Design of Control System Trainer Based on IoT as Electronic Learning Media for Natural Science Course

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Abstract: The development of controller system trainer based on Internet of Things (IoT) is one of the online learning media for practical activities that can motivate students in the natural science learning process so the student's competence in learning can be achieved. One indicator of quality education is that their alumnus has a good knowledge, skills and attitudes. This study aims to develop an IoT-based trainer controller systems as a learning media in electronic 2 of natural science course. The trainer control system in this study used a website developed in accordance with the electronic 2 course which is connected to the trainers in the Electronic's Laboratory via arduino uno microcontroller on trainer. This control system trainer is a development of basic physical law theory that emphasizes Kirchoff's laws using Maxwell's equations. Where the discussion in the electronics course 2 emphasizes the working principle of transistors. The research method used is the Research and Development (R&D) method with the product development model used is the Borg and Gall model. Product testing describes the design of assessment, type of data, data collection instruments and data analysis techniques. The instrument used in this study is a questionnaire for the material expert test and the media expert test. The data analysis technique used the content validity ratio (CVR) method. Based on the test result of material experts and media experts, the result of high validity was obtained. The result of blackbox testing get 100% results. Based on the test results, it can be concluded that the tool can work well which can remotely from a far using Arduino Mega and ESP8255 with the delay about 2 seconds. The test results for students' psychomotor skills get an average of 63.20 which means Good. So that this trainer control system can be used as a student independent learning media in natural science course.

Keywords: Control systems trainer; Internet of Things (IoT); Practical online learning media.

Introduction

Electronics is the science that studies weak current electrical devices that are operated by controlling the flow of electrons or electrically charged particles in a device such as a computer, electronic equipment, thermocouple, semiconductor, and so on. Electronics is also a branch of physics that studies the emission behavior and impact of electrons, as well as the control of charged particles in a vacuum, gas and semiconductor materials. Electronics also one of natural science topics in high school. In Electronics 2 lectures, learning material focuses on the working principles of transistors. In analyzing the working principle of the transistor, calculations are carried out using Kirchoff's law. Where the equation used is Maxwell's equation. The Single Electron Transistor [SET] have been made with critical dimensions of just a few nanometers using metal, semiconductor, carbon nanotubes or individual molecules. Unlike Field Effect Transistor (FET), the single electron device based on an intrinsically quantum phenomenon, the tunnel effect. In the FET, many electrons transmit from the Source to Drain and make current, in the SET, the electrons are transferred one-by-

one through the channel. The electrical behavior of the tunnel junction depends on how effectively the electron wave transmit through the barriers, which decrease exponentially with the thickness and on the number of electron waves modes that impinge on the barriers. It is given by the area of tunnel junction and divided by the square of wavelength (Simić et al., 2016).

Learning system of Electronics II is supported by an online learning system that can be accessed anytime and anywhere to improve student understanding and skills. Online learning is a structured form of student independent learning, and the results can be analyzed as an evaluation of student abilities. An effective learning process can be supported by the media used to make it easier for students to understand the material. Related to effective learning when students assume that they have the right knowledge and expertise then send the truth and use of that information (Deschryver, 2017; Halkic & Arnold, 2019; Shanti et al., 2022). Psychomotor development is developing their ability to meet their needs to interact with the surrounding environment (Avan et al., 2011; Karpudewan & Kulandaisamy, 2018; Lestari et al., 2019). Psychomotor domain learning is influenced by the surrounding learning environment. Therefore, it is necessary to develop a plan to implement learning and relate it to the psychomotor development of students, namely emotion regulation, and discipline behavior using structural equation modeling (SEM) (Shaver, 2017). Learning media is one of learning instrument which have an important role regarding the process of learning (Halkic & Arnold, 2019; McDougall et al., 2018).

E-Learning systems is a distance learning process by combining principles in the learning process with technology (Mhouti et al., 2018; Verzosa et al., 2021). This system utilizes the internet infrastructure in the teaching and learning process. So, students can access and understand a topic or a material. Students can access learning materials anywhere and anytime. With the development of the Internet of Things (IoT), the internet can also be used for other purpose that support learning process (Kaur et al., 2019; Maple, 2017; Meng et al., 2019; Tierney, 2019), including by utilizing internet for theoritical and practical learning activities. Internet is used as a means for an automatic control system form remote trainers using arduino uno Rev 3. IoT can improve the learning experience for students (Charmonwan, 2015). Students in Indonesia generally have smartphones which can be used as a learning media.

In learning process, IoT is a system which can help to increase the ease of teaching and learning. An example of application of IoT technology is the application of smart classrooms. The concept of smart classrooms is to integrate several sensor equipment, actuators, microcontrollers combined with a portal learning management system (LMS). In smart classrooms the entire room is controlled using technology that runs automatically. The examples of arrangements made in smart classrooms are the process regulating the temperature in the study room, the attendance system of students attending lectures with RFID, which is integrated with the database, and even the setting of the lights in the study room automatically. IoT technology in learning process allow the teaching and learning process to be carried out with mobile devices or multimedia devices.

IoT applied to smart campuses resulted in Smart E-Learning application with IoT which save costs and improves the learning process (Hijawi et al., 2020; Prince, 2012). IoT applications in E-Learning. According to Charmonman, IoT application have the potential to improve the learning experiences for students. Another study which examined the smart environment model for crowdsourcing-based e-learning (Veeramanickam & Mohanapriya, 2016). As a result, crowd sourcing can improve the learning process carried out by lecturers and students.

Reviewing various literatures studies, the proposed study has it own characteristics and there has been no previous study that specifically connect web-based learning systems using IoT Technology that is connected to trainers in laboratories as learning media. With this control trainer system, it is hoped that it can improve students' understanding and skills in the Electronics 2 course which is the application of the basic laws of Physics to Kirchoff's law in Natural science course.

Method

The design of this research product uses Research and Development methods. Research conducted in Mei - September 2020. The design of Internet of Things in E-learning based is integrated into a database that connected to the user's device, so it is hoped that the information sent from website that has been designed with Electronical material to trainer can run effectively and better understood by students during practicum.

The technique of data collection is the main step in a study because the main objective of the study is to get the data (Sugiyono, 2017).The technique of collecting data which used in this research were Observation to obtain data that support the study. Then, Interview method used to get information through lecturers about the curriculum and obstacle in learning. Then questionnaire Method to media experts to know feasibility of media in learning process, and to lecturer expert to know feasibility of material.

In this research, there are 3 kind of data there are validation instrument by experts, validation matter by

expert, validation media learning by experts. Validation instrument is done to know how much instrument can measuring the object to be observed. Validation instrument test is using Lawshe's CVR (Content Validity Ratio). Method and CVI (Content Validity Index). Lawshe (1975) proposes that each of SME (Subject Matter Experts) to answer question for each item with three options named: (1) Essential, (2) Useful but not Essential, (3) Not Required. Lawshe validity according to the Formula 1 used to analyze or counting each item:

$$CVR = (n\varepsilon - N/2)/(N/2) \tag{1}$$

Where CVR = Content Validity Ratio, $n\varepsilon$ = quantities of Experts who answer Essensial, N=total of Experts.
After count CVR (Content Validity Ratio) the next step is to calculate CVI (Content Validity Index) from all of question. CVI (Content Validity Index) calculated based on the average of CVR (Content Validity Ratio). Formula 2 to calculated CVI (Content Validity Index) is:

$$CVI = CVR / (\text{Quantities of Questions or statements}) \tag{2}$$

Where CVR = Content Validity Ratio Total, CVI = Content Validity Index

The result of CVI calculated has ratio from 0 to 1 which can categorize based on CVI value. CVI Value table can be seen as Table 1.

Table 1. CVI calculated ratio

Category	Ratio
Not Suitable	0 – 0.33
Suitable	0.34 – 0.67
Very Suitable	0.68 - 1

The survey that used to test the feasibility by Media Expert and Material Expert are using Guttman scale with two options, 1 as YES and 0 as NO. Guttman Scale used because it requires firm answer is learning media eligible for use or no. The results of the survey on every aspect must have answer yes to be announced eligible for use, if there was a no answers these aspects must be resolved. The validation data instrument from two Experts will be analysis using Coefficient Contain formula by Gregory with the aspect judge by expert. Before counting the validity of the instrument and the near future after receiving the data from the answers of the each of an instrument who were judged to be, the answers need to arranged beforehand with prepare contingency table to calculate the Gregory Index. Contingency Table to calculate the Gregory Index to be demonstrated at tables as Table 2.

Table 2. Contingency table to calculate Gregory index

		Expert 1	
		Poor	Strong
Expert 2	Poor	A	B
	Strong	C	D

After get the data from experts, move the data into Contingency Table by compared the corpuscular list of two expert with relevancy category strong with all corpuscular list (to grouping the strong and the poor one). The score for each answer can be calculated with Formula 3:

$$\text{Coefficient of Content Validity} = \frac{D}{A+B+C+D} \tag{3}$$

Where A = the answer of one expert NO and the other one NO as well (Poor-Poor), B = the answer of one expert YES and the other one NO (Strong-Poor), C = the answer of one expert NO and the other one YES (Poor-Strong), D = the answer of one expert YES and the other one YES as well (Strong-Strong).
The next step is the result of calculation that has coefficient of the validity interpreted it into the Agreement Expert index. Table Agreement Expert Index can be show in Table 3.

Table 3. Table agreement expert index

Percentage	Category
< 0.4	Low Validity
0.4-0.8	Enough Validity
>0.8	High Validity

Result and Discussion

The purpose of this study is to improve students' psychomotor abilities in understanding material in electronics course II which is the application of the basic concepts of Physics regarding Kirchoff's laws I and II. According to Richard Decaprio (2013), practicum has many benefits including activities centered on the development of process skills, motor skills and the formation of a scientific attitude. There are two phases, in learning motor skills, namely the cognitive phase, namely during the procedure, declarative knowledge is obtained (including procedural knowledge such as concepts and rules in the form of declarative knowledge) regarding the sequence of operational steps or sequences that must be made (Khasanah et al., 2017; Riopel et al., 2019). Electronics II course material emphasizes understanding of the working principles of NPN and PNP transistors. In calculating a base voltage source on the emitter diode in forward biased conditions through a resistor that limits the base resistance current, Kirchoff's voltage law is used which states that the voltage at RB (base resistance) is VBB (base voltage) –

VBE (emitter voltage). The transistor itself is a component that has the main function as a digital switch or switch in an electronic circuit. Transistors can also be used to adjust the size of the electric current that passes through an electronic circuit. NPN and PNP bipolar transistors require two voltage sources to function or work properly. In this PNP bipolar transistor, the positive pole of the first battery is connected to the emitter (P-type semiconductor) and the negative pole is connected to the base (N-type semiconductor).

The study data analysis contains the results of the IoT-based trainer test which consists of the results of hardware and software testing. The hardware test was carried out by testing the LED indicator with an arduino Mega. While the software testing is done by testing the ESP8255 connection to website. To test the feasibility of the tool as a learning media, the testing is done by material experts and media experts. This trainer is an application of Kirchoff's theory which uses Maxwell's equations as the principle of calculating transistors. Through the concept of Physics students understand the workings and calculations of electronic circuits into the trainer control system which has been designed as a practical learning medium. Trainer display based on IoT as shown in Figure 1.
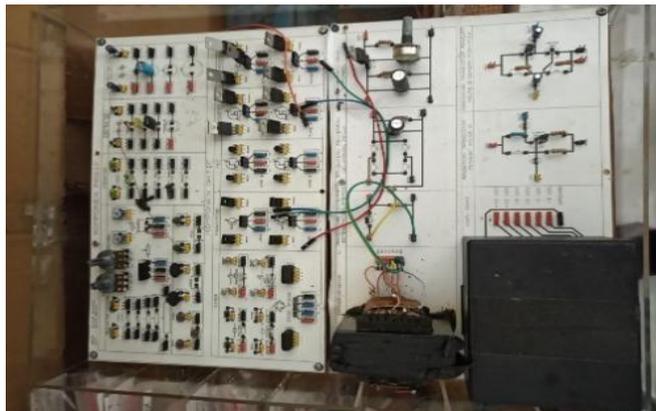

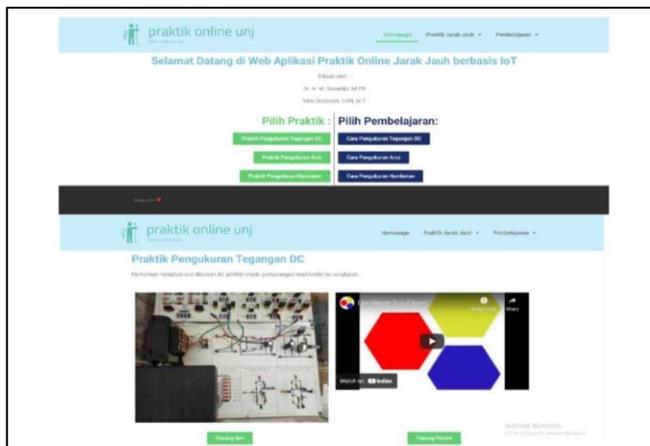**Figure 1.** Trainer display based on IoT

Figure 2. Web Design

Therefore, Web design as shown in Figure 2. The website has the menu bar that shows its learning media once it has been clicked. And then it will show the schematic capture of the following board of the trainer than can be configured and also updated in real time when we are using the simulator for simulation.

The software which has prepared then will be doing the test by experts, Lecture Expert and Media Expert. Both tests will be done to know if the media already feasibility or need more revision.

Before the questionnaire was given to media experts and material experts, the instrument was first tested by two experts. The result of instrument testing can be seen in Table 4.

Table 4. The result of instrument testing each expert

Expert of Instrument	Questionnaire for Media Experts	Questionnaire for Material Experts
1	1	1
2	1	1

Based on the CVI Calculation by the material expert instrument and media expert, the result is 1, which categorized the instrument is in the very appropriate category. Based on the accumulated CVI calculation in the test instrument, the result is 1 which is categorized the instrument which has been made is feasible to given to material experts and media experts.

Material that has been upload to website then tested to media experts and material experts. Material experts will evaluate the feasibility of the content of the material on the website. Material experts consist of 2 people. This material expert's test instrument uses a guttman scale that consist of 30 questions.

The results of the material experts test were analyzed using the content validity coefficient formula. The results obtained based on tests from material expert are:

$$\text{Content validity coefficient} = \frac{50}{(0+30+30+60)} = 0.41$$

Based on the percentage results, it can be concluded that the website gets result. 0.41. The score is in the "High Validity" interval. functional buttons on the website. Media experts consist of two people. The instrument of the test results of this media experts used the Guttman scale which consist of 30 questionnaires. The result of the media experts test was analyzed using the content validity coefficient formula. The results obtained based on tests from media expert are:

$$\text{Content validity coefficient} = \frac{49}{(14+18+43+50)} = 0.39$$

Based on the percentage results, it can be concluded that the website gets the results 0.39, the score is in the "High Validity" interval.

According to result of data analysis on 50 students, it can be summarized that there are 2.00% who have Enough category result, 21% who have Good category result and 77% who have Excellent category result. According to data, it can be summarized that the students skill on Good Category with mean data equals to 63.20%. The results can be seen on Figure 3.
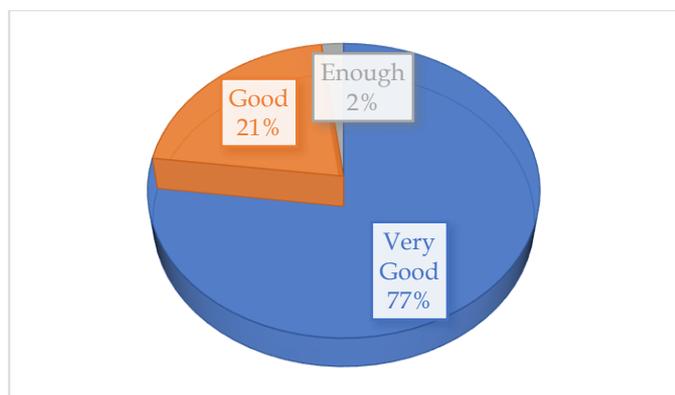

Figure 3. Respondent testing

The test results with blackbox testing show that all the functions on the website trainer can run well according to the commands given with a percentage of 100%. Testing LED Indicator with Arduino mega is to know whether the LED Indicator can be controlled by arduino according to what the reseacher has determined. The test result can be seen in Table 5.

Table 5. LED indicator test

No. Led	Condition	Criteria	Result
1	Low	Low	Low
2	High	High	High

Testing the ESP8255 connection to website is to know whether the web can receive the data sent by the ESP8255 according to what the reseacher specified. The test results can be seen in Table 6.

Table 6. Connection test ESP8255 to website

Data Sent	Data Criteria that Should Be Accepted	Result	Delay
255	255	255	2 seconds

When perform a test on register user, there are two conditions, and there are failure and success conditions. When failure condition occurs, the website will show a notification that the registration was not successful, otherwise, if success condition occurs, the website will show a notification that the registration was succesful. The register user testing result can be seen in Table 7.

Table 7. Register User Testing

Condition	Result
Fail	Registration was not successful
Success	Successful registration

When perform a test on logic user, there are two conditions, and hence, failure dan success. In case of failure condition, website will show a username notification or wrong password. Otherwise, in case of success condition, website will show the success notification and will show the interface of main dashboard of website. The login user testing result can be seen in Table 8.

Table 8. Login User Testing

Condition	Result
Fail	Username or password wrong
Success	Successful

The developed learning media has the ability to empower students' knowledge and skills in studying natural science course, especially for electronics topics. The development of instructional media is an important form of developing students' abilities in the 21st century, starting from critical thinking, creative thinking, communicating, and collaborating (Farisi, 2016; Kivunja, 2015; Ester van Laar et al., 2018). All of these abilities must be owned by students to be able to adapt to competition in the 21st century (Sadiqin et al., 2017; Siddiq et al., 2017; E. van Laar et al., 2019).

Conclusion

Based on the results of the research that has been done, through the stages of designing, manufacturing, and testing control system trainer based on IoT, it can be concluded that the tool can work well, being able to operate remotely using Arduino Mega and ESP8255 with delay 2 seconds. Then based on the expert test, it gets high validity which makes this tool worthy of being one of the practical learning tools for online lecturers. According to psychomotoric skills of students, the result of mean equals to 63.20 and thus the result is Good. Henceforth, the system control trainer can be used as learning media for students and the students to learn in Natural science course.

Acknowledgments

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