineering and robotics mainly aims to enable students to integrate engineering disciplines such as mechanical, electrical, computer, control, and information technology. Therefore, many studies attend to the student's point of view by emphasizing the engineering student's learning efficiency. For example, Ruangurai & Silawatchananai (2020) determined the optimum value for the control of electric motors to achieve the set goals. In addition, Silawatchananai & Parnichkun (2019) presented a methodology to control the exoskeleton to get the most realistic value. It can be seen that the field of mechatronic engineering requires the integration of science, technology, engineering, and mathematics, together to bring benefits. Therefore, in teaching, it is necessary to have a control process that must consist of a series of experiments or process simulations that simulate industrial processes. Howimanporn, Chookaew & Silawatchananai (2020) proposed an easy way to balance integrating science, engineering, mathematics, and technology knowledge and apply the control theory teachers need to teach their students to learn intangibles. Babayigit & Sattuf (2019) demonstrated how knowledge gained from PLC and SCADA courses is applied to industry-based learning objectives that focus on learners by integrating the teaching materials in software and hardware using long-distance command and display communication technology adopt a blended teaching method. This pandemic has successfully forced a global shutdown of educational activities, resulting in an impact on learning management in many universities that online learning has become an essential educational platform. Therefore, the teaching and learning process in the education system still needs to be continued (Adedoyin & Soykan, 2020). Aihara et al. (2020) found that good distance learning that is adjusted accordingly and fits into the situation will make distance learning equal to face-to-face learning. This ensures that students gain a detailed understanding of practical skills at a distance close to face-to-face learning for the intended objectives.

This study presents the combination of multimedia learning material and remote-control technology to promote engineering students' conceptual and practical experiments during online learning.

2. Related Works

2.1 Mechatronics Engineering Education

The learning objectives in mechatronics engineering tend to make smart factories. Therefore, engineering students acquire programming skills to control machines with scientific processes to complete the task. Thus, they can solve the problems of industrial production systems. In addition, engineers find solutions to problems from developed techniques. The next thing is to convey or teach others to understand and use it quickly and efficiently. Many studies proposed practical learning related to mechatronics engineering. For example, Shi, K. (2020) presented an innovative model of logistics education. Colombo et al. (2020) proposed that the cyber-physical systems align with Industry 4.0, as industrial machines need to be developed to be flexible and capable of integrating intelligent logic into devices. Calderón & Izquierdo (2020) proposed an engineering learning can advance the results of entrepreneurs. It is imperative to apply knowledge and experience inside and outside the classroom.

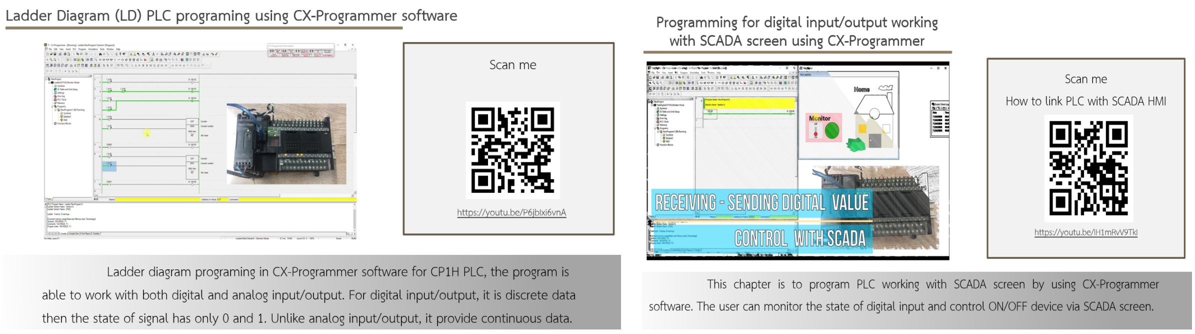
2.2 Online learning in STEM

STEM education is a learning framework that can be applied well to engineering education. Many studied applied STEM discipline to connect scientific knowledge and real-world situation. For example, Huang et al. (2021) presented an engineering work consists of STEM interdisciplinary systems and technologies using cutting-edge technology that simulates the work to be seen empirically. Mambo & Omusilibwa (2020) studied the spread of the coronavirus epidemic on science, technology, engineering, and mathematics education, making teaching efficiency change. Demaidi et al. (2019) applied online learning in the course material related to laboratory experiments suitable for learning engineering to increase learning efficiency. Lcaraz et al. (2019) proposed a model that uses various teaching materials, both in software, hardware, and information communication technology, to enhance learning skills and student satisfaction.

3. Methodology

3.1 Development of Multi-Material Learning

This study design an online learning system with multi-material learning such as multimedia (video), online platform (google classroom and google meet), application software, and experimental kit. In addition, remote-control technology is used to communicate between students' control via monitors and experimental kit in distant learning.

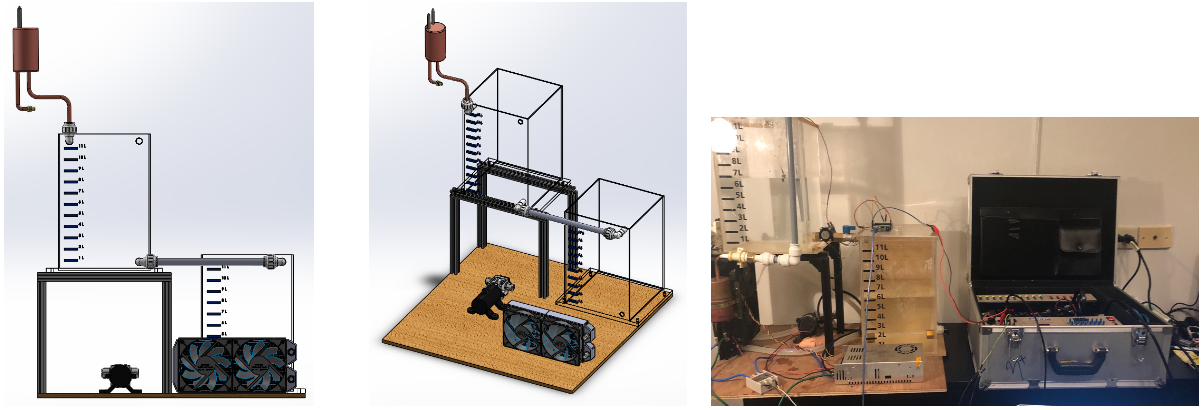


(a) PLC device content (b) SCADA system content

Figure 1. Example of multimedia material

Figure 1. (a) and (b) show the multimedia material that can scan the QR code for presenting the video via YouTube. The content covers the related topic of the control system. For example, using programmable logic controllers (PLCs) connected with a database such as an assembly line in the smart factory needing an easy and fast way to log or obtain data online about the production equipment. Besides, the introduction to SCADA systems is employed in manufacturing factories. In addition, we design the multimedia to incorporating students' hands-on activities in engineering education.

However, the student can search the other information on internet sources independently. After that, they can connect the PLC experiment kit with remote-control technology follow the steps by step.



(a) Front view (b) 3D view (c) Experimental kit

Figure 2. The experimental kits for studying close loop control

Figure 2 (a) and (b) illustrate the experimental design kit in front and 3D view. After that, we built an experimental kit for hands-on activity consisting of a Programmable Logic Controller (PLC), as shown in Figure 2 (c). The student has to write a program for controlling the temperature treatment process of PLC with teleoperation or control machine at a distance.

Thus, the experimental kit can be used in the laboratory or any place to facilitate the learning process. For experiment shows the water level and temperature measurement with sensors and connects to a PLC. Even though online learning cannot be directly controlled through a hardware device, the students can see the operation control from the online camera.

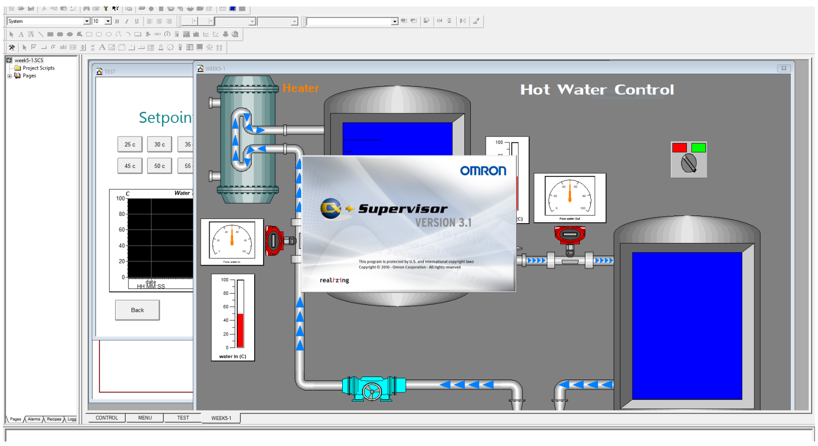


Figure 3. SCADA Software for remote and monitoring

In addition, remote-control technology can create virtual simulation software that can be commanded and displayed in real-time. Supervisory Control and Data Acquisition (SCADA) is software to use remote and monitoring the control operations and display remotely in real-time. The students can simulate working with SCADA software and remote directly into the laboratory as actual behavior, as shown in Figure 3. The students can see their actions from the program. They can control and modify based principles and theory through this online system. At the same time, the responsible teacher provides when students have questions or explain how the actual phenomenon is consistent with the theory.

3.2 *Learning activity procedure*

Figure 4 shows the close-loop control diagram based on course learning objectives. It is necessary to use the signal received to control it to meet the specified goals. The output signal must be measured against the target signal. By comparison, there is an error signal. Thus, the student must analyze to solve problems. After that, they can write a program to direct the problem and send the program into the laboratory remotely.

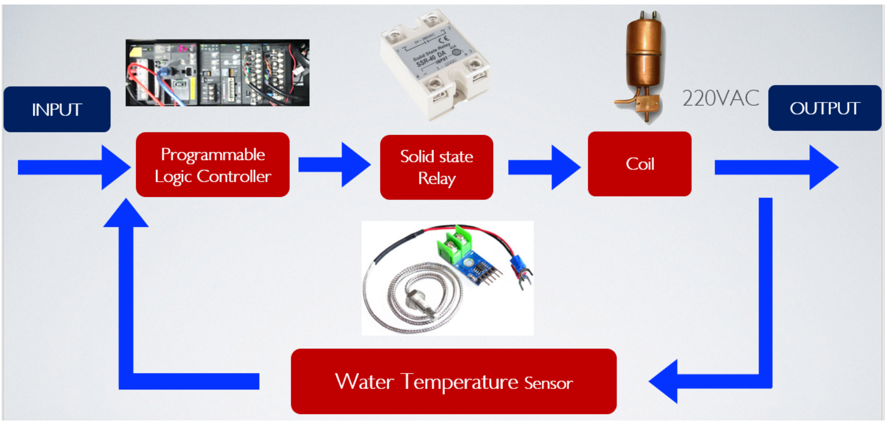


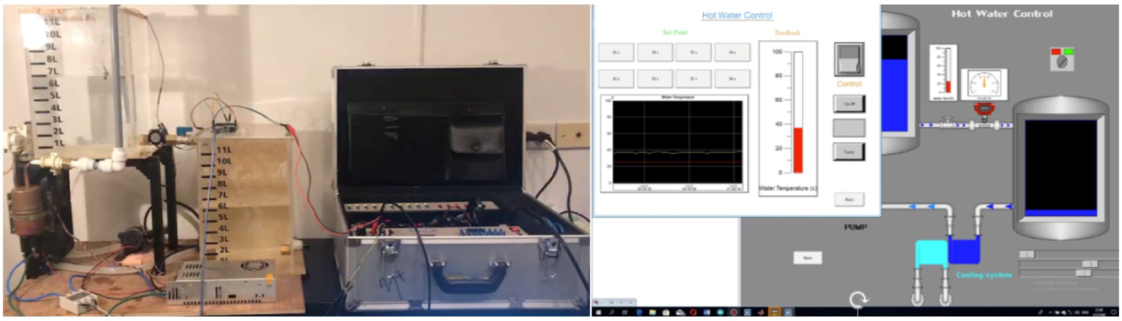
Figure 4. Close loop control diagram

In this experiment design, after the teacher and student are logs in to the online learning system. The learning activity procedure includes eight steps as follow:

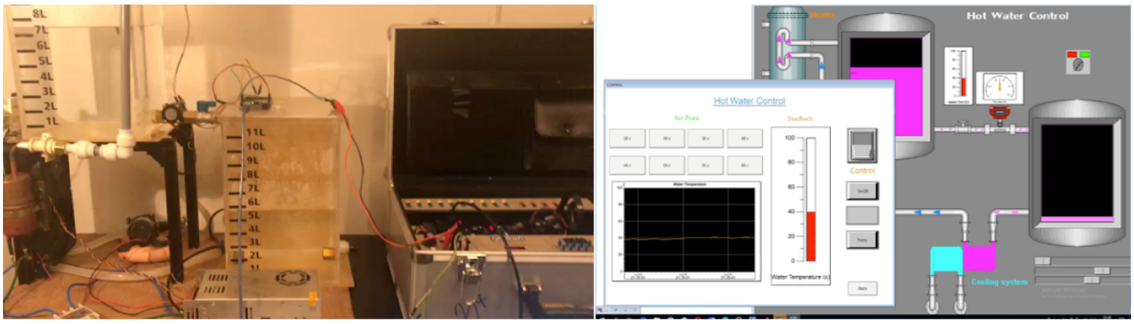
- *Step 1:* The teacher informs and explains the learning objectives of the course.
- *Step 2:* The students take a pre-test to measure the student prior knowledge.
- *Step 3:* The students to study the contents and technical procedures from the multimedia via YouTube.
- *Step 4:* The teacher has examples and assigns exercises. They are then allowing students to discuss and exchange knowledge among themselves and to create cooperation. The teacher suggests and discusses methods derived from the students' conclusions while the students test remotely.
- *Step 5:* The student configures the software to remotely operate with defining the input and output to order via the PLC control device.
- *Step 6*: The students design and write programs based on the conditions identified by the laboratory sheets and simulate the specified conditions.
- *Step 7:* The student configures remote programs to the PLC control device and performs remote testing with SCADA. The teacher observes student behavior and records it in the checklist.
- *Step 8:* The student takes the post-test after finish class.

4. Results

This finding shows a combination of hardware as a physical laboratory and software as a virtual laboratory to promote engineering students learning. Multi-material learning and remote-control technology can achieve learning objectives in an online environment. Figure 5 shows the learning material that can be commanded and displayed at a distance. The students can control with SCADA screen as an actual event. It can also bring the results to control based on the theory that creates students' knowledge and develops their skills even if they are not testing in the laboratory. The student can modify the control program based on the theoretical assumptions. The remote control process allows them to take the signals received from the process and modify them to optimize their values.



(a) Commanded and displayed of low temperature control



(b) Commanded and displayed high temperature control

Figure 5. Example of operation control at a distance with SCADA

5. Conclusions

Due to the COVID-19 epidemic situation, lack of practice face-to-face interaction. However, teaching and learning in engineering subjects must be done online teaching. Combining learning materials between software and hardware through communication with remote-control technology makes teaching efficiency close to face-to-face teaching.

The finding shows that this multi-material learning can operate and motivate engineering students in the distance learning situation. However, the laboratory activities and their sequence are essential to improving the effectiveness of engineering education. Online learning should be tailored to meet both student and academic requirements, which obviously will depend on the teacher and the program. Students are provided with learning material, giving the practical sequence and instructions for performing the learning activities. However, the laboratory activities and learning strategy can be modified as desired.

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