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EFFECTS OF THE COMBINATION OF REAL AND VIRTUAL LABS BASED ON THE 5E LEARNING CYCLE MODEL ON ELECTRICAL STUDENT LEARNING OUTCOMES

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ABSTRACT

The 5E instructional model is an inquiry-based learning approach. This model is an effective approach to improving student learning outcomes. It is currently implemented using virtual experiments or a combination of real and virtual experiments. This research aims to investigate the effects of using a real laboratory (RL), a virtual laboratory (VL), and a combination of RL and VL based on the 5E learning cycle model on student learning outcomes in the subject of electricity. A quasi-experimental design involving pre-test and post-test comparisons between groups was employed in this research. The research sample consisted of 166 first-year students from a rural middle school. Students were divided by reasoned choice into three groups. The first group (RL) included 58 students (using real laboratory activities), the second group (VL) included 56 students (using virtual laboratory activities), and the third group (RL+VL) included 52 students (using both real and virtual laboratory activities). The research was conducted during the second semester of the 2023 school year. Data were analyzed using a paired-sample t-test, one-way ANOVA, and N-Gain. The results reveal that the combined use of real and virtual lab activities results in a more substantial improvement in student learning outcomes than using real or virtual labs alone.

Keywords: learning cycle 5E; real labs; simulation interactives; student learning outcomes; virtual labs

INTRODUCTION

Middle school physics laboratory activities play a very important role in teaching and learning physics, especially electricity. These activities allow students to test and practice the physics concepts they have learned in class and develop their practical skills, such as observing results directly, solving practical problems, working in teams through conducting group experiments, interpreting data, and drawing conclusions. Physics lab activities can be used to teach electrical concepts. They can engage students, enhancing their motivation to learn physics. In middle school, electricity is a major topic in physics. To ensure students understand this concept thoroughly, it is essential to provide ample hands-on experiences and practical examples. However, teaching electricity to students faces several barriers, including the complexity and abstraction of the subject (Mbonyiryivuze et al., 2019), lack of adequate teaching materials and hands-on activities (Chekour et al., 2015), the dangerousness of some experiments (Ndihokubwayo, 2017), and lack of interest in the subject. All these challenges can negatively influence students' performance in physics, especially electricity. Student performance in science, specifically physics, has been a serious

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challenge that must be addressed. Some studies indicate that student performance in science has fallen below expectations (Akanbi et al., 2018; Christian et al., 2019) and remains discouraging across various levels of instruction (Ugwuanyi et al., 2020).

In Morocco, the content of several national (INESEFRS, 2019) and international PISA 2018 (Schleicher, 2019), TIMSS (Stephens et al., 2016; Martin et al., 2019) reports states that Moroccan students' performance in physics is low. Morocco ranked among the lowest-scoring countries in the TIMSS 2019 assessment (Martin et al., 2019). It should be noted that Morocco, like all developing countries, has undertaken several initiatives to improve the teaching of physics in schools; the Ministry of National Education initiated the GENIE program (Generalization of Information Technology and Communication in Education) in 2006, aiming to encourage active teacher participation in integrating ICT into teaching, thereby enhancing the quality of teaching and learning. In addition, it has taken the initiative to develop a new strategic vision for the 2015-2030 reform of the education system. This strategy aims to reinforce the integration of educational technologies, such as digital media and interactive tools, within teaching and learning activities (CSEFRS, 2015). Previous research has suggested that using real experiments is often beneficial in improving students' understanding of science topics in general. Meanwhile, others argue for the efficacy of virtual experiments (interactive simulations) in learning and teaching physics (Ben Ouahi et al., 2021; Hamamous & Benjelloun, 2023).

Real or practical laboratories are experiments performed using physical materials and measuring devices. It allows students to solve problems and develop practical 21st-century skills (Asrizal et al., 2022). Practical laboratory activities must be integrated into a broader educational framework to strengthen students' critical thinking and reasoning (Kluge, 2014).

Despite their importance, actual laboratories still face many challenges that render them ineffective, such as a lack of or insufficient technological equipment, insufficient time, and overcrowding of students in the classroom (Ben Ouahi et al., 2020; Ouahi et al., 2022). In addition, handling equipment is time-consuming, and conducting laboratory experiments often boils down to performing a list of tasks in a ritualistic manner, which prevents students from engaging with the overall purpose of the laboratory. In parallel, the literature shows that virtual laboratories significantly affect students' knowledge, skills, attitudes, and outcomes (Alneyadi, 2019). Similarly, a study by Kapici et al. (2019) finds that virtual laboratories are more effective than hands-on laboratories for improving students' subject knowledge and research skills. When applied to electricity, virtual labs have also been shown to positively impact students' problem-solving skills (Gunawan et al., 2017).

Simulations are effective teaching methods to teach concepts, activities, and experiments, especially in various scientific subjects like chemistry and physics, which are challenging to teach with conventional methods (Biju., 2017). They allow for the study of invisible phenomena such as currents (Chiu et al., 2015); they also allow for experiments to be performed more easily and quickly than in real laboratories (Cheng & Chan, 2019) and repeat them if necessary (Aljuhani et al., 2018). This allows them to fully apply their knowledge, skills, and understanding (Al-Moameri et al., 2018).

Numerous studies have found that using simulations improves student achievement (Ahmad et al., 2021; Ben Ouahi et al., 2021). For example, Ben Ouahi et al. (2021) find that students who use computer simulations to learn physics achieve better outcomes than those who follow traditional teaching methods. Meanwhile, results from other studies show no difference between the two methods (Darrah et al., 2014; Crandall et al., 2015). Some studies suggest combining simulations with hands-on practice (laboratory activities) as the best way to teach students about direct-current electrical circuits (Ekmekci & Gulacar, 2015; Taher & Khan, 2015).

Such diversity in teaching methods increases the possibility of meeting students' diverse interests and learning needs. The combined use of simulation and laboratory activities results in statistically significant learning outcomes compared to employing either method alone, and it is the most effective way to help students achieve a conceptual understanding of electricity (Tenzin et al., 2023). This combination provides students with perspectives and learning experiences in an environment that utilizes the advantages of both real and virtual experiments, which is something neither could achieve independently (Alkhaldi et al., 2016). Moreover, students who combine research laboratories with virtual labs show more significant improvements in conceptual knowledge (Hurtado-Bermúdez & Romero-Abrio, 2020), conceptual understanding (Wang & Tseng, 2018), and development of inquiry skills (de Jong et al., 2013) more than those using either one individually. However, Sarabando et al. (2016) find that using simulations (virtual labs) alone is more effective than combining them with practical activities (real labs). In contrast, many have not found clear evidence that combining real experiments with virtual experiments is superior to using either method alone (Chini et al., 2012; Sullivan et al., 2017).

Several studies have been conducted on physics instruction using 5E-based simulations versus the traditional method. These studies have been conducted on student achievement in science, attitude, and motivation (Taşlidere, 2015; Guzel, 2017; Sarı et al., 2017; Öner & Yaman, 2020). However, few studies have examined the effectiveness of combining real and virtual experiences based on the 5E model in teaching electricity to rural first-year middle school students. Therefore, we need empirical evidence to fill this gap by comparing rural middle school student's school performance in electricity in different types of 5E-based labs, including a real lab (RL), a virtual lab (VL), and a combination of both (RL and VL).

The Learning Cycle 5E (Engage, Explore, Explain, Elaborate, and Evaluate) is a well-known inquiry-based teaching method used extensively in science education to enhance students' achievement (Ong et al., 2020). By combining this approach with real and virtual experiences, teachers can provide students with a more immersive and interactive learning environment, helping them better understand electricity concepts.

Studies on applying the 5E model in teaching electrical circuits have shown improvements in student performance. Guzel (2017) finds that the 5E model enhances motivation and positively affects understanding abstract electricity concepts. On the other hand, the 5E learning environment integrated with simulations can improve academic performance and attitudes toward physics (Sarı et al., 2017) and develop critical thinking skills (Irhamna et al., 2017). Makamu and Ramnarain (2022) find that simulations offer teachers a way to engage students in hands-on, research-based learning within the 5E model.

This research compares the impact of combining real and virtual laboratories based on the 5E learning model on first-year middle school students' performance in the electricity unit. This research aims to identify differences in average scores among students in the three groups before and after the implementation, as well as their progress in learning, to determine whether virtual laboratories can complement real laboratories. The data for this research were limited to 166 first-year middle school students learning about electricity. To generalize the results, it would be beneficial to conduct similar research across different grade levels involving a larger number of students and over an extended period.

This research extensively examines the effectiveness of combining real and virtual labs in teaching electricity in middle schools. It demonstrates how this combination, based on the 5E model, can positively impact student learning outcomes. This research will benefit schools that lack physical equipment for physics experiments by improving the quality of their science teaching. In addition, it could serve as a reference for researchers interested in computer simulations (virtual laboratories), technology, experiential learning, and the development of educational programs. Thus, this research intends to answer the research questions framed as follows: 1) What is the effect of using a combination of real and virtual labs in teaching the concept of electricity based on the 5E learning cycle model?, and 2) In which type of activities did students progress significantly?

METHODS

The participants of this research were first-year students at a rural public middle school in Morocco, which was selected from among public schools equipped with computers to conduct the experiment. A total of 166 students, aged between 13 and 15, came from 6 different classes. In terms of gender, the participants consisted of 78 (47%) females and 88 (53 %) males.

Table 1 presents the demographic data of the participants. The physics teacher concerned, who taught the students in all three conditions, has over 15 years of experience teaching physics. A random selection process for the different treatments could not be done because the students were already divided into classrooms. All students had already used computers.

Table 1. Demographic Profile of the Participants

Group	R		V		R+V	
Gender	Frequency	%	Frequency	%	Frequency	%
Female	25	43.10	22	39.30	31	59.61
Male	33	56.90	34	60.70	21	40.39
Total	58	100	56	100	52	100

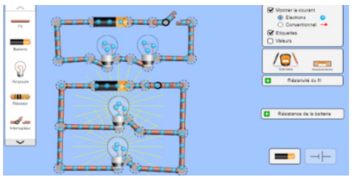
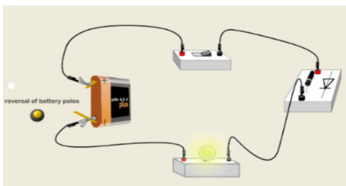
The research employed a pre-test and post-test control group design. The R+V group was taught using a combination of simulations and the laboratory method; the R group used the laboratory method, and the V group used interactive simulations. The research was conducted over four weeks during the 2022-2023 school year (second semester). Each week, the students carried out their experiments using three different methods (real laboratory, interactive simulations, and a combination of simulations interactives and real laboratory) (see Table 2).

Table 2. Quasi-experimental Study Design

Group	Pre-test	Method	Study duration	Post-test
R V R+V	Diagnostic Test of Simple Electrical (25 min)	Real Laboratory Simulations interactive Combining simulations, interactives, and real laboratory	Four Week, 2 hours per week	Electric Performance Test (55 min)

Before implementing this research, we organized a meeting with the physics teacher who conducted it. During this meeting, we explained the research objectives and presented the interactive simulations we used with the teachers as virtual labs. These interactive simulations were selected in adequacy with the pedagogical program of physics at the first-year middle school level. Table 3 shows some simulations used to teach students the electricity unit.

Table 3. Examples of the Simulations Used to Teach Students the Electricity Unit (PhET and PCCL)

Name of the Simulation	The Screenshot of the Simulation	Description of Simulation
The circuit in series and parallel		The circuit construction kit simulation allows students to build circuits using batteries, wires, bulbs, resistors, switches, and virtual capacitors and inductors.
Role of diode		The simulation shows the students the direction of the current.

We also explained the research objective to the students and informed them that the sessions would occur in an academic environment, adhering to ethical principles. Additionally, we noted that the collected data would be shared in a scientific journal. Also, we emphasized that their participation was strictly voluntary and anonymous.

After informing the students about these ethical considerations, we administered a pre-test to students in three groups before the research was implemented. Then, students in the R group performed their experiment activities using physical materials (e.g., wires, lamps, switches, etc.). These activities were included in the electricity theme (The simple electrical circuit, types of electrical assemblies, and the direct electrical current). In the V group, students worked in small groups using interactive simulations. In the R+V group, students used two different combinations of alternating real and virtual (interactive simulations) laboratories to perform their experiment activities. The simulations used were PHET (Physics Education Technology), built by the University of Colorado, and PCCL (Physics and Chemistry by Clear Learning). The RL and VL activities were the same as those described above. The learning objectives, learning activities based on the 5E learning cycle model, time on task, and assessment were the same for all three groups.

In the Engagement phase, the teacher assessed each group of students' prior knowledge of the concepts studied in electricity. The teacher began the lesson by using animations and asking questions to arouse their curiosity and enthusiasm. In the Exploration phase, the R group used the materials themselves to carry out real experiments, such as building a simple electrical circuit. The V group used simulations on the computers, while the RV group was left alone to use both the real experiments and the simulations.

In the Explanation phase, the teacher presented the lesson to provide students with the main ideas to record in their notebooks. In the Elaboration phase, the teacher allowed students to develop their understanding of electricity by asking questions and inviting them to present examples of research projects. Finally, in the Evaluation phase, the lesson concluded with quizzes to ensure students had acquired the knowledge and achieved the objectives. At the end of the study, students took an identical knowledge post-test to measure and compare the effect and effectiveness of each method used on student learning outcomes.

The analysis involved both descriptive and inferential statistics using SPSS V23. Descriptive statistics were reported as mean scores (M) and standard deviations (SD) for the students' pre-test and post-test results in the three groups. The Kolmogorov-Smirnov test was performed to evaluate data normality, with a significance threshold set at $p > 0.05$. Furthermore, a paired samples T-test was used to evaluate whether there was a significant difference between the scores of the same group before and after implementing the research.

The ANOVA test was used to determine if there were significant differences in the learning outcomes among the three groups. The effectiveness of the learning method on student outcomes was analyzed using the N-gain equation (1) below, a useful single-parameter measure of teaching effectiveness (Coletta & Steinert, 2020). Table 4 illustrates the interpretation of the normalized gain values.

$$\text{N} - \text{Gain} = \frac{\text{Spost} - \text{Spre}}{\text{Smak} - \text{Spre}}$$

Spost: post-test value obtained, Spre: pre-test value obtained, Smak = a maximum score that can be obtained).

Table 4. Category and Level of Effectiveness in Improving Student Outcomes

Interval	Category	Level of Effectiveness
N-gain > 0.70	High	Effective
0.30≤N-gain ≤ 0.70	Medium	Effective enough
N-gain < 0.3	Low	Less effective

To check whether the pre-test and post-test in the three groups follow a normal distribution or not and to compare variances, we used the Kolmogorov-Smirnov normality test and the homogeneity test, as shown in Table 5.

Based on Table 5, the significant results of each group in the pre-test and post-test were higher than 0.05, confirming that the data distribution followed a normal distribution. After that, the test of homogeneity had been carried out. The homogeneity test results of the three groups at the posttest and pretest were 0.450 and 0.912, respectively. These significance values were higher than the significance level (α = 0.05). This indicates that the variances of the three groups analyzed are equal (homogeneous). For this, we used parametric tests to analyze the data of the pre-test and post-test scores.

Table 5. Test of Normality and Homogeneity of Variance (Pre-test and Post-test)

		Kolmogorov-Smirnova			Homogeneity of variance		
	Method used	**Statistics**	**df**	**Sig.**	**Levene's Statistic**	**Sig.**	**Description**
Pretest	RL	.091	58	.200*			
	VL	.111	56	.081	.093	.912	
	RL+VL	.082	52	.200*			Homogeny
Posttest	RL	.113	58	.063			
	VL	.090	56	.200*	.802	.450	
	RL+VL	.112	52	.134			

A diagnostic test of a simple electrical circuit was used to compare the initial state of knowledge of electricity between the groups. This test was developed by the researchers and validated by educational experts. It consisted of 6 multiple-choice questions and 7 open-ended questions. The performance test was used to determine the effect and effectiveness of each method used on student performance. This post-test consisted of three exercises that can be described as follows: The first exercise was designed to assess the student's ability to retrieve and exploit scientific knowledge (concepts—principles, laws, units, order of magnitude, etc.). The second exercise mobilized and used knowledge. The third exercise assessed the student's ability to solve a problem situation. To ensure that the test questions were fair to all three groups, all questions were based on scientific content in the students' textbooks.

To assess the validity and reliability of the items on the two tests, we called on experts in physics, two teachers, and a physics inspector with considerable experience in high school education. After incorporating their suggestions and making the necessary modifications, the two performance tests were administered to 34 students not included in the participant list to evaluate item reliability. The reliability of the tests was determined using Cronbach's Alpha, which was α= .780 for the pretest and α= .708 for the posttest. These reliability scores confirmed the suitability of the test items for application across all three groups before and after the study.

RESULTS AND DISCUSSION

The objective of this research was to compare the effect of using real laboratory (RL), virtual laboratory (VL), and a combination of RL and VL based on the 5E model on the learning outcomes of first-year middle school students in electricity.

Table 6. Mean, Standard Deviations of Pre-test and Post-test

		Pre-test		Post-test	
Group	N	M	SD	M	SD
R	58	9.52	3.011	10.22	3.035
V	56	9.48	2.977	12.36	3.116
R+V	52	9.13	3.072	14.30	3.666
Total	166	9.385	3.005	12.22	3.652

According to Table 6, the mean score and standard deviation of the students in the R group are M = 9.52, SD =3.011 on the pretest and M=10.22, SD=3.035 on the posttest, while the mean score and standard deviation of the students in the virtual group are M=9.48, SD=2.977 on the pretest and M=12.36, SD=3.116 on the posttest. On the other hand, the mean score and standard deviation of students in the R+V group are M=9.13, SD =3.072 on the pretest, and M=14.30, SD=3.666 on the posttest. These results show a slight difference between the pre-test scores of the three groups, which are generally low (below 10). However, the post-test averages of the students in the three groups certainly show an increase in students' scores. The R+V group scored slightly higher than the V group and the R group.

To test whether the difference observed in Table 6 is significant, we used the ANOVA test to compare the means of three independent samples. As indicated in Table 6, the data followed a normal distribution. A one-way ANOVA was used for this analysis. The results of the ANOVA analysis are presented in Table 7.

Table 7. Result of ANOVA for Pre-test and Post-test

	Sources of Variations	SS	df	MS	F	Sig.
Pre-test score	Between Groups	4.803	2	2.401	.263	.769
	Within Groups	1486.023	163	9.117		
	Total	1490.825	165			
Post-test score	Between Groups	456.791	2	228.396	21.335	.000
	Within Groups	1744.962	163	10.705		
	Total	2201.753	165			

As shown in Table 7, the ANOVA results indicate no significant differences between the three groups in the pretest scores ($F (2, 163) = 0.263<1$, $p=0.769 > 0.05$). Thus, it can be concluded that all students have almost the same knowledge about the concept of electrical circuits before implementing the research. However, the averages obtained from these students are low.

This can be explained by the teaching methods and pedagogical approaches used in elementary schools, especially in rural areas. Some of these schools focus more on rote learning than understanding and applying scientific concepts. In addition, some primary school teachers (with literary specialties) may lack science training and skills, making science teaching less effective and engaging for students. On the other hand, the result of the ANOVA test for the posttest is (F (2, 163) =21.335, $p < .05$), indicating a significant difference between the mean scores of the three groups that use different teaching methods.

We conducted Tukey's post hoc multiple comparison tests to determine if there were significant differences between the mean post-test scores of the three groups after implementing different laboratory methods. As shown in Table 8, the mean difference between the R+V group and the R group is 4.07 ($p<0.05$), while the mean difference between the R+V group and the V group is 1.93($p=0.007<0.05$). It shows that the students who use the combination of real and virtual labs based on the 5E learning cycle to learn electricity obtain higher results than those who use real or virtual labs alone. Further, there is a statistical difference between the V and R groups (MD=2.14, $p<0.05$). This difference is in favor of the V group. Some studies have reported that real labs (practical strategy) are more efficient than virtual labs, which is contrary to the current research, which shows that real labs are less efficient than virtual labs (Rytting et al., 2019).

It can be stated that the combination of real and virtual laboratory activities based on 5E is more effective than the use alone. Therefore, it can be concluded that integrating both types of labs with the 5E learning cycle significantly and positively affects students' learning outcomes, providing opportunities for students to explore concepts at their own pace, develop ideas, and evaluate their understanding. They are provided with opportunities to engage in a variety of learning activities, which can help maintain their enthusiasm and foster their curiosity. Additionally, integrating real and virtual labs is particularly beneficial for handling complex materials where the risk of damage from incorrect use cannot be ignored.

These results align with the results of several studies that compare the combined use of real and virtual experiences to groups that use only real or virtual experiences (Zacharia & Michael, 2016; Wang & Tseng, 2018; Gumilar et al., 2019; Kapici et al., 2019). The results from these studies indicate that the combined use of real and virtual experiments significantly improves students' understanding compared to relying on real or virtual experiments alone. Similarly, Yehya et al. (2019) conduct research with 87 grade 11 students, showing that combining simulations with hands-on activities is more effective for learning about capacitors than simulations alone. Moreover, integrating real and virtual activities significantly improves students' conceptual knowledge of electrical circuits compared to using real activities alone (Kapici et al., 2019; Manunure et al., 2020). This approach is particularly beneficial in inquiry-based learning, as it fosters a deeper understanding of science (Sypsas et al., 2020). In contrast, some studies have found that combining different types of laboratory activities has equivalent effectiveness to an isolated laboratory environment on students' conceptual knowledge, skills, and results (Darrah et al., 2014; Anam et al., 2023).

These differing results may be linked to several factors, including the insufficient number of participants, the length of the study, the subject matter, the grade level, and the simulations chosen to teach the students.

Table 8. Tukey Post Hoc Multiple Comparison Tests

Dependent variable	(I) Method used	(J) Method used	Mean difference (I-J)	Standard error	Sig.
Posttest	RL	VL	-2.142*	.613	.002
		RL + VL	-4.074*	.625	.000
	VL	RL	2.142*	.613	.002
		RL+VL	-1.932*	.630	.007
	RL+VL	RL	4.074*	.625	.000
		VL	1.932*	.630	.007

To analyze the test results further, we have classified the students' scores into five categories (Very low [0-6[, Low [6-10[, Medium [10-14[, High [4-18[, Very high [18-20]).

Figure 1 illustrates the percentage of students categorized into five modalities:

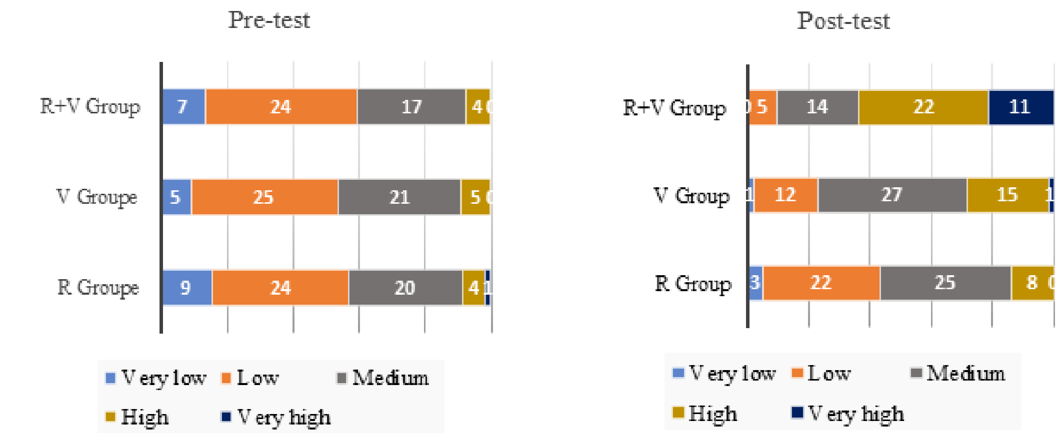


Figure 1. Comparison of Test Results (Pre and Post) for the Three Groups

The pre-test result analysis (Figure 1) shows that 56.90% of the students in the R group are very low to low, while the other 43.10% have a medium to high level. In the V group, 53.57% of the students have a very low to low level, while 46.43% have a medium to high level. In the R+V group, 59.62% of the students are very low to low, compared to 40.38% with a medium to high level. However, the post-test results of the R+V group show that there is an increase in the high and very high categories and a decrease in the categories of very low, low, and medium. In the V group, there is an increase in the categories of medium, high, and very high and a decrease in the very low and low categories. Similarly, in the R group, there is an increase in the medium and high categories and a decrease in the categories of very low, low, and very high.

To determine if there is a progression in student learning in each group, we conducted a paired-sample t-test. The results are presented in Table 9 below.

Table 9. Paired Samples T-Test for Pre-test and Post-test

Group	Measurement	Mean Difference	t	df	sig
R		.70690	1.680	57	.098
V	Posttest-pretest	2.38393	7.091	55	.000
R+V		5.16346	12.366	51	.000

Table 9 shows that the mean difference in scores between the post-test and pre-test in the R group is positive (MD post-pre = 0.70) but is not statically significant (P=0.098>0.05). In contrast, the mean differences in scores for the V group (MD = 2.38) and the R+V group (MD = 5.16) are both positive and statistically significant (P = 0.000 < 0.05).

Paired comparisons reveal a significant difference between the post-test scores of students in the R group and those in the V group, favoring the V group. The virtual labs (interactive simulation) based on the 5E model are more effective than the real labs in improving students' electrical scores. Integrating 5E-based interactive simulations as virtual lab activities encourages students to actively engage and explore knowledge through reasoning, which helps improve their learning outcomes. Several studies show similar results. Sarı et al. (2017) find that using the 5E teaching model combined with simulations in teaching light refraction concepts enhances students' academic performance and attitudes toward physics. Furthermore, Tseng et al. (2023) present that using virtual experiments as simulations is more effective in helping students understand the concept of heat and temperature than using real experiments (physical experiments). In contrast, Evangelou and Kotsis (2019) find that both experimental methods are similarly effective for understanding frictional force. Conversely, the paired-sample t-tests in this research reveal that students in the R+V group and the V group significantly improve their understanding of electricity concepts.

These results indicate that the students in these two groups make strong progress in learning, but they do not indicate whether this progress is significant. For this, we calculate relative gains (see Table 10).

Table 10. The Results of N-Gain

Method used	N-Gain	Category
VL	0.26	Low
RL+VL	0.50	Medium

Based on Table 10, the N-gain of the V group is 0.26, which is below the minimum threshold for which it is considered that there is significant progress in learning (corresponding to a low category). While in the R+V group, the N-gain value is 0.50 with a level ($0.3 \leq g \leq 0.7$) that is classified as medium (above the minimum threshold). In conclusion, the combination of real and virtual labs based on the 5E model proves to be sufficiently effective for learning electricity concepts, unlike virtual labs, which are less effective. Although these virtual labs have advantages, they do not contribute significantly to developing skills in handling laboratory equipment, such as reading measuring devices, adjusting the position of various buttons, or measuring elapsed time.

CONCLUSION

In conclusion, the results of this research demonstrate that the combination of real and virtual laboratories, when implemented through the 5E learning cycle, provides more effective learning experiences for the electricity unit and yields better student learning outcomes than using each method independently. This learning cycle is based on constructivist learning theory. It focuses on students, emphasizing their participation and active interaction with the learning content. The paired-sample t-test reveals that students in the virtual group who used the interactive simulations to learn physics scored higher than students in the real group. However, the N-Gain score for school outcomes in the R+V group is 0.50, with the medium category. Therefore, the combination of real and virtual laboratories based on 5E is effective in learning physics and can be considered by the relevant authorities of the National Ministry of Education to integrate it into all levels of education.

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