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The Analysis of Electric Circuit Studio-based Virtual Laboratory for Dynamic Electrical Material

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ABSTRACT

This study aimed to analyze the use of a virtual laboratory based on an electric circuit (EC) studio on dynamic electrical materials and to help physics education students and to determine the effect of using an EC studio-based virtual laboratory on dynamic electrical materials. This study uses qualitative descriptive research with a survey method through the provision of questionnaires filled out by 15 second-semester students of the physics education study program, at Cenderawasih University. Quantitative data was collected using a questionnaire with an approach to science process skills on dynamic electrical materials with the help of the EC studio application, while qualitative data was in the form of responses given by students about virtual laboratory media on dynamic electrical materials. There are three indicators that serve as a reference in analyzing the EC studio-based virtual laboratory on dynamic electricity: learning motivation, the stimulus for higher-order thinking skills, and understanding of concepts and problem-solving. Based on the results of the questionnaire, it was found that students' responses were very good to the EC studio-based virtual laboratory media because students could repeat themselves if they did not understand. The use of this media makes it easier for students to understand dynamic electricity.

INTISARI

Penelitian ini dilakukan bertujuan untuk menganalisis penggunaan virtual laboratory berbasis electric circuit (EC) studio pada materi listrik dinamis dan membantu mahasiswa pendidikan fisika dan untuk mengetahui pengaruh pemanfaatan penggunaan virtual laboratory berbasis EC studio pada materi listrik dinamis. Penelitian ini menggunakan jenis penelitian deskriptif kualitatif dengan metode survey melalui pemberian angket yang diisi oleh 15 orang mahasiswa semester II program studi pendidikan fisika, Universitas Cenderawasih. Data kuantitatif dikumpulkan menggunakan angket dengan pendekatan keterampilan proses sains pada materi listrik dinamis dengan bantuan aplikasi EC studio sedangkan data kualitatif berupa tanggapan yang diberikan mahasiswa tentang media virtual laboratory pada materi listrik dinamis. Terdapat tiga indikator yang menjadi acuan dalam menganalisis virtual laboratory berbasis EC studio pada materi listrik dinamis: motivasi belajar, stimulus terhadap kemampuan berpikir tingkat tinggi, dan pemahaman konsep

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dan pemecahan masalah. Berdasarkan hasil angket, ditemukan bahwa respons mahasiswa sangat baik terhadap media virtual laboratory berbasis EC studio karena mahasiswa dapat mengulang sendiri jika belum paham. Penggunaan media ini membuat mahasiswa lebih mudah dalam memahami materi listrik dinamis

A. Introduction

The global issues surrounding the Corona Disease-19 Virus (COVID-19) have significantly altered the educational process, impacting areas such as learning methods [1], budgeting [2], objectives [3], and assessment. [4]. This inherently implies the need for online learning. Online learning is a form of education conducted without face-to-face interaction through platforms with internet connectivity and available personal devices [5]. The government has adopted online learning as an alternative policy to facilitate the continuation of the learning process. [6] and [7] explain that online learning has emerged as a viable alternative policy that supports the continuation of the learning process. However, the teacher has not prepared any learning activities to counterbalance the online learning tasks [8].

The development of virtual laboratory technology, or Lab-Vir, allows for interaction and visualization of phenomena experienced by students during experiments in real laboratories [9]. Lab-Vir helps to get people excited about and better their experience with Android-based practicals. It has three features: 1) virtual laboratories with all the tools and materials you need to do simulations or experiments in real labs [10]; 2) capable to use anywhere [11]; and 3) free internet (offline) [12]. Virtual laboratory-based learning is one of the flagship products resulting from advancements in information technology and laboratories [13]. Students conduct experiments in the laboratory based on the theories they have learned in class[14]. These experiments serve to enhance students' understanding of the studied material by supporting their learning [15]. However, due to budget constraints in providing laboratory equipment and the high operational costs of laboratories, virtual laboratory-based learning can serve as an alternative to eliminate the limitations of laboratory devices [16]. In the context of educational technology development, studying a studio-based virtual laboratory for dynamic electrical materials is important because it combines the interactivity of studio-based learning with the accessibility of digital simulations. Dynamic electrical phenomena—such as current and voltage variations over time—are often difficult for students to visualize and understand through static instruction or conventional laboratories. By integrating a studio-based approach, this research emphasizes active experimentation, collaboration, and iterative design, allowing students to explore real-time changes in electrical circuits through simulation. This approach not only supports conceptual understanding of dynamic electrical matter but also contributes to the innovation of technology-enhanced learning environments in engineering education.

In the learning activities, educators should assist students in developing their understanding by providing guidance and organization for learning, motivation to learn, explanations of concepts that are not easily learned independently by students, activities that can help pupils recognize (become aware of) and correct misconceptions, and opportunities to guide problem-solving [17]. Visualizing physical phenomena and their related concepts through animations at the microscopic level and simulations related to everyday examples can enhance students' knowledge visually and stimulate more students to achieve a high level of understanding of physics concepts [18]. Students are more motivated to learn physics concepts when accompanied by visualizations of abstract concepts [19]. Virtual labs can also serve as an effective educational tool because they can create active learning, thereby motivating students to learn. Rustaman, et al. [20] and Saputra et al. [21] explain that virtual labs can serve as an effective educational tool by fostering active learning, which in turn motivates students to learn. Motivation is important because it can enhance interest in learning and make it easier for students to start engaging in new learning activities. In addition, motivation can help students push themselves in order to achieve what they aspire to Sarwono & Lyau [22]. The internet operates the most ideal virtual lab, enabling participants to conduct experiments from any location and at any time [16]. However, learners can also run it in an intranet environment or on a standalone computer. A virtual lab converts physical buildings and lab equipment into computers and virtual lab software[14]. From the presented information, it is evident that virtual labs serve as a viable alternative to help humans improve productivity and well-being, solve problems, estimate various solution options, and implement solutions. Dynamic electricity is one of the physics topics taught via virtual labs.

Dynamic electricity is a fundamental subject that students need to understand, and currently, physics is one of the subjects that is considered difficult for learners to grasp [23]. Appropriate media is necessary in physics learning to enhance students' understanding of concepts through visualization-level explanations [24]. Developing learning models that can visually explain physics phenomena is necessary to achieve this [25]. The virtual lab developed and used in this research utilizes the features of the electric circuit (EC) studio program. Several studies, that found the EC studio program effective as a virtual lab medium for physics learning, informed the choice of this medium [26], [27]. According to Shan et al. [24], a meta-analysis of 46 studies in engineering education shows that virtual laboratories have a significant effect on learning outcomes with Hedges' g = 0.686 (CI 0.414–0.959), especially in motivating and increasing student engagement. Wahyudin et al. [28] found that although virtual laboratories offer better accessibility and flexibility, there are still challenges such as limited interactivity and content that does not fully simulate the physical laboratory experience. In the field of electrical engineering in particular, Wahyudin et al [28] showed that the use of virtual labs during the pandemic provided a practical alternative

when physical laboratories were limited — but they also highlighted the need for strong pedagogical design to ensure effective learning.

The research questions in this study are: 1) Is the use of the EC studio-based virtual laboratory on dynamic electricity acceptable and helpful for physics education students? 2) What is the students' reaction to using the EC studio-based virtual laboratory on dynamic electricity? The goal of this study is to determine whether the use of dynamic electricity in the EC studio-based virtual laboratory is acceptable and beneficial to physics education students. This research aims to understand the impact of utilizing the EC studio-based virtual laboratory on dynamic electricity in a way that is acceptable and beneficial for physics education students. For students in the physics education program, this research can help assess the effectiveness of using the EC studio-based virtual laboratory on dynamic electricity and how it can support their learning. This study contributes to a deeper understanding of dynamic electrical matter by demonstrating how a studio-based virtual laboratory can effectively simulate and visualize time-dependent electrical phenomena. The developed system enhances students' conceptual comprehension of current, voltage, and resistance variations in dynamic circuits. Furthermore, it provides a pedagogical framework for integrating simulation-based learning into electrical engineering education.

B. Method

This research employs a qualitative descriptive research type using a survey method through a questionnaire filled out by 15 second-semester students from the Physics Education program at Cenderawasih University. This research was conducted at the Faculty of Teacher Training and Education at Cenderawasih University, specifically in the Physics Education program. The research date is Monday, April 11, 2022. The respondents participating in this study focus on second-semester students who have already taken or are currently taking Basic Physics I and II courses. The research instruments used is student response questionnaires. The questionnaire is filled out by placing a check mark (√) in the assessment column that corresponds to the respondent's opinion with the answer options: very poor, poor, good, and very good. There are ten positive statements in the questionnaire given to the students. The answer choice score category uses a positive statement score category [29]. In this study, the researchers used a Likert scale, so the students' answers were then analyzed for their scores.

To begin using the Electrical Circuit Studio, students first select the desired components from the component library and drag them onto the workspace to build a circuit schematic. Each component can be connected using virtual wires to form complete circuit configurations. After constructing the circuit, students can set parameters such as voltage amplitude, resistance, frequency, or time constants to define circuit behavior. Once the circuit design is completed, the "Simulation" feature allows students to observe the dynamic response of the circuit in real time. The

software displays graphical outputs of voltage, current, and power as functions of time, helping students visualize transient and steady-state phenomena. The “Analysis” module enables users to calculate important electrical parameters automatically and compare them with theoretical predictions from class lectures. The Electrical Circuit Studio also integrates features for collaborative and reflective learning. Instructors can assign design-based projects where students propose circuit solutions, simulate them, and present their results within the same platform. This approach follows the principles of studio-based learning, emphasizing iterative design, peer feedback, and experimentation. Through this process, students not only learn how to assemble and analyze electrical circuits but also develop higher-order thinking skills such as problem-solving, design reasoning, and conceptual understanding of dynamic electrical phenomena.

C. Result and Discussion

The researchers looked at how the electric circuit (EC) studio-based virtual laboratory was used on dynamic electricity material and how it helped physics education students. We also wanted to see what effect using the EC studio-based virtual laboratory had on the dynamic electricity material. The survey results from the students were very different. The analysis of the students' responses is presented below.

Motivation

Item 1 is the first statement. Respondents said, "Learning using virtual laboratory media with the help of the EC Studio application can increase my motivation to learn." Table 1 displays the respondents' answers to item 1.

Table 1. The Respondent Statement for Item 1

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	4	26.6
4	Extremely excellent	11	73.3

The data indicates that the majority of respondents rated their experience as extremely excellent when asked whether using virtual laboratory media with the help of the EC Studio application can provide motivation in learning. 11 respondents (73.3%) rated their experience as Extremely Excellent, while 4 respondents (26.6%) rated it as Excellent.

Reasoning and Thinking Skills

Item 2 is the second statement. Respondents said, "My reasoning skills and thinking abilities have developed more during learning using virtual laboratory media with the EC Studio application." Table 2 displays the respondents' answers to item 2.

Table 2. The Respondent Statement for Item 2

No	Responses	n	%
1	Extremely poor	1	6.7
2	Under Average	0	0
3	Excellent	4	26.6
4	Extremely excellent	10	66.7

The data shows that the majority of respondents rated the reasoning and thinking skills of students as Extremely excellent when learning with the use of virtual laboratory media aided by the EC Studio application. This is evidenced by 10 respondents (66.7%) stating Extremely excellent, and 4 respondents (26.6%) stating Excellent regarding reasoning in this component.

Learning Outcomes

Item 3 is the third statement. Respondents answered the question "The use of virtual laboratory media using the EC studio application can improve my learning outcomes." The responses to item 3 are shown in Table 3.

Table 3. The Respondent Statement for Item 3

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	4	26.6
4	Extremely excellent	11	73.3

The data shows that the majority of respondents rated the use of virtual laboratory media through the EC Studio application as extremely excellent in enhancing students' learning outcomes in understanding and solving problems related to dynamic electricity. 11 respondents (73.3%) rated it as Extremely Excellent, while 4 respondents (26.6%) rated it as Excellent.

Thinking Skills

Item 4 is the fourth statement. The researchers asked the respondents to explain how "the virtual laboratory media using the EC Studio application enhances my thinking skills." Table 4 displays the respondents' answers.

Table 4. The Respondent Statement for Item 4

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	3	20
4	Extremely excellent	12	80

The data shows that most respondents answered "Extremely excellent" to the question of whether the virtual laboratory media using the EC Studio application enhances students' thinking skills regarding dynamic electricity material. This is shown when 12 respondents (80%) stated Extremely Excellent, and 3 respondents (20%) stated Excellent.

Participating in Learning

Item 5 is the fifth statement. The content of the statement is "Learning by using virtual laboratory media decreases my interest in participating in learning." The respondents' answers to item 5 are shown in Table 5.

Table 5. The Respondent Statement for Item 5

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	2	13.3
3	Excellent	4	26.7
4	Extremely excellent	9	60

The data shows that the majority of respondents rated it as extremely excellent regarding the question that learning through the use of virtual laboratory media decreases students' interest in participating in learning. This is shown where 9 respondents (60%) stated Extremely Excellent, and 4 respondents (26.7%) stated Excellent. Meanwhile, students feel that the virtual laboratory media provides its own motivation without having to participate in the teaching and learning process related to dynamic electricity, although 2 respondents (13.3%) stated Under Average in the use of the virtual laboratory media.

Images And Simulations Using The EC Studio Application

Item 6 contains the sixth statement. The content of the statement is "images and simulations using the EC studio application are very interesting." The respondents' answers to item 6 are shown in Table 6.

Table 6. The Respondent Statement for Item 6

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	1	6.7
4	Extremely excellent	14	93.3

Data shows that the majority of respondents rated the question about images and simulations using the EC Studio application as extremely excellent, indicating that it is very engaging and helps students understand dynamic electrical components more quickly. Additionally, the application provides formulas along with simulation examples that can assist students in more easily creating the circuits they wish to build. This is shown when 14 respondents (93.3%) stated Extremely Excellent, and 1 respondent (6.7%) stated Excellent.

Learning Experience

Item 7 contains the seventh statement. The content of the statement is "Learning using virtual laboratory media with the EC studio application is very interesting, and I can repeat it myself if I do not understand." The respondents' answers to item 7 are shown in Table 7.

Table 7. The Respondent Statement for Item 7

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	1	6.7
3	Excellent	3	20
4	Extremely excellent	11	73.3

Data shows that respondents rated their learning experience using the virtual laboratory media with the EC Studio application as extremely excellent, which is very interesting. Students can review on their own if they do not understand. This is indicated by 11 respondents (73.3%) stating Extremely Excellent, and 3 respondents (20%) stating Excellent because the EC studio application is very practical. If students do not understand, there is a guidance feature like simulations that can assist them (Simanullang, 2021). Nevertheless, there is 1 (6.7%) respondent who stated Under Average.

Effectiveness of Using EC Studio Application

Item 8 contains the statement of the seventh item. The content of that statement is "The virtual laboratory media is more effective when using the EC studio application." The respondents' answers to item 8 are shown in Table 8.

Table 8. The Respondent Statement for Item 8

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	1	6.7
3	Excellent	5	33.3
4	Extremely excellent	9	60

The data shows that respondents rated the virtual laboratory media question as extremely excellent when using the EC Studio application. Students can repeat on their own if they do not understand. This is evidenced by 9 respondents (60%) stating it is Extremely excellent, and 5 respondents (33.3%) stating Excellent because the EC studio application is very practical. If students do not understand, there is an option for repetition and easy access to help them (Hasanah, 2021; Simanullang, 2021). Nevertheless, there is 1 (6.7%) respondent who stated Under Average.

Self Learning

Item 9 contains the seventh statement. The content of the statement is "The virtual laboratory media using the EC studio application allows me to work independently in learning, especially in studying dynamic electricity material." The respondents' answers to item 9 are shown in Table 9.

Table 9. The Respondent Statement for Item 9

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	3	20
4	Extremely excellent	12	80

Data shows that a significant number of respondents rated the virtual laboratory media using the EC Studio application as Extremely Excellent in enabling students to work independently in their studies, particularly in learning dynamic electricity material. This is evidenced by 12 respondents (80%) stating Extremely Excellent, while 3 respondents (20%) rated it as Excellent.

Conceptual Understanding

Item 10 contains the seventh statement. The content of the statement is "The use of virtual laboratory media using the EC studio application makes it easier for me to understand dynamic electricity material." The respondents' answers to item 10 are shown in Table 10.

Table 10. The Respondent Statement for Item 10

No	Responses	n	%
1	Extremely poor	0	0
2	Under Average	0	0
3	Excellent	4	26.7
4	Extremely excellent	11	73.3

Data shows that a significant number of respondents rated the use of the virtual laboratory media through the EC Studio application as extremely excellent, indicating that it makes it easier for students to understand dynamic electricity material. This is shown when 11 respondents (73.3%) stated Extremely Excellent, and 4 respondents (26.7%) stated Excellent.

This research advances education in dynamic electrical learning by providing a studio-based virtual laboratory that allows students to construct, simulate, and analyze time-varying circuits interactively. By visualizing voltage, current, and power in real time and promoting active, collaborative experimentation, the platform enhances conceptual understanding and problem-solving skills. These findings demonstrate how virtual laboratories can effectively complement traditional hands-on instruction, offering a scalable solution for technology-enhanced engineering education.

The use of the Electrical Circuit Studio offers several advantages in enhancing students' understanding of dynamic electrical phenomena. Its interactive and visual features allow learners to observe current and voltage variations in real time, supporting conceptual comprehension that is often difficult to achieve in traditional laboratories. The platform also provides a cost-effective, flexible, and safe learning environment, enabling students to conduct experiments anytime and anywhere without the need for physical components. Furthermore, the integration of studio-based learning principles fosters collaboration, creativity, and iterative design practices. However, despite these benefits, the virtual nature of the Electrical Circuit Studio also presents limitations. It cannot fully replicate the tactile experiences and troubleshooting challenges of real laboratory work, which are essential for developing practical engineering skills. Additionally, dependence on device performance and the absence of physical feedback may reduce students' engagement with real-world experimentation. Therefore, while the Electrical Circuit Studio is an effective tool for conceptual and interactive learning, it should be complemented by hands-on laboratory activities to provide a balanced and comprehensive learning experience.

The application of the Electrical Circuit Studio in learning may encounter several challenges that require careful consideration. Technological limitations, such as inadequate hardware, unstable software, or limited internet access, can hinder effective use and create unequal learning experiences among students. In addition, varying levels of digital literacy among learners and instructors may affect the efficiency of virtual laboratory implementation. The absence of real tactile interaction also limits the development of practical skills such as circuit wiring and

troubleshooting, which are essential in engineering education. Furthermore, adapting teaching strategies and assessments to suit a virtual studio-based environment can be demanding for educators. Maintaining students' motivation and engagement in a non-physical learning setting also remains a persistent challenge. These obstacles suggest that successful integration of the Electrical Circuit Studio should involve balanced pedagogical planning and, where possible, a combination of virtual and hands-on laboratory experiences.

D. Conclusion

The results for the first indicator, the correlation between the EC Studio application and student motivation, are as follows: Extremely excellent (68.3%), Excellent (26.6%), Under Average (3.33%), and Extremely poor (1.66%). Based on these results, students' responses are Extremely excellent regarding the use of the virtual laboratory media with the EC Studio application, which can enhance student motivation in learning, especially in dynamic electricity material. The results also improve students' reasoning abilities, their developing thinking skills, and their learning outcomes. The use of media now has a significant connection to the decreasing interest in participating in learning. The second indicator is the application that stimulates higher-order thinking skills. The results obtained are Extremely Excellent (77.7%), Excellent (20%), Under Average (2.22%), and Extremely Poor (5.5%). Thus, students' responses are Extremely Excellent towards the virtual laboratory media using the EC studio application. This media can enhance thinking skills because the images and simulations in the EC Studio application components are very engaging and effective. The third indicator is conceptual understanding and problem-solving, with results of Extremely Excellent (75.5%), Excellent (28.8%), Under Average (2.22%), and Extremely Poor (0%). Based on these results, students' responses are Extremely Excellent towards the virtual laboratory media using the EC Studio application because it is very engaging. Students can also repeat if they do not understand, as this media allows them to work independently. The use of the virtual laboratory media with the EC Studio application makes it easier for students to grasp the material on dynamic electricity.

Future research is recommended to explore the integration of the Electrical Circuit Studio with physical laboratory activities to create a blended or hybrid learning environment. Such studies could examine how combining virtual and real experiments enhances students' conceptual understanding and practical skills simultaneously. Further investigations may also focus on assessing long-term learning outcomes, student engagement, and cognitive development when using studio-based virtual laboratories in electrical engineering education. In addition, future work could expand the application of the Electrical Circuit Studio to other domains of dynamic systems, such as electronics, control systems, or renewable energy, to evaluate its adaptability across different learning contexts. Finally, more advanced studies involving artificial

intelligence, real-time data logging, or augmented reality integration could be conducted to improve interactivity, feedback precision, and the overall realism of virtual laboratory experiences.

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