Development of Electrical Circuit Learning Media Using Virtual Simulation

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Abstract. The Covid-19 pandemic has had a major impact on the world of education. One of the impacts is related to the learning process of electrical circuits. Online lectures make students have difficulty in studying electrical circuit courses. An appropriate learning media is needed as a solution to overcome these problems. This study aims to develop electrical circuit learning media using virtual simulations and determine the feasibility of applying the media. This type of research is research and development with the ADDIE model. The stages of development carried out are Analyze, Design, Development, Implementation, and Evaluation. The research was conducted at the Electrical Engineering Education Study Program, Faculty of Engineering, UNY. The virtual simulation used is a Falstad circuit simulation. This simulation can be accessed online or offline. In this research, the focus is on developing learning media using online Falstad simulation. The results showed that 1) the electric circuit learning media using virtual simulations can run well, 2) based on user trials, the electrical circuit learning media using virtual simulation is classified as very feasible.

Keywords: electrical circuits, virtual simulations, the covid 19 pandemic

1. Introduction
The Covid-19 pandemic affects all activities of human life, including in the field of education. Educational activities usually carried out face-to-face in class have now been stopped to avoid the spread of the Covid-19 pandemic. The cessation of face-to-face learning activities is shifted to online-based learning (distance) by utilizing technology that is connected to the internet. This distance learning system applies to all levels of education, including vocational education.

Vocational education is one of the formal educations with the aim of focusing more on increasing work-ready competencies in specific fields. One of the fields in vocational education is the electricity sector. A quality learning process is needed to prepare graduates with electrical competence who can compete in the world of work. The learning process carried out in vocational education is divided into three, namely theory, practice, and field. One of the electricity courses given is the Electrical Circuit Course. In the era of the COVID-19 pandemic, lectures became very difficult because they had to be carried out online. The electrical circuit course is the basic guideline for students in the electricity sector. This course studies the analysis of electrical circuits that require understanding in principle, theoretically, and practically. The learning process of electric circuits can be qualified if one of the course's learning objectives is achieved.

To achieve the learning objectives, it is essential media that can improve the ability of students [1]. Learning media can be used to stimulate the thoughts, feelings, and interests and willingness of
students so that the learning process occurs to achieve learning objectives [2]. Based on the above opinion, it can be concluded that to achieve the learning objectives of electric circuits. Learning media is needed that can stimulate the thoughts, interests and feelings of students to improve their abilities.

Based on the results of observations of the implementation of the electrical circuit course, data were obtained if: (1) the impact of the covid-19 pandemic made it difficult for students to understand the basic concepts of electric circuits. It happens because learning is carried out online. (2) The need to increase student interest and motivation in the electric circuit learning process. Increased motivation can be through media that is easy to understand and interesting for students. One of the media that should be applied is virtual simulation-based media. Virtual simulations can prepare students to understand basic concepts and materials more efficiently [3]. The virtual simulation that will be used is the Falstad circuit. The development of electric circuit learning media using virtual simulation is the title of the research offered to increase student competence.

2. Main Theory
Learning media is a tool that can help the teaching and learning process so that learning objectives can be adequately achieved. Learning media are everything that can be used to channel messages to stimulate the thoughts, feelings, and interests and willingness of students to achieve learning objectives effectively [2]. Learning media can be understood as anything that can convey and distribute messages from sources in a planned manner to create a conducive learning environment [4]. Based on the description above, it can be concluded that learning media is anything that is used to clarify the meaning of the message conveyed so that it stimulates the thoughts, feelings, attention, and interests and willingness of students so that learning objectives are achieved effectively and efficiently.

2.1. Virtual Simulation
Virtual simulation is a medium that serves to convey ideas and concepts in the form of digital simulations. Virtual simulations can provide students with the opportunity to apply theoretical concepts to the simulated experience [5]. The application of virtual simulation media can improve students' mastery of concepts and higher-order thinking skills [6]. The use of virtual simulations in education is needed to explain a material or problem that is difficult for students to understand if they do not use teaching aids because the simulation can be an example of what should be done. Virtual simulation is very useful to be used to explain a complicated variable relationship about a teaching material so that it can increase the involvement of students actively in finding concepts and knowledge in learning. The virtual simulation that will be used is the Falstad Circuit which can be accessed via the page: https://www.falstad.com/circuit/circuitjs.html. Falstad simulation is one of the simulations that can be applied to electrical circuit courses. This simulation is easy to use and understand in solving electrical circuits. In general, virtual simulation media is beneficial in the practicum-based learning process because, with the virtual simulation, students can learn quickly in understanding the material that has been studied [7].

2.2. Electrical Circuit Course
Electrical circuit is a compulsory subject for electrical engineering students. This course studies the basics and analysis of electrical circuits. In this simulation-based learning media, three primary materials will be developed, namely: 1) node voltage analysis, 2) mesh analysis and 3) resonance in RLC series circuits. Node analysis is based on Kirchoff's Law I / KCL, where the amount of current entering and leaving the branching point will be equal to zero, where the voltage is an unknown parameter [8]. Mesh is a property of plane circuits and is not defined for non-plane circuits. Mesh analysis can be used only on circuits that lie in one plane. A planar circuit is a circuit on a plane surface so that no branches pass above or below other components [8]. To solve it by using the concept of mesh current and Kirchoff's 2nd Law (Kirchoff Voltage Law/KVL). Resonance occurs when the magnitude of XL = XC [9].
3. Methods

This study is included in research and development (R&D) research. The purpose of this development research is to develop an electric circuit learning media using virtual simulation. The development model used in this research is the ADDIE approach. The ADDIE approach includes: Analysis, design, develop, implementation, and evaluation [10]. The implementation chart of the ADDIE model is shown in Figure 1 below.

![Figure 1. Implementation of the ADDIE Model](image)

The analysis activity begins with identifying the problem of implementing learning in the electrical circuit course, looking for differences between learning objectives and the reality of the learning process that has been implemented. Analyzing the urgency of whether or not the development of learning media is necessary and adapted to various aspects of supporting the electric circuit learning media. The results of the analysis showed that: (1) the impact of the covid-19 pandemic made it difficult for students to understand the basic concepts of electrical circuits. This happens because learning is carried out online. (2) The need to increase student interest and motivation in the electric circuit learning process. The electrical circuit course is the basic guideline for students in the electricity sector. This course studies the analysis of electrical circuits that require understanding in principle, theoretically, and practically.

The next stage is design, which is an activity to design learning media products that will be developed starting from determining the material to be studied. Determine the design of the electrical circuit be developed, and adapt it to the Falstad virtual simulation. The design of the material to be studied is shown in Figure 2 below.
After the material is determined, the next step is to determine the electrical circuit that will be included in the electric circuit learning media. The circuit that will be included is an electrical circuit that will be analyzed using node analysis, mesh analysis, and the RLC series circuit shown in Figures 3, 4, and 5 below.

Figure 2. Material to be Designed

Figure 3. The Electrical Circuit for Node Analysis.

Figure 4. The Electrical Circuit for Mesh Analysis
The next step is to make a theoretical circuit solution formula. To complete the theoretical node analysis, the steps taken are as follows. 1) Specifies the reference node. 2) Determine the Node voltage (V). 3) Create a circuit equation [11]. In Figure 3, the circuit equation according to the node analysis rules is as follows.

$$\frac{V-V_g}{R_2} = \frac{V_1-V}{R_1} + \frac{V_2-V}{R_3}$$

(1)

To complete the mesh analysis theoretically is as follows. 1) Determine the type of circuit (planar circuit). 2) Make loop assumptions. 3) Make a circuit equation [11]. In Figure 4, the circuit equations according to the mesh analysis rule are as follows.

Loop 1:

$$-V_1 + R_1 I_1 + R_3 I_3 + V_2 = 0$$

(2)

Loop 2:

$$R_2 I_2 + R_4 I_4 - V_2 + R_3 I_3 = 0$$

(3)

To complete the resonance analysis on the RLC series circuit is as follows.

$$X_L = X_C$$

(4)

$$2\pi f L = \frac{1}{2\pi f C}$$

(5)

$$f^2 = \frac{1}{4\pi^2 L C}$$

(6)

The third stage is development, which is the stage used to realize the concept that has been designed into a product that is ready to be implemented. At this stage, the researchers developed an electric circuit learning media using virtual simulation. The virtual simulation used is the Falstad circuit.

The next stage is implementation, which is the stage to apply the product that has been developed in real conditions. Implementation is done on a limited basis. Respondents in the implementation were students of the UNY Electrical Engineering Education Study Program who took electrical circuit courses. Evaluations are the last stage. After a limited application, the electrical circuit learning media was evaluated to provide feedback on the following application.

4. Results and Discussion

At the development stage, the main step is to incorporate the circuit design into the virtual simulation. In this study, there are three electrical circuits that will be developed. The results of the node analysis in the virtual simulation are shown in Figure 6 below.
Figure 6. Virtual Simulation of Node Analysis

This circuit is composed of \( V_1 = V_2 = 9 \) V, \( R_1 = R_2 = 10 \Omega \), \( R_3 = 15 \Omega \). Based on the results of the electric circuit learning media, it was found that there was no difference between theoretical calculations and virtual simulations. In detail, the simulation results are shown in Table 1 below.

| VS   | Calculation Voltage (V) & Current (A) | Simulation Voltage (V) & Current (A) |
|------|--------------------------------------|-------------------------------------|
| V1   | V2 | VR1 | VR2 | VR3 | IR1 | IR2 | IR3 | VR1 | VR2 | VR3 | IR1 | IR2 | IR3 |
| 9    | 9  | 3.375 | 5.625 | 3.375 | 0.375 | 0.5625 | 0.225 | 3.375 | 5.625 | 3.375 | 0.375 | 0.5625 | 0.225 |

The second material is mesh analysis in electrical circuits. The results of the mesh analysis in the virtual simulation are shown in Figure 7 below.

Figure 7. Mesh Analysis Simulation

This circuit is composed of \( V_1 = 10 \) V, \( V_2 = 5 \) V, \( R_1 = 5 \Omega \), \( R_2 = 10 \Omega \), \( R_3 = 6 \Omega \), \( R_4 = 4 \Omega \). Based on the results of the electric circuit learning media, it was found that there was no difference between
theoretical calculations and virtual simulations. In detail, the results of the mesh analysis simulation are shown in Table 2 below.

Table 2. Result of Virtual Simulation for Analysis Mesh

| VS  | Calculation Voltage (V) & Current (A) | Simulation Voltage (V) & Current (A) |
|-----|--------------------------------------|--------------------------------------|
| V1  | VR1  | VR2  | VR3  | VR4  | IR1  | IR2  | IR3  | VR1  | VR2  | VR3  | VR4  | IR1  | IR2  | IR3  |
| 10  | 5    | 3.75 | 1.25 | 3.75 | 2.5  | 0.75 | 0.125| 0.625| 3.75 | 1.25 | 3.75 | 2.5  | 0.75 | 0.125| 0.625|

The third material is resonance analysis in RLC series circuits. This circuit is composed of \( V = 8 \text{VPP}, R = 2 \text{K} \Omega, L = 300 \text{mH}, C = 0.01 \mu\text{F} \). Based on theoretical calculations, the magnitude of the resonant frequency is 2907.23 Hz. The results of the resonance analysis in the virtual simulation are shown in Figure 8 below.

![Figure 8. Virtual Simulation of Resonance in RLC Series Circuits](image)

Based on the results of the electric circuit learning media, it was found that there was no difference between theoretical calculations and virtual simulations on resonance material. The experimental results of the resonance analysis are shown in Table 3 below.

Table 3. Resonance Analysis Results on RLC Series Load

| Frequency (Hz) | Volt VR (Vp-p) | Result |
|----------------|----------------|--------|
|                | I Rms          | XL     | XC    | Z     |
| 1000,00 Hz     | 1.129          | 199.60 \mu \text{A} | 1884 \Omega | 15923.6 \Omega | 14181.3 \Omega |
| 2000,00 Hz     | 3.449          | 609.91 \mu \text{A} | 3768 \Omega | 7961.8 \Omega | 4646.3 \Omega |
| 2907,23 Hz     | 7.997          | 1.426mA | 5477.2 \Omega | 5477.2 \Omega | 2000 \Omega |
| 4000,00 Hz     | 3.901          | 690.299 \mu \text{A} | 7536 \Omega | 3980.9 \Omega | 4079.1 \Omega |
| 5000,00 Hz     | 2.426          | 429.916 \mu \text{A} | 9420 \Omega | 3184.7 \Omega | 6548.2 \Omega |
When there is a resonant frequency, the voltage across the resistor is equal to the source voltage. The effective current is at its peak and the impedance is equal to the resistance in the resistor. Figure 9 shows a graph between the XL, XC, and Z.

![Graph showing XL, XC, and Z](image)

**Figure 9.** XL, XC, and Z Graphs on the RLC Series Circuit

After the development stage is complete, the next stage is implementation. Implementation is carried out on a limited basis by involving students. In detail, the feasibility of using electric circuit learning media is reviewed from four aspects, namely material, media, ease of use, and motivation. The detailed feasibility results are shown in Figure 10 below.

![Feasibility Test Results](image)

**Figure 10.** Feasibility Test Results

Based on Figure 10, it can be explained that the results of the implementation of electric circuit learning media using virtual simulations are very feasible to use. Virtual simulation media is beneficial in the learning process [7]. Students can learn quickly in understanding the material that has been studied.
5. Conclusion

Due to the COVID-19 pandemic, learning must be carried out online. Students find it difficult, especially in electrical circuit courses. Therefore, a breakthrough was made to develop electric circuit learning media. Development of electric circuit learning media using the ADDIE model. The stages of development carried out are Analyze, Design, Development, Implementation, and Evaluation. The electric circuit learning media is designed using Falstad circuit simulation. The simulation results show that node analysis, mesh analysis, and resonance analysis on RLC series loads are the same as theoretical calculations. In terms of the material aspect, media aspect, ease of use, and motivation, the electrical circuit learning media using virtual simulation is very feasible.

6. References

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