Android-Based Courseware as an Educational Technology Innovation for Electrical Circuit Course: An Effectiveness Study

Doni Tri Putra Yanto*, Fivia Eliza, Ganefri, Sukardi, Hastuti, Maryatun Kabatiah, and Andrian

***Abstract*—This study investigates the effectiveness of Android-Based Courseware (AC) in teaching electrical circuits to vocational students in higher education. The courseware was developed using Android Studio and was implemented in the Electrical Circuit Course (ECC) at the Industrial Electrical Engineering study program, Universitas Negeri Padang, Indonesia. The AC consists of four primary menus designed to facilitate learning implementation: learning materials, simulations, animations, and interactive quizzes for evaluations. The study utilized a pre-experimental design with a one-group pre-test-post-test design involving a group of students who used the AC in the learning process. The cluster random sampling technique was employed to select the research subjects. This study involved 68 students as research subjects. Data was collected through a written test, utilizing a multiple-choice test as the research instrument. The effectiveness of the AC was evaluated based on the differential analysis of pre-test and post-test scores using the paired-sample t-test. Furthermore, the effect size of the AC on the learning process was determined using Cohen's d effect size analysis. The results showed a significant difference (alpha significance value is 0.000 and less than 0.05) between the post-test and pre-test scores, with the post-test scores ($\bar{x}$ = 85.00) being higher than the pre-test scores ($\bar{x}$ = 60.00). This indicates that the courseware effectively improves the learning process of the ECC. Additionally, the effect size analysis results show that the effect of using the courseware falls within the large category. These findings suggest that the AC can be an effective tool in the learning process of the ECC and can improve student learning outcomes. Specifically, the AC has a significant impact on enhancing students' cognitive and practical abilities concerning electrical circuit concepts.**

***Index Terms*—Android-based courseware, electrical circuit course, effectiveness analysis, vocational students**

I. Introduction

Electrical Circuit Course (ECC) is one of the subjects that vocational education students in the study program of industrial electrical engineering are required to study. This course is a fundamental course that plays a dominant role in supporting other advanced courses. A good command of the basic concepts of electric circuits in the ECC will assist students in comprehending more complex material in other advanced courses. In this course, students learn about basic concepts such as resistance, capacitance, inductance, electric current, and electric voltage. This ECC is crucial as the concepts learned are highly relevant to work or industrial needs. Hence, the course must be prepared and conducted optimally to achieve its objectives.

The ECC revealed some problems, which include: (1) Accessibility limitations: students have difficulty comprehending the latest electrical circuit concepts because they lack access to laboratories or adequate practical equipment for the latest and industry-relevant electrical circuit technology [1, 2]; (2) Interaction limitations: students face difficulty interacting with lecturers or instructors during the learning process due to a large number of students in one class, which prevents the lecturer from responding to specific questions in full [3]; (3) Limited availability of place and time: the available learning media has been insufficient in overcoming the problems of limited space and time, whereas the electrical circuit material is complex and requires comprehensive understanding [4, 5]; (4) Unavailability of learning media that can facilitate distance learning, which is increasingly popular after the COVID-19 pandemic, and the demands of 21st-century learning that require flexibility. These problems have resulted in the sub-optimal learning process in the ECC and low student learning outcomes [1, 3].

Previous research [1, 5] have demonstrated that interactive learning models such as problem-based learning, inquiry learning, and project-based learning can address learning challenges. Moreover, selecting and utilizing appropriate learning media play a vital role in tackling learning difficulties [6–8]. An interactive learning medium, presented as an Android application, is an innovative learning approach chosen to resolve learning problems in ECC. This is supported by the increasing popularity of Android or smartphone users in everyday life, which makes mobile-based learning increasingly popular [9–11]. AC can overcome the problem of the complexity of learning material because it does not have space and time limitations. Students can learn anywhere and anytime independently, apart from guided learning in class [9, 12]. This results in a more optimal learning process, in line with the characteristics and needs of each individual in the learning process.

The AC as an innovative way of ECC must undergo an effectiveness test. This test is carried out to ensure that the AC is feasible and effective in the learning process to solve problems optimally [13, 14]. Previous studies have focused

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on testing the effectiveness of research products before they are implemented and used according to their intended function [9, 13]. The results demonstrate that the research product obtained is effective for implementation in a real-world setting, aligning with the objectives of product development. Effectiveness serves as a crucial determinant of the quality of research products. However, research on the effectiveness of recently developed learning applications, specifically in the context of the ECC within vocational education, remains limited. Moreover, there is a lack of studies evaluating the effectiveness of learning media and analyzing the extent of their impact on students' learning outcomes. It is crucial to assess the effectiveness of developed learning media before their optimal implementation in the learning process. Therefore, conducting an effectiveness analysis test for developed learning media is essential to evaluate its efficacy in enhancing students' understanding and learning achievement within the learning process [13, 15]. The results of the test can be used to enhance the quality of the learning media used in vocational education. Therefore, this research aims to answer the following questions: (1) Is the AC effectively used as a learning medium in the ECC at vocational education for industrial electrical engineering? and (2) To what extent does the AC affect the learning process in the ECC in industrial electrical engineering vocational education?

The general objective of this study is to investigate and determine the effectiveness of AC as a learning medium in ECC in increasing students' understanding and learning achievement in vocational education. The specific objectives of this study are: (1) To analyze the effectiveness of AC as a learning medium in the context of Electrical Circuit Concepts (ECC) within industrial electrical engineering vocational education; (2) To assess the impact of AC on the learning process in the context of Electrical Circuit Concepts (ECC) within industrial electrical engineering vocational education. This research contributes to (1) providing useful information for the development of more effective the AC for the ECC in vocational education, (2) offering references for teachers and curriculum developers in vocational education to improve the quality of the learning process in the ECC, (3) enhancing the quality of vocational education in the study program of electric power engineering by optimizing the use of the AC in the ECC, and (4) providing references for future researchers who wish to conduct similar research on the development of android-based learning media to optimize the learning process.

The research results also offer several benefits, including (1) Enhancing students' understanding and achievement in ECC: For instance, by utilizing AC as a learning medium, students can enhance their comprehension of electrical concepts and develop practical skills related to the subject matter; (2) Improving the quality of the teaching process in ECC: The use of AC as an interactive and engaging teaching aid can foster greater student engagement and interest in the learning process; (3) Enriching the range of effective learning media options for ECC: For example, the inclusion of interactive simulations and animations in AC facilitates a better visualization of complex concepts, making them more accessible and comprehensible for students; (4) Enhancing the effectiveness of technology utilization in vocational education: Through the implementation of AC as an Android-based learning medium, students can cultivate their technological skills within the context of vocational education; (5) Providing a reference for developers of Android-based learning media in vocational education to enhance the quality of learning materials: The findings of this study serve as a valuable reference for developers, offering insights on how to optimize the utilization of AC to improve learning media; (6) Offering guidance for educational institutions and vocational education teachers to develop more effective learning media tailored to students' needs: This study provides educators and institutions with a framework for developing learning media that aligns with students' characteristics and requirements within the vocational education setting.

II. Literature Review

A. Android-Based Courseware

The Android-based Courseware (AC) is a learning program or application developed based on the Android operating system, which can be used as an interactive and effective learning medium in an educational environment [9, 16]. This application offers comprehensive features, such as learning materials, video tutorials, audio, interactive quizzes, and others, which can help students understand the subject matter more easily and enjoyably [1, 17]. The AC can be accessed by students via their smartphones or tablet devices. Students can study anytime and anywhere, without being tied to a specific time and location as in traditional learning. This provides students with greater flexibility in studying the subject matter.

The AC has several advantages as a learning medium, including (1) Flexibility, as it can be accessed and used anytime and anywhere using a smartphone or tablet device that is portable; (2) Interactivity and multimedia, as it has multimedia features such as audios, videos, animations, motion graphic, and images, which can enrich the learning experience, interest, motivation, and make it more interesting; (3) Immediate feedback, as it can provide direct and automatic feedback on students' answers in interactive quizzes, allowing them to immediately identify their strengths and weaknesses in understanding the subject matter; and (4) Integration with technology, as it can be integrated with other high technologies such as virtual reality, animations, and augmented reality to enhance the effectiveness and efficiency of learning [2, 9, 11, 18, 19].

However, the AC also has some drawbacks if not implemented optimally, including (1) Limitations of social interaction, as the use of the AC may reduce social interaction between students and lecturers, which can affect the formation of social relations in the educational environment; (2) Limited resources, as the use of the AC requires a smartphone or tablet device, which may not be available to all students; and (3) Limited technical support, as some students may face difficulties in using android-based learning applications, requiring complete technical support

[9, 12, 16]. Overall, these limitations have the potential to diminish the effectiveness of AC in the learning process. Reduced social interaction can hinder the development of essential interpersonal and collaborative skills. Limited resources can create disparities among students, hindering their access and engagement with AC. Additionally, insufficient technical support may impede students' ability to navigate and utilize AC effectively.

B. Educational Technology Innovation

Educational Technology Innovation refers to the development and implementation of technology aimed at enhancing the effectiveness of learning and teaching processes [2, 9]. By leveraging diverse digital devices, applications, and platforms, educational technology innovations offer a range of interactive, adaptive, and globally connected learning approaches. This innovation empowers educators to design more engaging learning experiences, facilitate broader access to education, and assist students in acquiring skills that are pertinent to the current era [10, 16]. Employing a creative and up-to-date approach, educational technology innovation effectively tackles learning challenges, fosters creativity, and equips students to confront progressively intricate future demands.

C. Electrical Circuit Course

Electrical Circuit Course (EEC) is a crucial subject for students pursuing vocational education in the study program of electrical power engineering [20]. This course is a fundamental course that plays a dominant role in supporting other advanced courses. A good command of the basic concepts of electric circuits in the ECC will assist students in comprehending more complex material in other advanced courses [21, 22]. The course covers fundamental concepts of electric circuits, including resistance, capacitance, inductance, electric current, and voltage [23, 24]. Students also learn about different types of electrical circuits, such as series, parallel, and mixed circuits, and techniques for analyzing them. In lectures, students engage in practical activities to apply their knowledge of electrical circuits in measurement and analysis [4, 23]. They also participate in projects that require them to apply electrical circuit concepts to design efficient and reliable electric power systems. This course is vital for vocational education students in the study program of industrial electrical engineering as the concepts studied are highly relevant to the demands of the industrial sector.

D. Effectiveness Study

The effectiveness test analysis for learning media is an evaluation process conducted to determine the extent to which learning media can assist students understand and master the course matter. This effectiveness test is usually carried out by comparing the learning outcomes of students who use learning media with a control group that does not use learning media or by comparing student learning outcomes before and after using learning media [2, 13, 25]. The importance of analyzing the effectiveness test of the developed learning media is to ensure that the learning media used are effective in helping students understand and master the subject matter [1, 9, 26]. Through this evaluation process, we can determine whether the developed learning media can improve student learning outcomes or not. If the yields of the effectiveness test analysis indicate that the learning media developed are not effective, we can improve them or look for other more effective alternatives. Additionally, the analysis of the effectiveness test can help developers of learning media to optimize the use of technology and multimedia features in learning media, which can lead to better and more effective learning media in the future [14, 26–28].

The results of the literature review demonstrate that AC, as an Android-based learning medium, holds the potential to enhance students' comprehension and achievement in ECC. With features like time and place flexibility, interactivity, direct feedback, and integration with technology, AC can effectively increase student engagement, interest, learning outcomes, and enrich overall learning experiences. The literature review also acknowledges the significance of developing educational technology innovations, such as AC, as a crucial step toward enhancing the effectiveness of the learning process. Moreover, the literature review highlights the importance of ECC as a significant subject for vocational education students, playing a dominant role in preparing them to meet the demands of the industrial sector. In light of this, the present study aims to analyze the effectiveness of AC as a learning medium in ECC, assessing its impact on improving student understanding and learning outcomes, as well as examining its influence on the overall learning process.

III. Method

A. Research Design

The experimental study using a pre-experimental design is used in this research, specifically the one-group pre-test post-test design [29]. The pre-test is conducted before the application of the research activities to assess students' initial abilities (O_1) before being exposed to the research intervention. The research intervention implemented in this study is the use of the AC as a learning medium for the electric circuits learning process (X). The post-test is administered after the application of the research intervention to evaluate students' final abilities (O_2) in understanding electric circuits using the AC as a learning medium.

B. Research Instruments

The research utilized a multiple-choice test as the research instrument for both pre-test and post-test assessments [26, 30]. The multiple-choice tests were self-developed based on Basic Competencies (BC) and Competency Achievement Indicators (CAI) of the ECC for vocational students as presented in Table I. The research instrument underwent validity, reliability, difficulty index, and discriminatory power analyses. Validity was analyzed using the Pearson Product Moment Correlation analysis, reliability was determined using Cronbach's Alpha reliability analysis, the difficulty index was analyzed using the difficulty index formula, and the discriminatory power was analyzed using discriminating power analysis through multiple choice questions [2, 26]. The results of the validity

analysis showed that the r-count value for all indicators was greater than the r-table (> 0.361), indicating the validity of all indicators in the research instrument. Cronbach's alpha analysis resulted in a value of 0.815, indicating that the research instrument is considered reliable since the value of Cronbach's alpha is greater than 0.60 (0.815 > 0.600). The difficulty index analysis shows that the difficulty index is 0.67 (in the moderate category). The discriminating power analysis showed that the discriminating power index of the research instrument tested was 0.71 (in the very good category). The final research instrument which consisted of 20 multiple-choice questions was then utilized to measure and investigate the level of cognitive understanding of students before (pre-test) and after (post-test) the learning process of electric circuits using the AC as a learning medium.

TABLE I: BASIC COMPETENCIES (BC) AND COMPETENCY ACHIEVEMENT INDICATOR (CAI) FOR RESEARCH INSTRUMENT

Basic Competencies	Competency Achievement Indicators	Item Number
BC.1. The students should be able to define, analyze, and explain the concepts of resistance, resistors, and resistive materials in electrical circuits	CAI.1. The students should be able to define, analyze, and explain the meanings of resistance, resistor, and resistive in electrical circuits.	1,2,3,4
	CAI.2. The students should be able to define, analyze, and explain the concept of Ohm's law in electrical circuits.	5,6,7,8
	CAI.3. The students should be able to define, analyze, and explain the concept of Kirchhoff's current law in electrical circuits.	9,10,11,12
	CAI.4. The students should be able to define, analyze, and explain the concept of Kirchhoff's voltage law in electrical circuits.	13,14,15,16
	CAI.5. The students should be able to define, analyze, and explain the types of resistor circuits, including series, parallel, and series-parallel, in electrical circuits.	17,18,19,20

C. Research Subject

This study involved a group of 68 vocational students who participated in the learning process of the ECC from the Industrial Electrical Engineering study program in the Electrical Engineering Department, Faculty of Engineering at Universitas Negeri Padang, Sumatera Barat, Indonesia. The research subjects were determined using cluster random sampling. All of these students participated in this research as the experimental group and followed the research procedures according to the research design, which included a pre-test, action research, and post-test.

D. Technique of Data Analysis

The data collected in this research pertains to the cognitive domain of student learning outcomes. The research data is categorized into pre-test and post-test data. Before conducting an effectiveness analysis, normality tests were carried out using the Kolmogorov-Smirnov Z normality analysis on the pre-test and post-test data [2, 30].

The effectiveness of the AC as a learning medium for the ECC was evaluated using two analytical techniques: (1) Paired Sample t-test Analysis, this analysis was utilized to determine the significant difference between the pre-test and post-test data; (2) Cohen's d effect size analysis, this analysis formula was conducted to assess the effectiveness of the AC as a learning medium for the ECC [26, 30]. All data analyses were performed using the Statistical Program for Social Science (SPSS) data analysis application.

The value of effect size obtained from Cohen's d effect Size analysis is interpreted using the effect size criteria table presented in Table II [2, 30]. This interpretation is conducted to determine the effect category of the given research action, which is the learning process of electric circuits using the AC as a learning medium. Based on the interpretation results, the level of effectiveness of the AC as a learning medium can be determined. The research utilized a multiple-choice test as the research instrument for both pre-test and post-test assessments [26, 31].

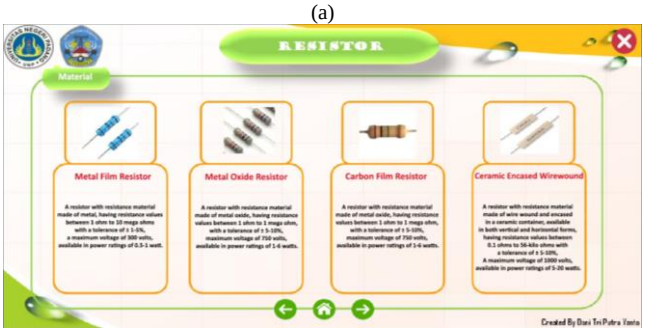
TABLE II: EFFECT SIZE CRITERIA

No.	d Value	Categories
1	$0.8 \leq d \leq 2.0$	Big Categorize
2	$0.5 \leq d < 0.8$	Medium Categorize
3	$0.2 \leq d < 0.5$	Small Categorize

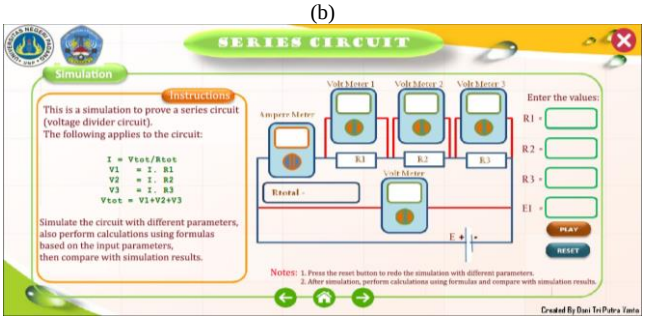
IV. RESULTS

The AC is a learning application developed for Android operating systems, which serves as an interactive and effective learning medium in an educational environment [9, 16]. This application provides a range of features such as learning materials, video tutorials, audio, interactive quizzes, and more, which can help students comprehend subject matter more easily and enjoyably [1, 9]. The AC can be accessed by students via their smartphones or tablet devices, providing them the flexibility to study anytime and anywhere without being bound to a particular time or location, as in traditional learning. In this way, it provides students with more flexibility in studying the subject matter. For the ECC in this study, an AC was developed using Android Studio, and the output file was in the form of an Android Package Kit (.APK) to facilitate the installation process on Android devices for each student. The AC has undergone a validation process conducted by experts. The results of validation and analysis using Aiken's V indicate that AC has been confirmed as valid across various aspects, including subject matter (V = 0.793), learning media (V = 0.690), language (V = 0.771), and technicality (V = 0.709). Some of the display features and menus on the AC developed and used in this study are presented in Fig. 1.

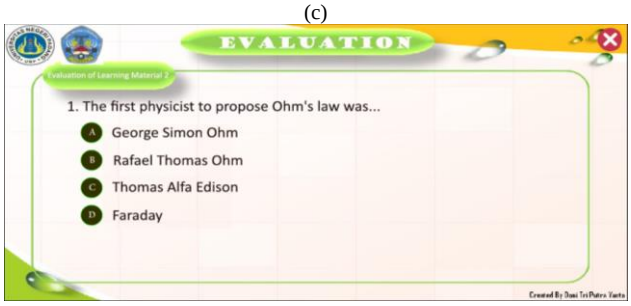
(a)



(b)



(c)



(d)

Fig. 1. The display features and menus on the AC: (a) main menu, (b) learning material, (c) simulation and animation, and (d) evaluation.

A. Research Data

The data of this research is quantitative data obtained from the yields of students' cognitive ability tests using research instruments in the form of multiple-choice tests. By the research design, data collection using research instruments was conducted twice, namely before (pre-test) and after (post-test) the implementation of learning in the ECC using the AC as a learning medium. The pre-test and post-test data are used as a reference for analyzing the effectiveness of the AC as a learning medium in the ECC for vocational students.

1) Pre-test data

The pre-test is an initial test given to students to assess their basic abilities before receiving research action in the form of a learning process that uses the AC as a learning medium in the ECC. Pre-test data were obtained through test results on students using research instruments in the form of multiple-choice tests given to all students who were research subjects. Pre-test data is needed to carry out data analysis to determine the effectiveness of implementing AC as a learning medium. The results of the pre-test data analysis showed that the minimum score of students' cognitive learning outcomes before using the AC as a learning medium was 45, and the maximum score was 75, with an average score of 60 for 68 students and a standard deviation of 7.813. The pre-test data normality test was carried out first to ensure that the data was normally distributed before it could be used for effectiveness analysis using effect size analysis and paired-sample t-test analysis. The results of the pre-test data normality analysis are presented in Table III. The results of the normality test analysis on the pre-test data presented in Table III indicate a significance value of 0.713, which is higher than the alpha value of 0.05. Therefore, it can be concluded that the pre-test data follows a normal distribution (α = 0.713 > 0.05). As a result, the pre-test data can be utilized for further analysis, namely the evaluation of the effectiveness of the AC as a learning medium in ECC. The frequency histogram of the pre-test data, accompanied by a normal curve, is depicted in Fig. 2.

TABLE III: NORMALITY TEST ANALYSIS OF PRE-TEST DATA

		Pre-test Score
N		68
Normal Parameters[a,b]	Mean	60.00
	Standard Deviation	7.813
Most Extr. Differ.	Absolute	0.100
	Positive (+)	0.063
	Negative (−)	−0.100
Kolm.-Smir. Z		0.516
Asymp. Significance (2-tailed)		0.713

Note: a. Test distribution is Normal.
b. Calculated from data.

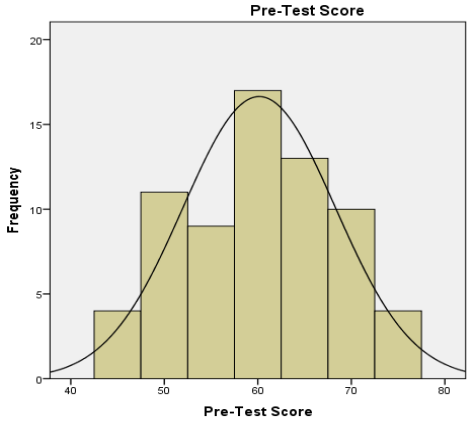


Fig. 2. The frequency histogram of the pre-test data, accompanied by a normal curve.

2) Post-test data

The post-test is a final assessment of students' cognitive learning outcomes after completing research activities in the form of an electric circuit learning process that utilizes the AC as a learning medium. The post-test data was obtained through the test results of each student using a research instrument in the form of multiple-choice tests. This post-test data complements the pre-test data used to analyze the effectiveness of using the AC as a learning medium in the ECC. The yields of the post-test data analysis showed that the minimum score for student learning outcomes after using the

AC was 60 and the maximum score was 95. The average score of the 68 students was 85 with a standard deviation of 5.117. A normality test was carried out on the post-test data as a prerequisite for analysis before it could be used for effectiveness analysis using effect size analysis and paired-sample t-test analysis. The results of the post-test data normality test are presented in Table IV. The normality test analysis results for the post-test data in Table IV reveal a significance value of 0.815, which is greater than the standard alpha value of 0.05. Therefore, it can be concluded that the post-test data follows a normal distribution ($\alpha = 0.815 > 0.05$). Consequently, the post-test data can be used for further analysis, specifically an assessment of the effectiveness of utilizing the AC as a learning medium in the ECC. The frequency histogram of the post-test data, accompanied by a normal curve, is depicted in Fig. 3.

TABLE IV: NORMALITY TEST ANALYSIS OF POST-TEST DATA

		Post-test Score
N		68
Normal Parameters[a,b]	Mean	85.00
	Standard Deviation	5.117
Most Extr. Differ.	Absolute	0.135
	Positive (+)	0.069
	Negative (−)	−0.130
Kolm.-Smir. Z		0.912
Asymp. Significance (2-tailed)		0.815

Note: a. Test distribution is Normal.
b. Calculated from data.

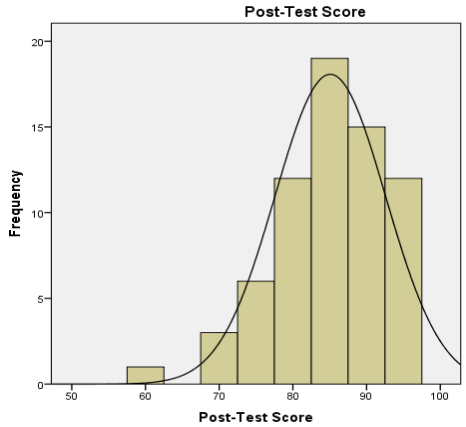


Fig. 3. The frequency histogram of the post-test data, accompanied by a normal curve.

B. Effectiveness Analysis of the AC

The effectiveness of using the AC as a learning medium in vocational education for ECC was evaluated through a paired-sample t-test analysis. This analysis aimed to determine and investigate significant differences in students' cognitive abilities before and after participating in the learning process using the AC. The results of the paired-sample t-test analysis in Table V indicate that the t-count value (6.567) is greater than the t-table value (1.684), and the alpha significance value (0.000) is less than 0.05. Therefore, it can be concluded that there is a significant difference between students' learning outcomes in the pre-test and post-test, where the post-test students' cognitive learning outcomes are better than the pre-test students. This is supported by the fact that the post-test students' average cognitive score (85) is higher than the pre-test average (60). Thus, it can be concluded that the AC is an effective learning medium in the learning process in the ECC for vocational students.

TABLE V: THE RESULTS OF THE PAIRED SAMPLE T-TEST ANALYSIS

	Paired Differences			t	Sig. 2-tailed
	Mean	Std. Deviation	Std. Error Mean		
Posttest score−Pretest score	24	9.78	1.323	6.567	0.000

The effectiveness of using the AC as a learning medium in the ECC in vocational education was also evaluated through Cohen's d effect size analysis to measure the effect size. The analysis of the effect size between the pre-test and post-test data resulted in an effective index value of 1.77 (d = 1.77). According to the effect size criteria table, this effect size is considered to have a big category of influence. Thus, based on the result of the effect size analysis and the effect size category, it can be concluded that the AC is an effective learning medium for use in the learning process in the ECC for vocational students, with a big effect size. Therefore, using the AC in the learning process can be an option for implementing effective learning in vocational education, especially in the ECC.

However, the research findings also reveal some of the weaknesses of Android-based learning media based on students' opinions as users. Firstly, the limited screen size of Android devices can impede the presentation of complex or detailed content, which may harm students' understanding and engagement. Additionally, the wide range of Android device models and versions available in the market may result in compatibility issues, making it challenging for developers to ensure a seamless user experience across multiple devices. Lastly, the potential for distraction caused by other applications and notifications on Android devices can divert learners' attention away from educational content, leading to reduced focus and diminished learning outcomes. These findings underscore the significance of considering and overcoming these limitations when employing Android-based learning media to optimize the effectiveness of educational interventions.

V. DISCUSSION

The AC incorporates various features and functions designed to enhance the learning experience and engage students in the context of the ECC. Firstly, the AC provides a menu that displays fundamental competencies, competency achievement indicators, and learning objectives. These serve as references for students before engaging in learning activities. Secondly, the AC grants access to comprehensive and well-structured learning materials presented in electronic format. These materials encompass textual content, images, and diagrams, facilitating comprehension of intricate concepts. Thirdly, the AC is equipped with simulation and animation features that enrich students' learning experiences. The simulation feature enables students to practically apply the learned concepts through virtual experiences. For instance, in the field of electrical circuits, the AC offers

interactive simulations for students to virtually analyze and simulate electrical circuits. Furthermore, the animation feature in AC provides dynamic and visually appealing representations of abstract concepts. Through animated visuals, students can visualize complex processes and grasp difficult-to-understand concepts more effectively. Lastly, the AC includes interactive quizzes that actively involve students in the learning process. These quizzes allow students to assess their understanding and receive immediate feedback. By engaging in quizzes, students can monitor their learning progress, identify areas for improvement, and enhance their overall engagement in the learning process.

Compared to traditional learning media, the AC offers several unique and innovative aspects. Its flexibility and accessibility enable students to study anytime and anywhere. In traditional learning, students are confined to specific times and locations. However, with the AC, students can access learning materials through their devices, such as smartphones or tablets, providing them with the flexibility to choose when and where to study. This allows students to learn at their own pace, fostering greater engagement and independence in the learning process.

Furthermore, the AC incorporates interactive features such as simulations and evaluations, including quizzes, which actively involve students in the learning process. Students are not merely passive recipients of information, they are prompted to think, analyze, and apply the concepts they have learned. This interactive approach enhances student engagement and reinforces their understanding through more dynamic and participatory learning experiences.

The findings of this study indicate that the utilization of the AC as an effective learning medium significantly enhances students' cognitive abilities. The results of the paired t-test analysis revealed a notable difference between students' cognitive abilities before and after utilizing the AC. This demonstrates that the AC has a positive impact on enhancing comprehension and mastery of the subject matter. Improving cognitive abilities is crucial for enhancing overall student learning outcomes. By improving their understanding and mastery of the material, students gain better proficiency in connecting complex concepts and applying them in practical scenarios. Consequently, the utilization of the AC as a learning medium contributes significantly to helping students achieve learning outcomes.

Additionally, the AC plays a vital role in fostering an engaging and interactive learning environment. Through features such as simulations, animations, interactive quizzes, and comprehensive learning materials, the AC creates a learning environment that encourages active student engagement. This interactive learning environment offers opportunities for students to deeply engage with the subject matter and apply the concepts they are learning. In this context, the AC as a learning medium delivers valuable benefits in enhancing students' cognitive understanding and serves as a crucial foundation for the development of effective, innovative, and adaptive vocational education.

This research consistently supports previous findings that highlight the effectiveness of Android-based learning media in enhancing comprehension and mastery of the subject matter [2, 9, 10]. However, this research's unique contribution lies in developing customized AC tailored to the curriculum, subject matter of electrical circuits, and the specific needs and characteristics of students in ECC. With a clear focus on the vocational education context, this research provides additional evidence on the effectiveness of Android-based learning media in specific educational settings.

The study's results also emphasize the positive impact of utilizing the AC as a learning medium on students' cognitive abilities. This finding aligns with previous studies indicating a significant difference in students' cognitive abilities before and after using Android-based learning media [3, 9, 32, 33]. However, this study makes a distinctive contribution by employing Cohen's D effect size analysis, revealing that the use of the AC as a learning medium in the ECC yields large effect sizes. This suggests that the utilization of the AC significantly enhances students' cognitive understanding in the ECC, with a substantial impact.

Moreover, this study highlights the importance of flexibility and accessibility in learning, which are achieved through the utilization of the AC as a learning medium. This finding aligns with previous studies exploring the advantages of temporal and spatial flexibility in technology-based learning [14, 16, 19, 34]. However, this research makes a unique contribution by emphasizing the application of the AC as a learning medium in vocational education environments, specifically in the context of the ECC. In this regard, the research provides empirical evidence of how the use of the AC can enrich and expand students' learning experiences in the ECC by offering flexibility and accessibility.

Furthermore, this study emphasizes the significance of evaluating the effectiveness of instructional media in vocational education. Its unique contribution lies in combining paired t-test analysis and Cohen's D effect size analysis to evaluate the effectiveness of AC. By employing these two methods, the study provides a deeper understanding of the changes in students' cognitive abilities before and after utilizing the AC. The results of this study lay a strong foundation for further development and improvement of vocational learning approaches that focus on Android-based learning media in the ECC.

VI. Conclusions

The AC is a learning program or application developed based on Android, which can be used as an effective and interactive learning medium in vocational education, particularly in the ECC. It plays a significant role in optimizing the implementation of learning, particularly in supporting independent and flexible learning without any time or space limitations. The results indicate that the developed AC was an effective learning medium for the ECC, where the effect size was in a large category. Its increased students' cognitive understanding of electrical circuit concepts that were previously difficult to comprehend using conventional media. Therefore, the AC can be considered as a choice for implementing effective, innovative, and adaptive learning with technological developments in vocational education, particularly in the ECC. The research findings also

highlight the weaknesses of Android-based learning media, including limited screen size hindering content presentation, compatibility issues due to various device models and versions, and potential distractions from other applications and notifications. Overcoming these limitations is crucial for optimizing the effectiveness of educational interventions using Android-based learning media.

The study was conducted solely on the ECC in vocational education; therefore, the generalization of the research results must be done with caution before being applied to different courses or levels of education. Moreover, the effectiveness test only examined students' cognitive aspects, and further research is required to investigate the effects of the AC on students' affective and psychomotor aspects. Furthermore, the research was conducted with a limited number of participants and was only conducted at one vocational education institution. Therefore, broader research is necessary to test the effectiveness of the AC on a wider population. Based on these research limitations, future work for this study includes (1) examining the effectiveness of the AC in different subjects and at different levels of education, (2) studying the effectiveness of the AC on students' affective and psychomotor aspects, and (3) conducting more extensive research to test the effectiveness of the AC in different educational institutions and with a more extensive population. Additionally, new features in the AC must be continually developed to increase its effectiveness as a learning medium in line with science and technology developments.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

Conceptualization: D.T.P.Y, F.E., and G.; Methodology: D.T.P.Y., H, M.K., and S.; Validation: D.T.P.Y., F.E., S., and A.; Formal Analysis: H., G., and S.; Original Draft Preparation: D.T.P.Y., F.E., H., and A.; Writing Review and Editing: S., H., and M.K. All authors had approved the final version.

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REFERENCES

[1] S. Jacques and T. Lequeu, "The attractiveness of reversing teaching forms—Feedback on an electrical engineering course," *International Journal of Engineering Pedagogy (iJEP)*, vol. 10, no. 3, pp. 21–34, May 2020, doi: 10.3991/IJEP.V10I3.12361

[2] Y. Dosymov *et al.*, "Effectiveness of computer modeling in the study of electrical circuits: Application and evaluation," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 4, pp. 93–112, Jun. 2023, doi: 10.3991/IJEP.V13I4.34921

[3] X. Pei, "Virtual instrument based on electronic and electrician's experiment teaching laboratory design," *Procedia Comput. Sci.*, vol. 183, pp. 120–125, Jan. 2021, doi: 10.1016/J.PROCS.2021.02.039

[4] E. Fendzi-Donfack, D. Kumar, E. Tala-Tebue, L. Nana, J. P. Nguenang, and A. Kenfack-Jiotsa, "Construction of exotical soliton-like for a fractional nonlinear electrical circuit equation using differential-difference Jacobi elliptic functions sub-equation method," *Results Phys.*, vol. 32, 105086, Jan. 2022, doi: 10.1016/J.RINP.2021.105086

[5] A. A. Zaher, G. A. Hussain, and H. Altabbakh, "An active learning approach for applying STEAMeD-based education in engineering programs," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 3, pp. 4–26, Apr. 2023, doi: 10.3991/IJEP.V13I3.34819

[6] D. Beneroso and J. Robinson, "Online project-based learning in engineering design: Supporting the acquisition of design skills," *Education for Chemical Engineers*, vol. 38, pp. 38–47, Jan. 2022, doi: 10.1016/j.ece.2021.09.002

[7] M. Barak and S. Yuan, "A cultural perspective to project-based learning and the cultivation of innovative thinking," *Think Skills Creat.*, vol. 39, Mar. 2021, doi: 10.1016/j.tsc.2020.100766

[8] A. Quelin and N. Damay, "Coupling electrical parameters of a battery equivalent circuit model to electrodes dimensions," *J. Power Sources*, vol. 561, 232690, Mar. 2023, doi: J.JPOWSOUR.2023.232690

[9] S. Hartanto, A. Huda, R. E. Wulansari, A. Mubai, Firdaus, and Shalehoddin, "The design of android-based interactive lean manufacturing application to increase students' work skill in vocational high school: The development and validity," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 13, pp. 130–139, Jul. 2022, doi: 10.3991/IJIM.V16I13.30595

[10] M. Nazar, Rusman, K. Puspita, and H. Yaqin, "Android-based mobile learning resource for chemistry students in comprehending the concept of redox reactions," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 03, pp. 123–135, Feb. 2022, doi: 10.3991/IJIM.V16I03.24133

[11] D. T. P. Yanto, Sukardi, M. Kabatiah, H. Zaswita, and O. Candra, "Analysis of factors affecting vocational students' intentions to use a virtual laboratory based on the technology acceptance model," *International Journal of Interactive Mobile Technologies*, vol. 17, no. 12, pp. 94–111, Jun. 2023, doi: 10.3991/ijim.v17i12.38627

[12] M. Drolia, E. Sifaki, S. Papadakis, and M. Kalogiannakis, "An overview of mobile learning for refugee students: Juxtaposing refugee needs with mobile applications' characteristics," *Challenges*, vol. 11, no. 2, p. 31, Dec. 2020, doi: 10.3390/challe11020031

[13] Krismadinata, R. Mulya, and M. D. Juwita, "E-learning courseware development for power electronics course," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 3, pp. 66–81, 2022, doi: 10.3991/IJIM.V16I03.27723

[14] A. Huda, N. Azhar, Almasri, K. Anshari, and S. Hartanto, "Practicality and effectiveness test of graphic design learning media based on android," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 04, pp. 192–203, Mar. 2020, doi: 10.3991/IJIM.V14I04.12737

[15] A. Rauscher, M. Hufnagel, and C. Endisch, "Pareto optimization of wavelet filter design for partial discharge detection in electrical machines," *Measurement*, vol. 205, 112163, Dec. 2022, doi: 10.1016/J.MEASUREMENT.2022.112163

[16] G. D áz-Sainz *et al.*, "Mobile learning in chemical engineering: An outlook based on case studies," *Education for Chemical Engineers*, vol. 35, pp. 132–145, Apr. 2021, doi: 10.1016/J.ECE.2021.01.013

[17] Salina *et al.*, "Application mattampu as fetal growth education media during pregnancy based on android," *Enferm. Clin.*, vol. 30, pp. 602–605, Mar. 2020, doi: 10.1016/J.ENFCLI.2019.07.170

[18] D. Karahoca, Z. F. Zaripova, A. R. Bayanova, L. S. Chikileva, S. V. Lyalyaev, and X. Baoyun, "During the COVID-19 pandemic, students' opinions on distance education in department of engineering," *International Journal of Engineering Pedagogy*, vol. 12, no. 2, pp. 4–19, 2022, doi: 10.3991/IJEP.V12I2.29321

[19] M. Neitola, "Circuit theory e-assessment realized in an open-source learning environment," *International Journal of Engineering Pedagogy (iJEP)*, vol. 9, no. 1, pp. 4–18, Feb. 2019, doi: 10.3991/IJEP.V9I1.9072

[20] O. Candra, A. Putra, S. Islami, D. T. P. Yanto, R. Revina, and R. Yolanda, "Work willingness of VHS students at post-industrial placement," *TEM Journal*, vol. 12, no. 1, pp. 265–274, Feb. 2023, doi: 10.18421/TEM121-33

[21] T. Tsurugi, J. Koyama, K. Kodama, H. Nakajima, T. Sakamoto, and K. Okumura, "Defibrillation failure with an electrical short circuit caused by internal insulation breach," *HeartRhythm Case Rep*, vol. 7, no. 7, pp. 489–491, Jul. 2021, doi: 10.1016/J.HRCR.2021.04.009

[22] D. T. P. Yanto, S. Sukardi, and D. Puyada, "Effectiveness of interactive instructional media on electrical circuits course: The effects on

students' cognitive abilities," in *Proc. 4rd International Conference on Technical and Vocational Education and Training*, 2017, pp. 75–80.
[23] R. V. Fursenko and E. S. Odintsov, "A novel concept of automatic soap flowmeter with bubble detection by closing an electrical circuit," *Flow Measurement and Instrumentation*, vol. 85, 102165, Jun. 2022, doi: 10.1016/J.FLOWMEASINST.2022.102165
[24] S. Sukardi, D. Puyada, R. E. Wulansari, and D. T. P. Yanto, "The validity of interactive instructional media on electrical circuits at vocational high school and technology," in *Proc. the 2nd INCOTEPD*, 2017, pp. 21–22.
[25] K. Mohiuddin, H. Fatima, M. A. Khan, M. A. Khaleel, O. A. Nasr, and S. Shahwar, "Mobile learning evolution and emerging computing paradigms: An edge-based cloud architecture for reduced latencies and quick response time," *Array*, vol. 16, 100259, Dec. 2022, doi: 10.1016/J.ARRAY.2022.100259
[26] M. L. Santos and M. Prudente, "Effectiveness of virtual laboratories in science education: A meta-analysis," *International Journal of Information and Education Technology*, vol. 12, no. 2, pp. 150–156, Feb. 2022, doi: 10.18178/ijiet.2022.12.2.1598
[27] S. S. Nath, L. K. Nielsen, and J. Villadsen, "Elucidating dynamics and mechanism of cyclic bioreaction networks using topologically-equivalent electrical circuits," *Chem. Eng. Sci.*, vol. 262, 118015, Nov. 2022, doi: 10.1016/J.CES.2022.118015
[28] P. Alkorta, J. A. Cortajarena, O. Barambones, and F. J. Maseda, "Effective generalized predictive control of induction motor," *ISA Trans*, vol. 103, pp. 295–305, 2020, doi: 10.1016/j.isatra.2020.04.008
[29] D. T. P. Yanto, M. Kabatiah, H. Zaswita, N. Jalinus, and R. Refdinal, "Virtual laboratory as a new educational trend post COVID-19: An effectiveness study," *Mimbar. Ilmu*, vol. 27, no. 3, 2022, doi: 10.23887/mi.v27i3.53996
[30] L. M. Jeno, K. Egelandsdal, and J.-A. Grytnes, "A qualitative investigation of psychological need-satisfying experiences of a mobile learning application: A self-determination theory approach," *Computers and Education Open*, vol. 3, 100108, Dec. 2022, doi: 10.1016/J.CAEO.2022.100108
[31] V. Syrris and D. Geneiatakis, "On machine learning effectiveness for malware detection in Android OS using static analysis data," *Journal of Information Security and Applications*, vol. 59, 102794, Jun. 2021, doi: 10.1016/J.JISA.2021.102794
[32] Sujarwo *et al.*, "Android-based interactive media to raise student learning outcomes in social science," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 07, pp. 4–21, Apr. 2022, doi: 10.3991/IJIM.V16I07.25739
[33] R. A. Abumalloh *et al.*, "The impact of coronavirus pandemic (COVID-19) on education: The role of virtual and remote laboratories in education," *Technol. Soc.*, vol. 67, 101728, Nov. 2021, doi: 10.1016/J.TECHSOC.2021.101728
[34] A. Qohar, Susiswo, S. H. Nasution, and S. Wahyuningsih, "Development of android-based mathematics learning game on the topic of congruence and similarity," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 09, pp. 52–69, May 2021, doi: 10.3991/IJIM.V15I09.20723