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Simulation-based learning using phet on the concept of series and parallel electrical circuits in secondary schools in timor-leste

Kristiani[1*], Pedro Correia[2], Paulo Alves Cabral[3], Isabel Tina Guterres[4]
[1,3,4]Departemen Pendidikan Fisika, Fakultas Pendidikan, Universitas Nasional Timor Lorosa'e (UNTL), Indonesia
[2]Departemen Pendidikan Kimia, Fakultas Pendidikan, Universitas Nasional Timor Lorosa'e (UNTL), Indonesia
*Corresponding Author e-mail: kristiani.2021@untl.edu.tl

Abstract: *The teaching methods employed by instructors can vary depending on learning objectives, student profiles, and available resources. Commonly used teaching methods include traditional or conventional approaches, demonstration methods, experimental methods, and others. This study implemented a PhET simulation-based teaching project on the concept of series and parallel electrical circuits: a study involving 12th-grade students majoring in Electrical Engineering at São João Bosco Secondary School in Venilale, Timor-Leste. The study aimed to investigate students' learning outcomes following the PhET simulation-based instruction on series and parallel circuit concepts. To achieve this objective, a survey test instrument was employed. The test was administered to 34 students. The results indicated that the calculated t-value was greater than the critical t-value (t_calculated > t_table) or (23.63 > 2.035), demonstrating a significant difference before and after the use of PhET simulations in teaching the concepts of series and parallel electrical circuits. This had a positive impact on the development of students' knowledge.*
Keywords: *PhET Simulation, Series and Parallel Electrical Circuits, Teaching Methods, Student Knowledge*

Abstrack: Metode pengajaran yang diterapkan oleh guru dapat bervariasi berdasarkan tujuan pembelajaran, karakteristik siswa, dan ketersediaan sumber daya. Metode utama yang umum digunakan meliputi metode tradisional, demonstrasi, eksperimental, dan metode berbasis teknologi. Penelitian ini mengkaji penerapan simulasi PhET dalam pembelajaran konsep rangkaian listrik seri dan paralel, dengan subjek penelitian berupa siswa kelas 12 jurusan Teknik Elektro di Sekolah Menengah Umum São João Bosco, Venilale, Timor Leste. Tujuan penelitian adalah untuk mengevaluasi peningkatan hasil belajar siswa setelah mengikuti pembelajaran berbasis simulasi PhET pada konsep rangkaian listrik seri dan paralel. Penelitian ini menggunakan desain eksperimen dengan instrumen berupa tes survei yang diberikan kepada 34 siswa. Analisis data menunjukkan bahwa nilai t-hitung lebih besar daripada nilai t-tabel (t-hitung > t-tabel) yaitu 23,63 > 2,035, yang menunjukkan adanya perbedaan signifikan antara hasil belajar siswa sebelum dan sesudah penerapan simulasi PhET. Temuan ini menegaskan bahwa penggunaan simulasi PhET memberikan pengaruh positif terhadap peningkatan pemahaman konsep kelistrikan pada sambungan seri dan paralel.
Kata Kunci: Simulasi PhET, Rangkaian Listrik Seri dan Paralel, Metode Pengajaran, Hasil Belajar Siswa

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INTRODUCTION

Education is a social practice aimed at developing human potential, skills, and competencies. Every individual has the right to receive education, which serves to plan human development through teaching and learning processes. In general, the role of education is fundamental and central in ensuring the quality of development across various sectors of a country. The implementation of education can enhance human resources and guarantee their potential to compete in diverse professional fields.

Education represents an opportunity for society; children in Timor-Leste must attend school and receive quality education to support national development. Accordingly, the government strives to realize this vision and remove barriers to educational access to ensure quality education (Ribeiro, 2015). Education has remained the most crucial factor in Timor-Leste since gaining independence. One of the challenges in the country's education system lies in human resources, particularly teachers, who play a vital role in educating, motivating, and teaching curriculum-related content.

Timor-Leste operates two school systems: public and private schools. Public schools are institutions governed and managed by the government, whereas private schools operate under the authority of religious foundations, such as Catholic, Christian, or Islamic organizations. Naturally, the learning processes in these two systems differ significantly. In public schools, instruction follows the national curriculum from primary to senior secondary education, while private schools often supplement the national curriculum with additional subjects according to the school's needs. Effective learning in schools requires the support of textbooks, lesson plans, and Portuguese-language reference materials (Araújo et al., 2018). Since independence from the Indonesian invasion, between 2010 and 2013 until the present, Portuguese has been used as the medium of instruction in the country's education system (de Albuquerque & Ramos, 2020).

Teaching methods employed by instructors vary according to the defined learning objectives. Teachers commonly use lectures, demonstrations, experimental methods, and other approaches. Based on the researcher's observations across several schools in Timor-Leste, teachers primarily relied on lectures and demonstrations using simple tools due to the limited availability of laboratory equipment.

The integration of modern technology into education is necessary to motivate students and facilitate their understanding of scientific concepts. PhET simulations not only deepen students' understanding of physics but also enhance learning in chemistry, biology, and mathematics. PhET, which stands for Physics Education Technology, provides interactive simulations for science learning (Alfonso & Lima, 2023). In physics instruction, PhET simulations enable students to conduct experiments without requiring physical laboratory equipment.

According to Oliveira (2021), PhET simulations were developed in 2002 by Nobel laureate Carl Wieman at the University of Colorado Boulder. He created free interactive simulations to support visualized and hands-on science learning. In simulations of electrical circuits, students can experiment virtually, manipulate components, and observe the outcomes. This approach enhances students' knowledge and comprehension during the learning process.

Living in the digital era, technology plays a critical role in society, including in education. Technology serves as a bridge for acquiring new knowledge globally (de Medeiros et al., 2024). PhET-based learning represents an interactive instructional strategy that fosters students' conceptual understanding, particularly in physics.

This study specifically focuses on understanding the characteristics of series and parallel electrical circuits. According to Dayana (2023), the characteristics of series circuits include a uniform current flowing through each load, source voltage divided across resistors of equal resistance, and the interruption of current flow if any component is disconnected. In contrast, parallel circuits are characterized by most electrical components being connected in parallel, resulting in lower total resistance. Consequently, the total current increases, leading to higher energy consumption.

The research problem addressed in this study is whether PhET simulation-based learning can enhance students' understanding of series and parallel circuit concepts. The study aims to investigate students' learning outcomes before and after implementing PhET simulation-based instruction.

METHOD

This study employed a quantitative research design. According to Murniarti (2025), quantitative research involves obtaining results from a specific action, such as measuring the outcomes of a test. Data collection is conducted by administering tests to the research sample, and the results are analyzed by focusing solely on the outcomes or achievements. This design was chosen to determine whether there is a significant improvement in students' learning outcomes before and after implementing PhET simulations, using statistical analysis.

The sample consisted of 34 12th-grade science students at São João Bosco Secondary School in Venilale, Timor-Leste. The students underwent two rounds of testing: a pre-test conducted before the implementation of the PhET simulation and a post-test conducted afterward. Both tests consisted of the same questions and the same number of items: 10 multiple-choice questions and 4 essay questions. Each multiple-choice question had only one correct answer, scored as 1 for correct and 0 for incorrect. The essay section included 4 questions, each containing two sub-questions scored 0.75 for correct answers. All questions were related to physics concepts on series and parallel circuits. The test duration was 60 minutes.

According to Putra et al. (2018), to determine whether there is a significant difference between the pre-test and post-test results after implementing PhET simulations, the calculated t-value can be determined using the formula:

$$t = \frac{Md}{\sqrt{\frac{\sum x_d^2}{N(N-1)}}}$$

where:

Md = mean of deviations (d) between post-test and pre-test

x^d = individual deviation from the mean deviation

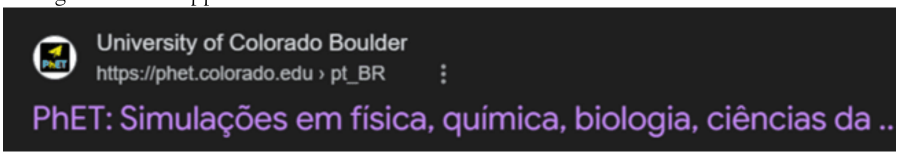
$\sum x_d^2$ = sum of squared deviations

N = sample size

The calculated t-value is used to test the hypothesis, including the null hypothesis (H0) and alternative hypothesis (Ha). If the calculated t-value is smaller than the critical t-value (t_calculated < t_table), it indicates no significant difference. Conversely, if the calculated t-value is greater than the critical t-value (t_calculated > t_table), it signifies a highly significant difference between students' learning outcomes before and after implementing PhET simulations. This indicates that PhET simulations are highly effective in improving students' learning outcomes in the classroom.
For the implementation of PhET simulations on the concept of series and parallel electrical circuits, the researcher prepared a detailed lesson plan as follows:

1. Learning Objectives
   a. Students can assemble series and parallel electrical circuits.
   b. Students can identify the differences in characteristics between series and parallel circuits.
   c. Students can provide examples of the application of series and parallel circuits in daily life.
2. PhET Simulation Implementation Steps
   a. Access the simulation on Google by typing "PhET simulation," as shown in the following figure,

and the following screen will appear

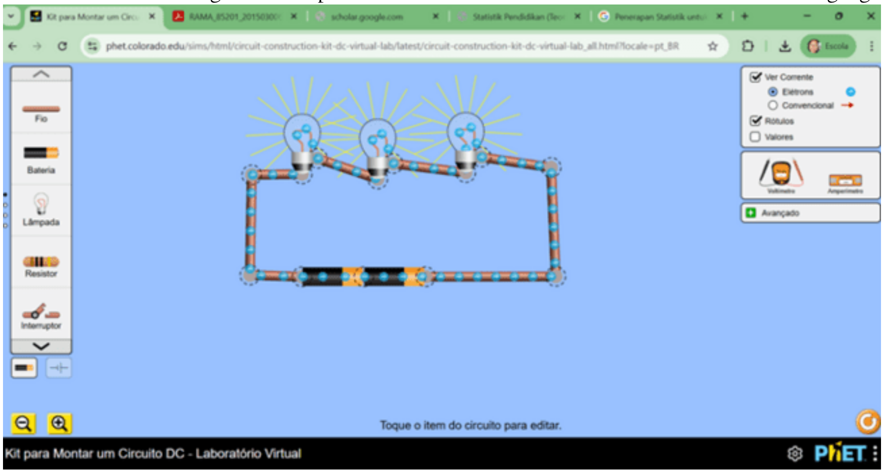


Select and click the option above, and the following image will appear.

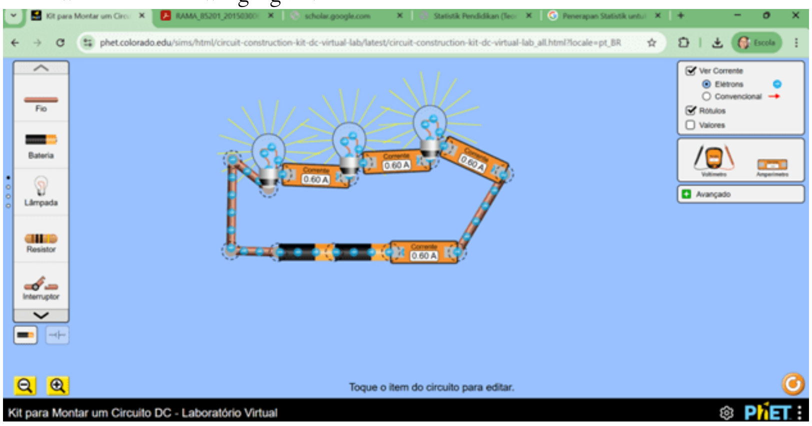
Click the "EXPLORE NOSSAS SIMS" button and select the kit menu to assemble a DC circuit as shown below.

The workspace screen will appear to begin the experiment activities using the PhET simulation, as shown below.

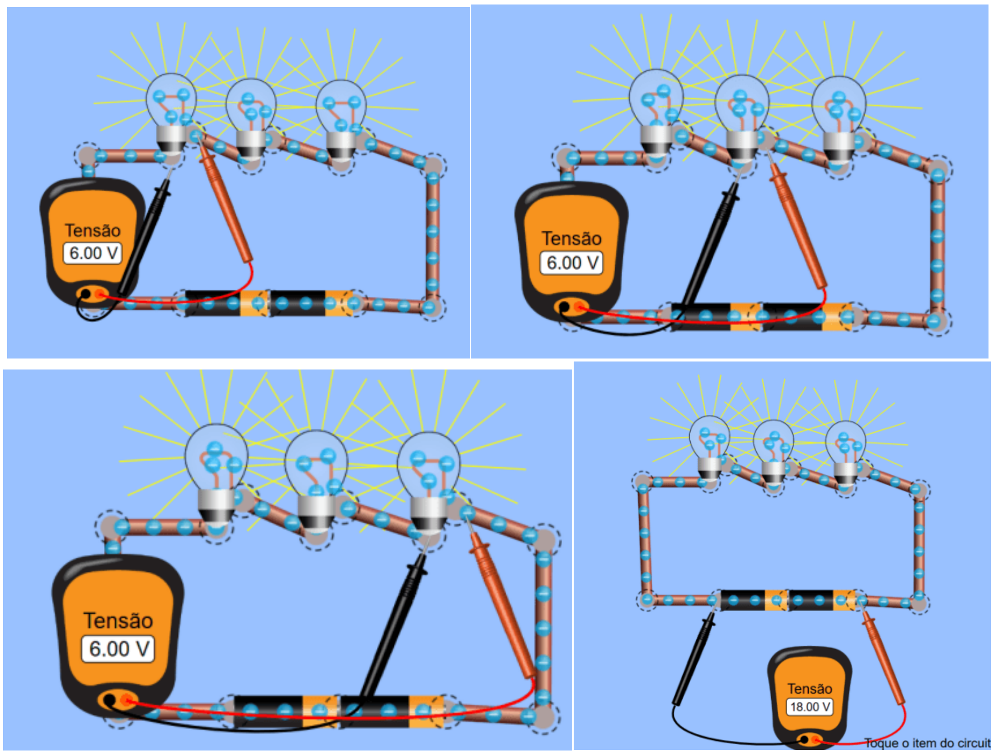
b. Assemble a DC series circuit using three lamps, wires, and two batteries, as shown in the following figure.



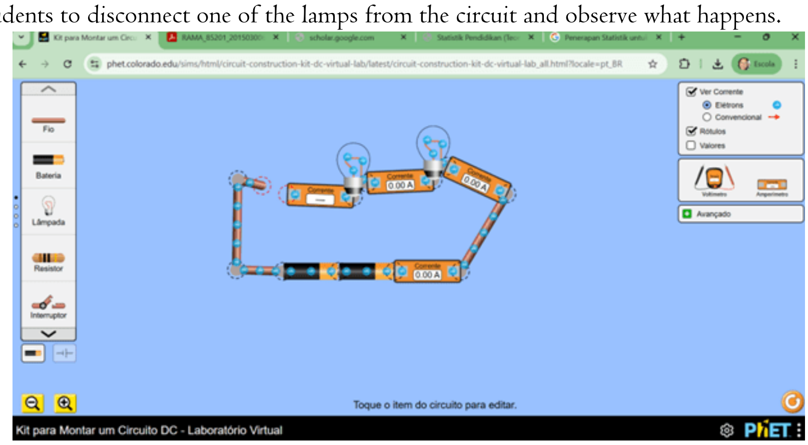
c. Instruct the students to observe the brightness of the lamps. Then, ask them to measure the electric current by connecting an ammeter to each lamp and battery (reminding them that the ammeter must be connected in series with the load), as shown in the following figure.



Additionally, measure the voltage across each lamp and battery by connecting a voltmeter (reminding them that the voltmeter must be connected in parallel with the load), as shown in the following figure.

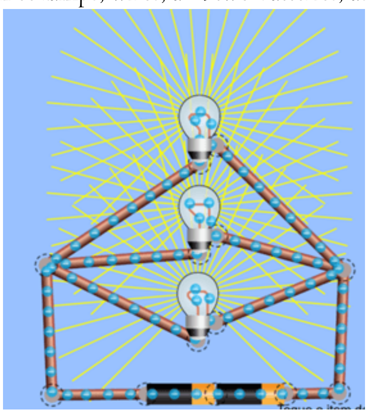


d. Instruct the students to disconnect one of the lamps from the circuit and observe what happens.

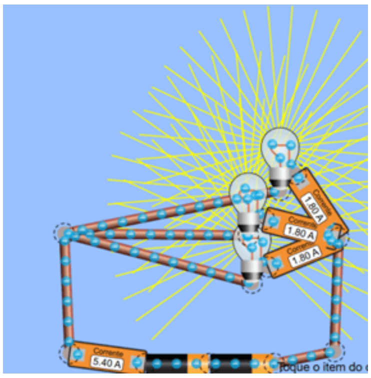


For the parallel electrical circuit, students are asked to perform the activities described in steps 2 through 4, as follows.

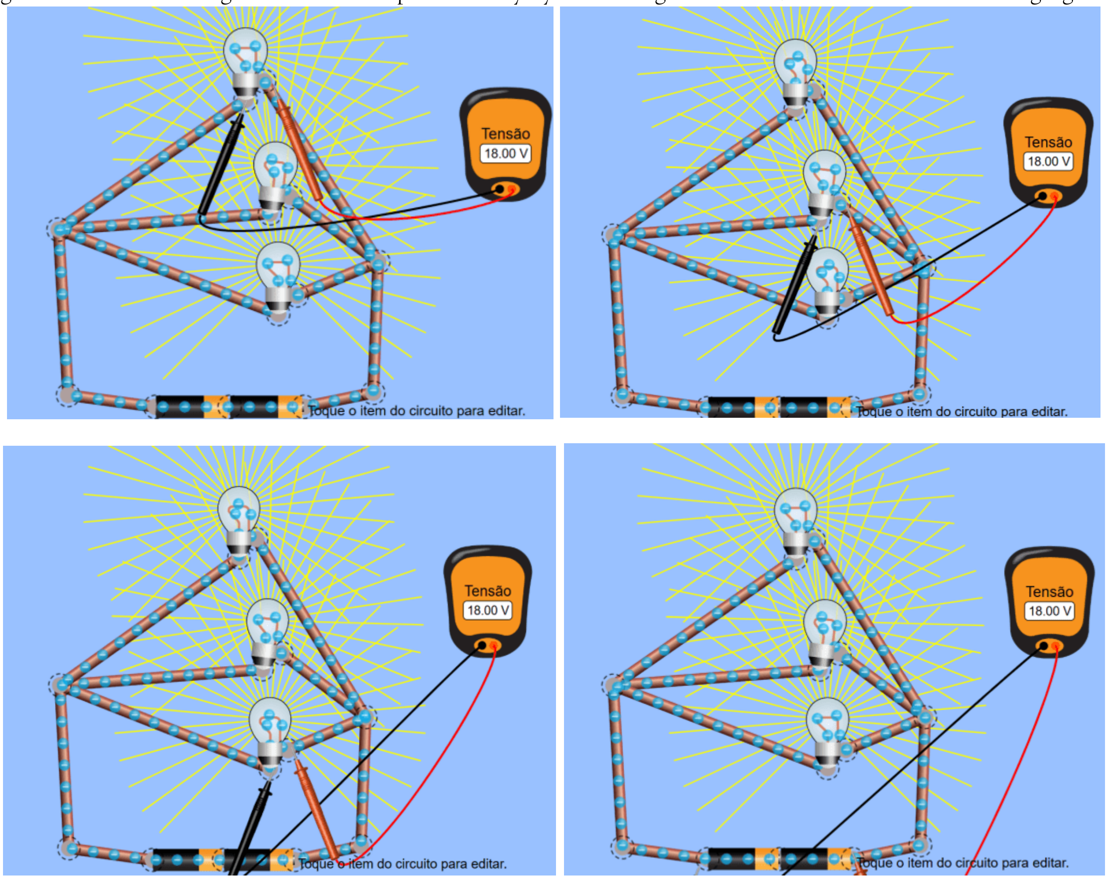
e. Assemble a DC parallel circuit using three lamps, wires, and two batteries, as shown in the following figure.



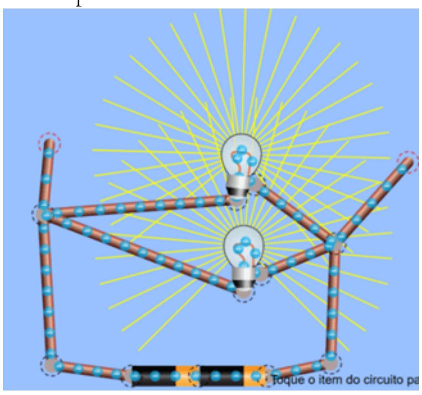
f. Instruct the students to observe the brightness of each lamp and to measure the electric current by connecting an ammeter to each lamp and battery, as shown in the following figure.



g. Measure the voltage across each lamp and battery by connecting a voltmeter, as shown in the following figure.



h. Instruct the students to disconnect one lamp from the circuit and observe what happens.



i. Instruct the students to engage in a discussion to draw conclusions from the activities above.

j. Ask the students to provide examples from daily life that illustrate the concepts of series and parallel circuits.

RESULT AND DISCUSSION

The students' scores before (pre-test) and after (post-test) implementing the PhET simulation are as follows:

N°	Pré - teste (X_1)	Post - teste (X_2)	$d = X_2 - X_1$	d^2	Xd = d - Md	X^2d
1.	3,1	6,5	3,4	11,56	0	0
2.	4,65	8,5	3,85	14,8225	0,45	0,2025
3.	2,55	6,1	3,55	12,6025	0,15	0,0225
4.	6,5	9,2	2,7	7,29	-0,7	0,49
5.	5,4	9,2	3,8	14,44	0,4	0,16
6.	5	8,8	3,8	14,44	0,4	0,16
7.	2,35	6,85	4,5	20,25	1,1	1,21
8.	2,75	6,5	3,75	14,0625	0,35	0,1225
9.	6,2	9,2	3	9	-0,4	0,16
10.	6,15	9,6	3,45	11,9025	0,05	0,0025
11.	3,55	7,65	4,1	16,81	0,7	0,49
12.	5,5	8,4	2,9	8,41	-0,5	0,25
13.	3,55	7,65	4,1	16,81	0,7	0,49
14.	4,3	7,3	3	9	-0,4	0,16
15.	3,5	7	3,5	12,25	0,1	0,01
16.	3,5	3,5	0	0	-3,4	11,56
17.	6,9	9,6	2,7	7,29	-0,7	0,49
18.	6,5	9,2	2,7	7,29	-0,7	0,49
19.	3,1	6,5	3,4	11,56	0	0
20.	6,55	9,2	2,65	7,0225	-0,75	0,5625
21.	3,1	6,5	3,4	11,56	0	0
22.	6,5	9,2	2,7	7,29	-0,7	0,49
23.	2,55	7,65	5,1	26,01	1,7	2,89
24.	3,1	6,9	3,8	14,44	0,4	0,16
25.	6,9	9,6	2,7	7,29	-0,7	0,49
26.	3,85	8	4,15	17,2225	0,75	0,5625
27.	3,85	8	4,15	17,2225	0,75	0,5625
28.	3,5	7,3	3,8	14,44	0,4	0,16
29.	4,3	7,65	3,35	11,2225	-0,05	0,0025
30.	3,55	7,3	3,75	14,0625	0,35	0,1225
31.	2,75	6,85	4,1	16,81	0,7	0,49
32.	3,5	7,3	3,8	14,44	0,4	0,16
33.	3,55	7,3	3,75	14,0625	0,35	0,1225
34.	3,9	7,25	3,35	11,2225	-0,05	0,0025
Σ	146,5	263,25	116,75	424,108	113,35	23,2475
			Md = 116,75/34=3,4			

d represents the difference between the post-test and pre-test scores (X2 − X1).
Analysis of the results

$$Md = \frac{\sum d}{N} = \frac{116{,}75}{34} = 3{,}4$$

Md is the total sum of the differences between the post-test and pre-test scores divided by the total sample size.

The calculated t-value (t_calculated) is obtained as follows:

$$t_{conta} = \frac{Md}{\sqrt{\frac{\sum x^2 d}{N(N-1)}}}$$

$$t = \frac{3{,}4}{\sqrt{\frac{23{,}2475}{34(34-1)}}} = \frac{3{,}4}{\sqrt{\frac{23{,}2475}{(1122)}}} = \frac{3{,}4}{\sqrt{0{,}0207}} = \frac{3{,}4}{0{,}1439} = 23{,}63$$

The study analyzed the pre-test and post-test scores of 34 12th-grade science students at São João Bosco Secondary School in Venilale (ESSJB), Timor-Leste, regarding the concept of series and parallel electrical circuits. The total pre-test score was 146.5, while the total post-test score was 263.25. The total difference between the pre-test and post-test scores was 116.75. The sum of squared deviations $(\sum x_d^2)$ was 23.2475. The degrees of freedom were calculated as N − 1 = 34 − 1 = 33, with a significance level of 5%, giving a critical t-value (t_{table}) of 2.035, as shown in the following table.

Distribuição t-Student: valores tc tais que P(-tc ≤ t ≤ tc) = 1 - p

Graus de Liberdade / p ▸	90%	80%	70%	60%	50%	40%	30%	20%	10%	8%	6%	5%	4%	2%	1%	0,2%	0,1%
1	0,158	0,325	0,510	0,727	1,000	1,376	1,963	3,078	6,314	7,916	10,579	12,706	15,895	31,821	63,657	318,309	636,619
2	0,142	0,289	0,445	0,617	0,816	1,061	1,386	1,886	2,920	3,320	3,896	4,303	4,849	6,965	9,925	22,327	31,599
3	0,137	0,277	0,424	0,584	0,765	0,978	1,250	1,638	2,353	2,605	2,951	3,182	3,482	4,541	5,841	10,215	12,924
4	0,134	0,271	0,414	0,569	0,741	0,941	1,190	1,533	2,132	2,333	2,601	2,776	2,999	3,747	4,604	7,173	8,610
5	0,132	0,267	0,408	0,559	0,727	0,920	1,156	1,476	2,015	2,191	2,422	2,571	2,757	3,365	4,032	5,893	6,869
6	0,131	0,265	0,404	0,553	0,718	0,906	1,134	1,440	1,943	2,104	2,313	2,447	2,612	3,143	3,707	5,208	5,959
7	0,130	0,263	0,402	0,549	0,711	0,896	1,119	1,415	1,895	2,046	2,241	2,365	2,517	2,998	3,499	4,785	5,408
8	0,130	0,262	0,399	0,546	0,706	0,889	1,108	1,397	1,860	2,004	2,189	2,306	2,449	2,896	3,355	4,501	5,041
9	0,129	0,261	0,398	0,543	0,703	0,883	1,100	1,383	1,833	1,973	2,150	2,262	2,398	2,821	3,250	4,297	4,781
10	0,129	0,260	0,397	0,542	0,700	0,879	1,093	1,372	1,812	1,948	2,120	2,228	2,359	2,764	3,169	4,144	4,587
11	0,129	0,260	0,396	0,540	0,697	0,876	1,088	1,363	1,796	1,928	2,096	2,201	2,328	2,718	3,106	4,025	4,437
12	0,128	0,259	0,395	0,539	0,695	0,873	1,083	1,356	1,782	1,912	2,076	2,179	2,303	2,681	3,055	3,930	4,318
13	0,128	0,259	0,394	0,538	0,694	0,870	1,079	1,350	1,771	1,899	2,060	2,160	2,282	2,650	3,012	3,852	4,221
14	0,128	0,258	0,393	0,537	0,692	0,868	1,076	1,345	1,761	1,887	2,046	2,145	2,264	2,624	2,977	3,787	4,140
15	0,128	0,258	0,393	0,536	0,691	0,866	1,074	1,341	1,753	1,878	2,034	2,131	2,249	2,602	2,947	3,733	4,073
16	0,128	0,258	0,392	0,535	0,690	0,865	1,071	1,337	1,746	1,869	2,024	2,120	2,235	2,583	2,921	3,686	4,015
17	0,128	0,257	0,392	0,534	0,689	0,863	1,069	1,333	1,740	1,862	2,015	2,110	2,224	2,567	2,898	3,646	3,965
18	0,127	0,257	0,392	0,534	0,688	0,862	1,067	1,330	1,734	1,855	2,007	2,101	2,214	2,552	2,878	3,610	3,922
19	0,127	0,257	0,391	0,533	0,688	0,861	1,066	1,328	1,729	1,850	2,000	2,093	2,205	2,539	2,861	3,579	3,883
20	0,127	0,257	0,391	0,533	0,687	0,860	1,064	1,325	1,725	1,844	1,994	2,086	2,197	2,528	2,845	3,552	3,850
21	0,127	0,257	0,391	0,532	0,686	0,859	1,063	1,323	1,721	1,840	1,988	2,080	2,189	2,518	2,831	3,527	3,819
22	0,127	0,256	0,390	0,532	0,686	0,858	1,061	1,321	1,717	1,835	1,983	2,074	2,183	2,508	2,819	3,505	3,792
23	0,127	0,256	0,390	0,532	0,685	0,858	1,060	1,319	1,714	1,832	1,978	2,069	2,177	2,500	2,807	3,485	3,768
24	0,127	0,256	0,390	0,531	0,685	0,857	1,059	1,318	1,711	1,828	1,974	2,064	2,172	2,492	2,797	3,467	3,745
25	0,127	0,256	0,390	0,531	0,684	0,856	1,058	1,316	1,708	1,825	1,970	2,060	2,167	2,485	2,787	3,450	3,725
26	0,127	0,256	0,390	0,531	0,684	0,856	1,058	1,315	1,706	1,822	1,967	2,056	2,162	2,479	2,779	3,435	3,707
27	0,127	0,256	0,389	0,531	0,684	0,855	1,057	1,314	1,703	1,819	1,963	2,052	2,158	2,473	2,771	3,421	3,690
28	0,127	0,256	0,389	0,530	0,683	0,855	1,056	1,313	1,701	1,817	1,960	2,048	2,154	2,467	2,763	3,408	3,674
29	0,127	0,256	0,389	0,530	0,683	0,854	1,055	1,311	1,699	1,814	1,957	2,045	2,150	2,462	2,756	3,396	3,659
30	0,127	0,256	0,389	0,530	0,683	0,854	1,055	1,310	1,697	1,812	1,955	2,042	2,147	2,457	2,750	3,385	3,646
31	0,127	0,256	0,389	0,530	0,682	0,853	1,054	1,309	1,696	1,810	1,952	2,040	2,144	2,453	2,744	3,375	3,633
32	0,127	0,255	0,389	0,530	0,682	0,853	1,054	1,309	1,694	1,808	1,950	2,037	2,141	2,449	2,738	3,365	3,622
33	0,127	0,255	0,389	0,530	0,682	0,853	1,053	1,308	1,692	1,806	1,948	2,035	2,138	2,445	2,733	3,356	3,611
34	0,127	0,255	0,389	0,529	0,682	0,852	1,052	1,307	1,691	1,805	1,946	2,032	2,136	2,441	2,728	3,348	3,601
35	0,127	0,255	0,388	0,529	0,682	0,852	1,052	1,306	1,690	1,803	1,944	2,030	2,133	2,438	2,724	3,340	3,591

Based on the results above, the calculated t-value is greater than the critical t-value ($t_{calculated} > t_{table}$), or (23.63 > 2.035).

CONCLUSION

Based on the analysis and discussion of the data, it can be concluded that the implementation of PhET simulations on the concept of series and parallel electrical circuits can enhance the understanding of 12th-grade science students at São João Bosco Secondary School in Venilale, Timor-Leste. This conclusion is supported by the calculated t-value being higher than the critical t-value (23.63 > 2.035), indicating a significant difference between the mean scores before and after the application of PhET simulations. Therefore, it can be concluded that students' learning outcomes improved significantly after teachers implemented PhET simulation-based instruction. The simulation is highly effective in enhancing students' knowledge in this area.

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