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Utilization of Electric Circuit Studio Application as a Learning Tool in Selected Topics in Electronics

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ABSTRACT

Traditional teaching methods have established the educational foundation; however, recent research supports the transition to modern pedagogical approaches such as technology integration. This paper assesses the utilization of Electric Circuit (EC) Studio as an intervention to improve the academic performance of 48 college students in selected topics in electronics courses. It employed an explanatory sequential mixed-method research design. The quantitative incorporated a quasi-experimental with a pre-test – post-test design. Qualitative data were obtained from the purposively selected respondents through interviews to explore the benefits gained with the utilization of the EC Studio. Before the main analysis, an independent samples t-test showed no statistical significant difference between the two groups ($t(46)=0.872, p=.388$). It confirmed that both groups were statistically equivalent at baseline. After the intervention, the mean improvement scores of the experimental group (9.2) were nearly twice that of the control group (4.83). An independent samples t-test ($t(46)=-3.164, p=.003, \alpha=0.05$) confirmed that the mean improvement scores between the control and experimental groups are significantly different. The effect size, measured using Cohen's d indicates a large practical effect ($d=0.913$). The thematic analysis of transcribed interviews from 14 respondents identified five key benefits of utilizing the Electric Circuit (EC) Studio application: (1) Enhanced Learning Efficiency and Understanding ($n=14$); (2) Increased Motivation and Interest ($n=10$); (3) Improved Classroom Engagement and Collaboration ($n=8$); (4) Accessibility and Portability ($n=7$); and (5) Application Beyond the Classroom ($n=5$). The results proved the effectiveness and insights of using of EC Studio as a learning tool. Thus, its integration into teaching-learning of electronics-related courses is highly recommended.

INTRODUCTION

Technology breakthroughs, shifting societal demands, and a growing understanding of effective learning strategies are all driving changes in the global educational landscape. Traditional teaching methods have established the educational foundation; however, recent research supports the need to transition to modern pedagogical approaches, such as technology integration (Babu *et al.*, 2024). In the Philippine higher education settings, studies reported key challenges such as varying quality of higher education institutions and programs (Chao, 2021), pandemic predicaments (Toquero, 2020), recurring extreme weather events (Preña & Labayo, 2024), and disrupting extracurricular demands. With these issues, educational institutions have been forced to adopt flexible learning modalities. To support this transition, the Commission on Higher Education (CHED) issued CMO No. 4, s. 2020, encouraging institutions and stakeholders to explore innovative pedagogical approaches that could ensure the continuity and enhancing educational quality of education in times of uncertainty and change. In recent years, there is a growing emphasis on integrating technology into education to cope with the demands of the 21st-century learning environment (Murugesan, 2021). Integrating technology in the classroom offers a dynamic and proactive teaching and learning environment (Ghavifekr *et al.*, 2014). Interactive computer simulations, in particular, have gained prominence in higher

education due to their ability to provide new educational opportunities and enhance student engagement (Sari, 2017).

Learning electronics poses significant challenges for many students, particularly in higher education, where abstract concepts and complex circuit analyses are core components of the course. One significant difficulty lies in students' limited ability to visualize and conceptualize circuit behavior, which often results in misconceptions and cognitive overload (Sangam, 2012). Traditional lecture-based methods—focused heavily on theoretical instruction with minimal hands-on experience—can further alienate learners, especially those with little prior exposure to electronics (Adjetey, 2024). Additionally, constraints in laboratory resources and limited access to simulation tools have been cited as barriers to meaningful engagement and comprehension (Dunleavy *et al.*, 2009). These factors contribute to a consistent struggle to master foundational topics. The lack of interactivity and contextualized application in traditional instruction models makes it difficult for students to connect theoretical knowledge with real-world problem-solving (Kim and Hannafin, 2011). Thus, exploring innovative and interactive tools that facilitate conceptual understanding and experiential learning in electronics has become increasingly important.

One promising tool for interactive learning in electronics is Electric Circuit Studio (EC Studio) by

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Kenneth S. Kundert and the University of California (ECStudioSystems, 2021). This software, which is freely available for mobile devices and personal computers, provides users with a suite of tools to build, simulate, and analyze electronic circuits. It provides calculations for basic circuits, an information center with resources, connector pinouts, and an interactive book explaining fundamental electrical theorems and laws. Most importantly, through EC Studio, students can actively explore electrical concepts like current, resistance, power, voltage, and circuit configurations in a virtual, hands-on environment.

Meanwhile, the teaching of physics courses at Palawan State University has predominantly relied on traditional methods, which have presented particular challenges. Students often perceive the courses as challenging, which can be attributed to the conventional approach that primarily involves hours of lecturing and limited practical applications of scientific concepts due to material constraints – an issue common in many public higher education institutions in the Philippines (Laguador, 2013). This long-standing stigma surrounding the course highlights the need for a revolutionary approach that promotes a more effective teaching-learning environment. This study is undertaken with the aim of investigating the potential impact of EC Studio as a learning tool on the academic performance of college students in the Fundamentals of Electronics course at Palawan State University. While numerous local studies advocate for the integration of technology into education, no research to date has specifically examined the application of mobile-based circuit simulators such as EC Studio in higher education. Most existing research focuses on more established platforms, with limited empirical evidence available on the effectiveness, accessibility, and pedagogical value of EC Studio in the Philippine context or similar resource-constrained environments. Furthermore, despite the recognized limitations of traditional lecture-based approaches, few localized studies have explored innovative, cost-effective alternatives tailored to the needs of electronics learners. The findings of this study could provide valuable, evidence-based insights on the efficacy of the EC Studio as a learning tool, potentially revolutionizing the teaching of electronics courses. Specifically, this study sought to answer the following questions:

What are the pre-test and post-test scores of students in selected topics in Fundamentals of Electronics using face-to-face instruction alone; and face-to-face instruction with the intervention of the EC Studio application?

What is the improvement in the student's academic performance in selected topics in Fundamentals of Electronics using face-to-face instruction alone; and face-to-face instruction with the intervention of the EC Studio application? Is there a significant difference in the improvement of academic performance between the students who were taught using face-to-face instruction alone and students taught using face-to-face instruction with the intervention of the EC Studio application?

What are the benefits gained by the students in utilizing the EC Studio application?

LITERATURE REVIEW

Learning Difficulties in Electronics

Many college students struggle with fundamental electrical concepts (Goris & Dyrenfurth, 2013). This hinders their ability to engage with more complex subjects, ultimately affecting their academic performance and professional readiness. The study conducted by Quezada-Espinoza *et al.* (2023) sheds light on the limitations of traditional teaching methods in the context of electronics courses. These methods, encompassing lectures, tutorials, and practical sessions, have faced criticism for failing to address the application and design aspects of the subject adequately. Consequently, students often overlook these crucial components of learning. Recognizing the need for an alternative approach that addresses these shortcomings and provides a more comprehensive learning experience, recent studies have explored the effectiveness of flipped classroom models in electronics education (Scachitti & Higley, 2018).

Moreover, material constraints further restrict hands-on learning opportunities, making it difficult for students to bridge the gap between theory and real-world application (AlYahyaee *et al.*, 2024). Without sufficient exposure to practical problem-solving and experiential learning, students may struggle to develop the critical thinking and technical skills required in the field. These challenges highlight the need for alternative pedagogical approaches that integrate active learning strategies, modern technological tools, and industry-relevant applications to enhance student engagement and comprehension (Rodriguez-Sanchez *et al.*, 2024).

Learning Electronics

Learning electronics is a valuable pursuit that offers numerous benefits. It provides a foundation for understanding the inner workings of electronic devices, enabling individuals to troubleshoot and repair them. Additionally, it opens up opportunities in various fields, such as engineering and telecommunications where electronics knowledge is essential (Batarseh & Harb, 2018). Learning electronics fosters problem-solving skills, logical thinking, and a mindset of continuous learning. By staying up-to-date with advancements, individuals can contribute to technological progress. New materials empower individuals to navigate the world of technology and unlock their creative potential (Kim *et al.*, 2022). Moreover, the study of Elaoufy (2023) found that despite the current challenges in teaching and learning, teachers and students responded favourably of technology integration in education.

Incorporating software simulations in electronics education can positively impact student learning outcomes by enhancing active learning and boosting confidence in knowledge acquisition (Coleman & Hosein, 2022). In their study, students benefited from simulation tasks by visualizing theoretical concepts, verifying and validating

outcomes, and experimenting with various scenarios both before and after physical laboratory sessions. Similarly, recent research has demonstrated that integrating electronic circuit simulation software into coursework improves students' motivation and participation, leading to a better understanding of complex concepts (AlYahyaee *et al.*, 2024). These findings suggest that incorporating simulation software to complement laboratory practicals is advisable whenever feasible.

Integrating simulation-based learning into electronics education provides students with a practical and immersive virtual environment to explore, experiment, and analyze electronic circuits. Utilizing simulation software enhances hands-on practice, deepens understanding, and facilitates the visualization of complex concepts. This approach offers a safe, cost-effective, and flexible method for acquiring essential knowledge and skills in the field. Recent studies have demonstrated the effectiveness of simulation-based learning in electronics education. For instance, Phacharoen and Akatimagool (2024) developed the RISDA simulation-based learning model for industrial electronics education. Their research demonstrated that students who participated in the RISDA model experienced higher learning achievement and expressed greater satisfaction with their learning experience, suggesting that structured simulation-based approaches can effectively promote competencies aligned with 21st-century learning skills.

Learning electronics through software is a contemporary and accessible method that brings numerous benefits. The study of Mukhtasar (2021) found out that using virtual reality enhances students' mastery of the subject matter by 85%. Moreover, students become an active participant in the learning process where they can express ideas freely, participate in discussions, debate on the topic, and develop practical skills. Software learning tools eliminate the requirement for physical components and costly equipment, enabling learners to design and simulate circuits in a safe environment. Visual and interactive interfaces facilitate comprehension, while scalability allows exploration of various circuit complexities. Moreover, Ratu and Erfan (2017) investigate how "Every Circuit Simulation" improves students' motivation and electrical circuit analysis skills. The findings indicated that students in the experimental group were more motivated than those in the control group. The experimental group's students demonstrate noticeably superior proficiency in examining electrical circuits compared to the control group. The researcher concluded that the Every Circuit Simulator improves student motivation and electrical circuit analysis skills.

Integration of Technology in Philippine Classroom

In the Philippines, Garcia's study (2017) focused on examining factors influencing college students' acceptance of e-learning technology, with a specific focus on learning management systems (LMS). The results indicated that factors such as internet connectivity experience, social media influence, integrated multimedia instruction, and

system interactivity, along with the original predictors from the Technology Acceptance Model (TAM), played significant roles in students' acceptance of e-learning technology. This study emphasizes the importance of considering various factors that influence students' perception of technology in education.

The study by Antipolo and Lopez (2021) examines the effectiveness of the mobile simulation application—the EveryCircuit. This study focuses on the effect of using the simulation application on the procedural knowledge of students. It uses the experimental pretest-posttest research design; one experimental group is exposed to a treatment or intervention and then compared to one control group (modular approach) who did not receive the treatment. The study concluded that the intervention or treatment, which uses the simulation application, is more effective than the pure modular learning approach. Moreover, Mamolo and Sugano's (2024) study examined how students' self-efficacy, anxiety, and general mathematics achievement were affected by the Digital Interactive Math Comics (DIMaC) smartphone application. The study used a one-group pre-posttest design, a type of quasi-experimental research. In the study, two modified questionnaires were used. The findings showed that after using the DIMaC App for six weeks, students' achievement significantly improved, and their anxiety dramatically decreased, and retained their self-efficacy. Anxiety and students' self-efficacy in mathematics were found to be negatively correlated. The findings showed that interactive teaching resources, such as the DIMaC app, improve learning outcomes and reduce students' learning anxiety in the new normal environment.

Recent studies looked into integrating PhET Interactive Simulations, one of the newest online simulations that span numerous scientific domains, in the classroom. According to the study's findings, PhET Simulation-Integrated education can raise students' level of competency in learning General Physics (Almadrones & Tadifa, 2024) and Biophysics (Villaruel, 2025). The argument that PhET Simulations can serve as a virtual lab for evaluating students' performance on demonstration applications was also reinforced. Additionally, using and incorporating PhET Simulations into physics instruction can help students have engaging and beneficial learning experiences.

MATERIALS AND METHODS

Research Design

An explanatory sequential mixed-method research design was used to assess the effectiveness of the EC Studio application as a tool in learning the selected topics in the electronics course (Fundamentals of Electricity, Introduction to Electrical Circuits, and DC Circuits and its Elements) by the 48 second-year Bachelor of Science in Information Technology students enrolled during the second semester of the 2024-2025 academic year at Palawan State University's main campus.

The quantitative design incorporated a quasi-experimental

method with a pretest-posttest design. In the quantitative phase, data were collected from both the control and experimental groups. A pre-test was administered at the outset to establish baseline academic performance and ensure comparability between the two groups. Both groups received face-to-face instruction; however, only the experimental group was exposed to the intervention involving the EC Studio application. The instructional phase lasted for three months, following the course syllabus for the completion of midterm topics in the Fundamentals of Electronics course: Fundamentals of Electricity, Introduction to Electrical Circuits, and DC Circuits and its Elements. After the instructional period, a post-test was administered to both groups. The gain scores—calculated as the difference between post-test and pre-test scores—were used to assess the extent of academic improvement within each group. An independent samples t-test was then performed to determine whether there was a statistically significant difference in academic performance gains between the control and experimental groups.

In the qualitative phase, data were gathered from purposively selected respondents within the experimental group, specifically those who demonstrated the highest and lowest levels of academic improvement based on their gain scores. Interviews were conducted to explore the perceived benefits during the use of the EC Studio application as a learning tool. The responses were analyzed using both thematic analysis and content analysis to identify emerging themes, recurring patterns, and significant insights related to the integration of the application into the learning process.

Research Instrument

In order to gather both qualitative and quantitative data, the researcher used (a) a researcher-constructed-parallelled pre-test and post-test that measured the student's academic performance and (b) interview guide questions administered to the selected respondents, seeking information about the benefits gained during the intervention. Both instruments underwent validation by a panel of four experienced physics teachers. The pre-test and post-test were validated by four physics teachers, and reliability testing yielded a Cronbach's alpha of 0.82, indicating good reliability. Likewise, the same four physics teachers validated the interview guide questions.

Research Procedure

To initiate this study, the researcher first sought

permission from the Palawan State University—College of Sciences Dean's Office and the Palawan State University—Research Ethical Review Committee (PSU-RERC). Then, the researcher informed the respondents about the research's objectives and the study's process, aiming to obtain their consent for participation.

The researcher administered a 30-item multiple-choice pre-test to both the control and experimental groups. The assessment covered key midterm topics in the Fundamentals of Electronics course, and was designed

Table 2: Cohens' d Value Descriptor

Cohen's d value	Descriptor
0 – 0.20	Weak effect
0.21 – 0.50	Modest effect
0.51 – 1.00	Moderate effect
>1.00	Strong effect

to evaluate baseline knowledge and ensure initial comparability between groups prior to the instructional intervention. Administering the pre-test at this stage also helped mitigate potential threats to internal validity, such as selection bias or pre-existing differences in content familiarity. To determine whether the two groups were statistically comparable, assumption testing was conducted. The assumption of normality was assessed using the Kolmogorov–Smirnov test, which indicated that the distribution of scores was normal: $D(48) = 0.109$, $p = 0.200$. Additionally, Levene's Test for Equality of Variances confirmed homogeneity of variance between the groups: $F(1, 46) = 0.542$, $p = 0.465$. An independent samples t-test was then performed to compare the pre-test scores of the control and experimental groups. The results showed no statistical significant difference between the two groups, $t(46)=0.872$, $p=0.388$. This confirms that both groups were statistically equivalent at baseline, ensuring their comparability for further analysis. These findings validated the use of parametric statistical methods for subsequent data analysis.

After administering the pre-test and confirming that there were no statistically significant differences between the control and experimental groups, the instructional intervention commenced. The intervention was structured around three selected topics: (1) Fundamentals of Electricity, (2) Introduction to Electrical Circuits, and (3) DC Circuits and Elements. Each topic had well-defined intended learning outcomes and was delivered through face-to-face instruction in both groups by the researcher, following the official course syllabus.

However, only the experimental group received the EC Studio application as an intervention tool. Students in this group were required to install EC Studio on their mobile phones or personal computers and were encouraged to use it both during class and at home, as needed. The EC Studio allowed real-time simulation and manipulation of parameters such as voltage, resistance, and current, enhancing conceptual understanding and practical

Table 1: Pre-test – Post-test Mean Percentage Score Descriptor

Range of Scores	Descriptor
25-30	Very Satisfactory
19-24	Satisfactory
13-18	Fairly Satisfactory
7-12	Poor
0 – 6	Did not meet expectation

Table 3: Frequency Distribution of Students' Pre-test and Post-test Scores of Control Group (n=24)

Range of Scores	Descriptive Interpretations	Pre-test		Post-test	
		f	%	f	%
25-30	Outstanding	0	0.00	0	0.00
19-24	Very Satisfactory	0	0.00	8	33.33
13-18	Satisfactory	8	33.33	15	62.50
7-12	Fairly Satisfactory	16	66.67	1	4.17
0 – 6	Did Not Meet Expectation	0	0.00	0	0.00
Mean		11 (Fairly Satisfactory)		15.83 (Satisfactory)	
Standard Deviation		2.60		2.90	
Mean Difference		4.83			

application. For instance, it was used in lectures alongside multimedia modules and board work to visualize circuit behavior and solve problems. In laboratory activities, it supported tasks such as simulating static and current electricity, designing block diagram-based circuits, and constructing DC circuits using virtual components. The control group, by contrast, received the same instructional content and engaged in similar activities—such as lectures, board work, and laboratory experiments—without access to the EC Studio.

The intervention lasted for approximately three months, aligning with the midterm coverage period outlined in the course syllabus. Instructional strategies and activities were based on a structured learning plan approved by the panel members.

Upon the completion of the teaching-learning activities covering the selected midterm topics, the researcher administered a parallel-form post-test to both the control and experimental groups. This assessment was designed to measure the academic gains resulting from each instructional approach. To evaluate the effectiveness of the two teaching interventions—face-to-face instruction alone and face-to-face instruction alone with the intervention of EC Studio application—mean scores and mean improvement scores (post-test minus pre-test) were calculated and compared.

To ensure the appropriateness of statistical procedures, assumption testing was again conducted. The normality of the improvement scores was assessed using the Kolmogorov–Smirnov test, which yielded $D(48) =$

0.109, $p = 0.200$, indicating that the data were normally distributed. Furthermore, Levene's Test for Equality of Variances revealed $F(1, 46) = 4.602$, $p = 0.037$, confirming the homogeneity of variances between groups. These results validated the use of parametric tests, such as the independent samples t-test, for analyzing the significance of the observed differences in learning gains. This allowed the researcher to draw evidence-based conclusions regarding the comparative effectiveness of the two instructional strategies employed in the study.

Within the experimental group, the researcher employed purposive sampling to select a subset of students for interviews. Specifically, participants were chosen based on their degree of improvement (post-test score minus pre-test score), and those who demonstrated the highest and lowest gains in performance were selected. The number of participants was determined until data saturation was reached, ensuring comprehensive insights into the benefits gained during the intervention.

Statistical Treatment

Quantitative statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS). The researcher calculated the mean scores and standard deviations (SD) for the pre-test and post-test scores of the respondents. Additionally, the researcher determined the difference between the mean scores (post-test minus pre-test) for both groups. The interpretation of the results was based on a scaling system adapted from Villaruel (2025).

The independent sample t-test for correlated samples was

Table 4: Frequency Distribution of Students' Pre-test and Post-test Scores of Experimental Group (n=24)

Range of Scores	Descriptive Interpretations	Pre-test		Post-test	
		f	%	f	%
25-30	Outstanding	0	0.00	7	29.17
19-24	Very Satisfactory	0	0.00	10	41.67
13-18	Satisfactory	7	29.10	5	20.83
7-12	Fairly Satisfactory	15	62.50	1	4.17
0 – 6	Did Not Meet Expectation	2	8.33	1	4.17
Mean		10.38 (Fairly Satisfactory)		19.58 (Very Satisfactory)	
Standard Deviation		2.36		5.86	
Mean Difference		9.21			

used to determine if the difference in the improvement of academic performance between the students who were taught using face-to-face instruction alone and students taught using face-to-face instruction with the intervention of the EC Studio application was statistically significant. Kolmogorov-Smirnov and Levene's tests were conducted to establish normality and homogeneity of variance before proceeding to the above-mentioned parametric test (Kim, 2015). In addition, the researcher computed the effect size using Cohen's d to assess the practical significance of the difference between groups

(Cohen, 1988). The following descriptor corresponded to the computed Cohen's d values (Yelpaze and Yakar, 2020): Moreover, qualitative data analysis involved transcribing interview data and using open coding to categorize key phrases and segments that captured the essence of the participants' experiences. These responses were then organized into thematic categories to analyze the benefits gained, challenges encountered, and coping mechanisms employed while using the EC Studio application. Content analysis followed to quantify the frequency of identified themes, offering a clearer picture of the most common

Table 5: Improvement of the Academic Performance of the Control and Experimental Group

Respondents	Mean	Standard Deviation	Mean Difference	p-value	Cohen's d
Control Group (n=24)	4.83	3.46	4.38	0.003	0.913
Experimental Group (n=24)	9.21	5.86			

*Significance level is 0.05. *Effect size $d = 0.20$ indicates a small effect; $= 0.50$ indicates a medium effect; ≥ 0.80 indicates a large effect *p value is asymptotic significance (2-tailed).

responses. Verbatim statements were used to support the analysis.

RESULTS AND DISCUSSION

This section presents the findings on the improvement in students' academic performance in selected topics in Fundamentals of Electronics under two instructional conditions: (a) Face-to-face instruction alone and (b) Face-to-face instruction with the intervention of the EC Studio application. The analysis is based on students' pre-test and post-test scores in each instructional setting. Before the instruction, the majority of students (66.67%) had scores in the range of 7-12, which corresponds to a Fairly Satisfactory level. Additionally, 33.33% of the students scored from 13 to 18, classified as Satisfactory. No students achieved a Very Satisfactory or Outstanding rating in the pre-test. The mean pre-test score was 11 (Fairly Satisfactory) with a standard deviation of 2.60.

These quantitative results align with common findings in education research, where pre-test scores are often low due to limited prior knowledge in learning content (Bergman *et al.*, 2015). According to studies, pre-tests serve to measure baseline knowledge and often reveal learning deficiencies that instructional interventions are designed to address (van Riesen *et al.*, 2019). The qualitative interviews from this study support this findings. As one of the respondents mentioned:

"Although I was familiar with the topic since I took STEM and had a physics subject in Grade 12, that was about two years ago. So, the lessons on electronics were no longer fresh in my memory."-S1

Likewise, another respondent shared

"I only had a little idea. Most of my answers were just guesses."-S5

These statements confirm that students' pre-test performance was constrained by prior knowledge gaps and unfamiliarity with the learning content. This validates the necessity of structured teaching interventions to

improve learning outcomes.

After the face-to-face instruction, students demonstrated improvement. A significant percentage of students (62.50%) reached the Satisfactory level (13-18 score range), while 33.33% progressed to the Very Satisfactory range (19-24). The mean post-test score increased to 15.83 (Satisfactory) with a standard deviation of 2.90. Several studies support the idea that post-tests typically reflect better outcomes due to instructional impact (Besonia *et al.*, 2025; Guo & Li, 2025; Peñas *et al.*, 2025).

"The pre-test made us aware of what our topics would be for the midterm. Then, after class lectures and we applied them in our lab activities, the post-test became much easier."-S11

The mean score difference between the pre-test and post-test was 4.83, indicating that face-to-face instruction alone positively impacted student performance. Tiwary *et al.* (2024) emphasize that structured in-person teaching provides students with more practical guidance and assessment opportunities, leading to enhanced learning outcomes. Similarly, McGee *et al.* (2024) found that traditional instructional approaches foster greater engagement and comprehension, particularly in hands-on subjects. In electronics education, the findings of El-Adl (2024) support the idea that interactive, face-to-face guidance contributes to higher achievement levels, reinforcing the importance of direct teacher-student interaction. However, despite the increase, no students reached the Outstanding level (25–30), and a portion of students remained in the Fairly Satisfactory category, suggesting that additional instructional interventions may be necessary for higher achievement. The second instructional method integrated the EC Studio application alongside face-to-face instruction. Table 4 displays the pre-test and post-test scores under this approach.

Before instruction, 62.50% of students were in the Fairly Satisfactory category (7-12 range), and 29.10% were in the Satisfactory category (13-18 range). However, a

small percentage (8.33%) fell within the Did Not Meet Expectation range (0-6). The mean pre-test score was 10.38 (Fairly Satisfactory) with a standard deviation of 2.36. This is attributed to limited prior knowledge in learning content (Bergman *et al.*, 2015).

Following instruction with EC Studio integration, a notable improvement was observed. A significant 29.17% reached the Outstanding level (25-30), while 41.67% of students achieved a Very Satisfactory performance (19-24). The mean post-test score rose to 19.58 (Very Satisfactory) with a standard deviation of 5.86. This result aligns with the findings of Rutten *et al.* (2020) that integrating simulations into traditional teaching significantly improves learning outcomes, particularly in complex topics like physics and electronics.

A comparison of the two instructional methods reveals that the experimental group resulted in a greater improvement. While both methods led to learning gains, the mean increase of 9.21 in the experimental group is higher than the 4.83 increase observed with the control group. The integration of EC Studio allowed students to achieve higher-level learning outcomes, with more students reaching Very Satisfactory and Outstanding performance levels. These results underscore the value of integrating technology into instruction. As Bornaa *et al.* (2023) recommend, teachers should take advantage of today's technology-driven landscape by blending traditional face-to-face instruction with e-learning approaches to enhance the teaching and learning. Such blended models can foster more engaging, flexible, and personalized learning experiences for students. However, the standard deviation of the post-test scores under experimental group (SD=5.86) was higher than that of control group (SD=2.90), indicating a wider spread of scores. This suggests that while many students benefited greatly, others may have required additional support to fully leverage the EC Studio tool.

The computed Kolmogorov-Smirnov value ($D(48)=0.109$, $p=.200$) confirmed that the data followed a normal distribution, while Levene's test ($F(1,46)=4.602$, $p=.037$) indicated homogeneity of variances. Thus, validating the appropriateness of using a parametric test for statistical analysis. An independent samples t-test was conducted to determine the significance of the difference in the improvement of academic performance between the control and experimental groups. The results indicate a statistically significant difference between students taught using face-to-face instruction alone and those who received additional support through the EC Studio application. The computed p-value, $t(46)=-3.164$, $p=.003$, is below the standard significance threshold ($\alpha=0.05$) confirming that the observed difference is not due to chance but rather the impact of the intervention. This finding aligns with recent research demonstrating that technology-enhanced learning environments significantly improve student performance when integrated with traditional teaching methods (Laun & Wolff, 2025). Additionally, the effect size, measured using Cohen's d

indicates a large practical effect ($d=0.913$), suggesting that the EC Studio application had a substantial impact on student learning outcomes compared to face-to-face instruction alone. This is consistent with findings from Avcu and Yaman (2024), who reported that educational technology interventions often yield high effect sizes, further supporting their efficacy in enhancing student engagement and comprehension. Further, these results underscore the potential of technology-assisted learning tools to bridge learning gaps and reinforce conceptual understanding in electronics education.

Fourteen (14) respondents in the experimental group were purposively selected based on their improvement for interview. The selection process alternating between those who demonstrated significant improvement and those who showed minimal progress. This approach ensured a balanced representation of varying learner experiences. The interviews continued until data saturation was reached, at which point no new themes or insights were emerging. Based on the thematic analysis of the interview data, five significant benefits of utilizing the EC Studio application were identified, which are the following:

Enhanced Learning Efficiency and Understanding

The use of EC Studio significantly enhanced students' learning efficiency by enabling real-time visualization of circuit designs and providing immediate verification of computations. Participants ($n=12$) frequently described how simulation allowed them to bridge theory and practice, improving both conceptual understanding and procedural knowledge. As expressed by students, EC Studio facilitated the achievement of learning outcomes not only during laboratory exercises but also in independent problem-solving.

"I recall that each lesson states the expected learning outcomes. EC Studio helped achieve those, especially in laboratory experiments. Aside from conducting physical experiments, we could also simulate them using EC Studio to get an idea of the expected results. [...] Aside from the laboratory exercises, the application was very beneficial. For example, when solving problems related to formulas and computations, I used EC Studio to check my answers instead of relying solely on my own calculations." –S1

"I learned how to correctly apply and use circuit elements. By navigating the information section and reading the provided details, I understood how to use them properly. Once I became familiar with it, EC Studio became a significant tool in my learning process. It made things much easier." –S5

This observation aligns with the findings of Singh and Ahmad (2024) which confirms that simulations are effective in enhancing operational skills and user experience in electronics laboratories by offering clear and interactive representations. Moreover, Ceberio *et al.* (2016) concluded that interactive simulations in physics education encourage scientific reasoning and problem-solving, a finding that translates well to

electronics education, where hands-on engagement with circuit elements strengthens conceptual retention and independent exploration.

"EC Studio made the lessons easier to approach. Seeing diagrams and visualizing how circuit components function really helped. It also increase my interest in Electronics. I even started working on small projects on my own. I'm already using it to explore circuit boards and understand them better." –S7

"Measuring voltage and resistance became simpler compared to doing it manually with a breadboard and multi-meter. Before, we were unsure where to place the probes. With EC Studio, it's faster. It makes the visualization clearer." –S13

Increased Motivation and Interest

During the interview, students (n=10) described how simulations boosted their confidence, allowing them to validate their computations and visualize what they are doing. This ease of interaction reduced cognitive barriers and made learning feel enjoyable and engaging.

"It motivated me to study because it provided a foundation for interpreting my answers. If I relied only on Ohm's Law and other theorems, I wouldn't be as confident in my answers. The simulation increased my confidence by showing expected results." –S1

"I think the ability to design circuits in EC Studio was very helpful. It taught me where to place the voltmeter and ammeter correctly in a circuit. Since it made things easier, studying became more enjoyable." –S3

"EC studio made the lessons easier to approach. Seeing diagrams and visualizing how circuit components function really helped. It also increase my interest in Electronics. [...] I even started working on small projects on my own. I'm already using it to explore circuit boards and understand them better." –S7

"If I had to compute manually, I wouldn't be as motivated because it seems difficult. But with EC Studio, I just have to type and set things up easily." –S5

"I'm not really fond of math, Sir. But I really enjoyed using EC Studio. Because it felt like I was just playing, Sir. You just put it in, and it works right away." –S14

Thus, incorporating real-world examples and simulations in laboratory classes significantly enhanced student motivation and engagement (Gero *et al.*, 2016). Similarly, Catz *et al.* (2018) reported that simulations, when paired with hands-on experiments, motivate learners and increase their interest in analog electronics.

Improved Classroom Engagement and Collaboration

A recurring theme that emerged from the respondents (n=8) is how the use of EC Studio fostered engagement and collaboration. The data suggest that EC Studio served not merely as a learning tool but as a catalyst for participatory learning and peer collaboration.

"When my classmates were working on EC Studio, I was also motivated to try it. I wanted to see how to set up and manipulate elements inside the app." –S5

"EC Studio made me more engage in class. For example, in our group activities, I was able to contribute more since I had access to a phone and a guide. I could help my group mates with the parts I understood." –S6

This observation aligns with findings by Bajaj (2024), who emphasized that digital learning platforms stimulate intrinsic motivation and engagement through peer modeling, leading to increased curiosity and proactive learning behaviors. Additionally, mobile learning platforms not only increase individual student participation but also build confidence by providing structured guidance, thereby enabling more meaningful contributions in collaborative settings (Pedraja-Rejas *et al.*, 2024).

"During group activities, we would work together using just one set of materials. But with EC Studio, we became more interactive. If someone made a mistake, we would correct each other. That helped us collaborate more." –S10

"When we had group activities, it was easier to collaborate since we were all using the app. It helped us figure out where to place components and what to do." –S11

Accessibility and Portability

Respondents (n=7) consistently highlighted the significance of portability as a key feature of EC Studio, enabling flexible learning beyond the confines of the traditional classroom. The application's ability to function seamlessly on smartphones allowed students to integrate learning into their daily routines.

"It's easy to use and doesn't require complex setup. The best feature is its portability—you can use it on a mobile phone like a calculator, making it more convenient than using a laptop." –S1

"Since it made things easier and more accessible, I was more inclined to use it. Instead of buying a multi-meter and other tools, I could just use the app." –S6

"It was easier, sir. You don't need as many physical materials. Aside from not needing to buy things, it's not as much of a struggle to connect components to boards. For me, it's better with EC Studio. It's not perfect, but it allows you to simulate what needs to be done, which makes things much easier through the app. That's my best experience with it." –S10

This observation aligns with the work of Dunleavy *et al.* (2019), which revealed that mobile digital education platforms facilitate flexible access to educational content, particularly by leveraging the portability of mobile devices. Al-Rahmi *et al.* (2021) noted that mobile learning applications democratize educational resources, reducing reliance on physical tools and infrastructure. Their studies emphasized how the affordability and accessibility of mobile platforms make them particularly advantageous for students from diverse socioeconomic backgrounds. Moreover, Bere and Rambe (2016), reported that device portability directly enhances learning flexibility, allowing students to simulate and experiment with educational content without the need for additional resources.

Application beyond the Classroom

The participants (n=6) highlighted how EC Studio extended its value beyond the traditional classroom, supporting not only academic coursework but also personal projects and real-world applications. The verbatim reflect a shift from learning tool usage toward lifelong learning and innovation.

"EC Studio made the lessons easier to approach. Seeing diagrams and visualizing how circuit components function really helped. It also increase my interest in Electronics. I even started working on small projects on my own. I'm already using it to explore circuit boards and understand them better." –S7

"It can be used in our System Integration class too." –S4
Educational simulations are often adaptable across multiple subject domains, particularly when students need to understand integrated systems and interdisciplinary concepts (Theelen *et al.*, 2019).

"EC Studio isn't just about building circuits. It also helps users understand different components and their functions in a circuit. It helps you understand components for real-world use." –S5

"It will be useful in the future if I have small personal projects at home. To be sure, I will simulate it first in EC Studio so I can make sure it's safe." –S14

This observation agrees with the findings of Chernikova *et al.* (2020), whose analysis confirmed that simulation-based learning tools contribute significantly to skill transfer beyond academic settings. EC Studio as a classroom resource, may become a tool that fosters applied learning, interdisciplinary integration, and lifelong curiosity. Its flexibility and practical utility prepare learners not only for academic success but also for real-world problem-solving and independent innovation.

CONCLUSIONS

This study examined the improvement in students' academic performance in selected topics in Fundamentals of Electronics under two instructional conditions: (a) face-to-face instruction alone and (b) face-to-face instruction supplemented with the EC Studio application. The findings revealed that while both instructional approaches led to significant learning gains, the integration of EC Studio application resulted in a greater improvement in student performance.

The statistical analysis revealed a significant difference in the improvement of academic performance between students who were taught using face-to-face instruction alone and those who received additional support through the EC Studio application and confirmed that the intervention of EC Studio had a large practical effect.

Thematic analysis of student interviews identified five major benefits of EC Studio: enhanced learning efficiency and understanding, increased motivation and interest, improved classroom engagement and collaboration, accessibility and portability, and application beyond the classroom.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance instructional practices and optimize student learning outcomes: (1) Students are encouraged to use the EC Studio application as a learning tool. They should explore its interactive features, apply theoretical concepts through simulations, and use it as a supplementary tool for independent study. (2) Teachers should incorporate similar simulation-based applications alongside traditional face-to-face instruction in electronics and related subjects. (3) Educational institutions should invest in technological infrastructure and its integration to support blended learning approaches. Additionally, institutions should conduct training and support both faculty and students to ensure the smooth adoption and effective use of technology in the classroom. (4) Further studies should explore the long-term impact of the EC Studio application on student performance across different topics and modes of instruction. Future researchers may investigate ways to optimize the application. Comparative studies with other digital learning tools can also provide deeper insights into the role of technology in education.

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