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Lab Modality and Measurement Accuracy:
A review of Electronics Practical Workbench versus other Approaches

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Abstract
This article sought to assess the impact of using an Electronics Practical Workbench (EPW) on the accuracy of students' measurements in KCSE Physics practical exams, which evaluate skills in mechanics, electricity and optics. A quasi-experimental design with non-equivalent groups was employed, using pre-tests, post-tests, observation checklists and teacher interviews. The focus was on measuring students' precision in recording voltage, current and resistance. Quantitative data were analyzed using the Mann-Whitney U Test and Ordinal Logistic Regression. Findings showed that students using the EPW achieved significantly higher accuracy and better overall performance in practical assessments compared to those using traditional lab setups. The article concludes that digital tools like the EPW enhance measurement precision and practical understanding, suggesting that integrating such technology in school labs can mitigate challenges related to outdated equipment. These improvements have important implications for strengthening physics education and student performance in Kenyan secondary schools.

KEY WORDS: Measurement Accuracy, Electronics Practical Workbench.

Introduction

In Kenyan secondary education, practical physics activities, particularly in electrical circuits, are essential and assessed through KCSE Paper 3 (Gacheri & Dege, 2014). Students engage in experiments like verifying Ohm's Law and building circuits, developing skills in measurement, documentation and graphing. These hands-on tasks enhance understanding and enthusiasm for physics. However, challenges such as limited lab resources, lack of tools like galvanometers and insufficient teacher training hinder effective implementation. Despite these issues, research confirms that practical work improves performance and student attitudes toward physics. Awuor & Okono (2022) recommend addressing these problems through increased resource allocation, enhanced teacher development and adoption of student-centered learning approaches to strengthen practical science education in Kenya.

Traditional teaching of circuit-based physics involves teacher-led demonstrations using blackboards or physical circuit boards (Kisiang’ani et al., 2024). Students follow step-by-step instructions to build basic circuits in series and parallel, using components like resistors, capacitors, bulbs, and batteries. Key concepts such as Ohm’s law, resistance and voltage are explained during these sessions. Learners then recreate the circuits independently or in groups, engaging in hands-on activities to observe and measure circuit behavior. They record their observations manually on worksheets or in notebooks, emphasizing experiential learning through direct interaction with physical components (Al-Hendawi et al., 2025). An electronics practical workstation in a secondary school is a dedicated space equipped with tools like resistors, capacitors, diodes, transistors, power supplies, multimeters, and breadboards for hands-on circuit experiments (Onime, Zennaro & Uhomoibhi, 2014). Students use it to build, test, and analyze circuits, learning concepts such as Ohm’s law and circuit behavior. Roberts (2011) emphasizes that such workbenches enhance students’ understanding by bridging theory and practice, allowing them to actively engage in constructing and measuring electronic circuits for deeper learning of physics principles.

The evaluation of hands-on work often focuses on students’ ability to build circuits and take accurate measurements using tools like ammeters and voltmeters (Steinberg et al., 2020). While students may perform calculations and write reports based on their observations, these methods often emphasize memorization over true understanding. Many schools also lack access to instructional videos, simulations and advanced technologies, which can hinder the development of critical thinking and problem-solving abilities (Zaremohzzabieh et al., 2025). Although traditional methods effectively introduce basic circuit concepts, they may fall short in promoting deep comprehension of physics or encouraging innovative thinking to solve real-world problems. This limits students' engagement with the underlying scientific principles and their application beyond the classroom. Before measuring voltage in circuit-based physics experiments, students must ensure the circuit is correctly assembled as per the diagram. They should use a digital or analog voltmeter set to the proper voltage range (Thatikonda, 2023). The voltmeter must be connected in parallel to the component being tested, with the positive lead at the higher potential and the negative at the lower. Saikiran (2023) advises checking for overloaded circuits and loose connections, and avoiding contact with metal parts to prevent errors. Careful measurement is essential, with attention to potential inaccuracies caused by faulty equipment or environmental factors like temperature. Overall, precision, safety, and thorough inspection are key to obtaining accurate voltage readings in circuit experiments.

To accurately measure electric current in a physics practical in Kenyan secondary schools, students must first ensure the circuit is correctly set up with all components properly connected (Okono, Wangila & Chebet, 2023). An ammeter should be placed in series with the target component and set to a suitable range for the expected current. Proper polarity must be observed to avoid damaging the device. Before switching on the power, students must check for a complete, secure circuit with no loose connections. For precise results, multiple readings should be taken and averaged. Additionally, to prevent overloading the ammeter, appropriate scales and ranges should be used, especially for higher currents. This systematic approach ensures safe and accurate current measurements. Ramongalo (2024) recommended that students measure resistance in a physics lab by building a simple circuit with a known power source, ammeter, and voltmeter. A resistor is added, ensuring tight connections to avoid errors. After switching on the power, students should record multiple voltage and current readings, using volts and amperes. Zulu (2023) emphasized applying Ohm’s Law ($V = IR$) to calculate resistance by dividing voltage by current. To improve accuracy, students should repeat measurements and compute the average resistance. Care should be taken to avoid overheating the resistor or power supply, which could affect results. This method provides a practical and accurate way to determine electrical resistance in a controlled lab setting.

Literature Review

This literature review explores key techniques for measuring voltage, current and resistance, fundamental to understanding circuits and Ohm’s Law. It highlights the importance of accuracy, limitations, and applications of these measurements in validating theory and developing reliable systems, with emphasis on their roles in education and research.

Measuring Voltage (V)

Physics education emphasizes the importance of best practices when measuring voltage in circuit-based experiments (Thatikonda, 2023). A key principle is connecting voltmeters in parallel with the component under examination. This arrangement allows accurate measurement of the potential difference without altering the circuit’s current flow, maintaining the system's integrity and ensuring reliable results. Proper voltmeter connection is essential not only for accurate data but also for safety and effective teaching of circuit concepts. In addition, selecting the correct voltage range on the voltmeter is vital. It is recommended to begin with the highest range to avoid damaging the instrument. Once it's confirmed that the voltage falls within a safer level, the range can be adjusted downward for more precise readings. This gradual, cautious approach protects equipment and reinforces correct instrument handling. Implementing these practices in educational settings fosters students' understanding of electrical measurements and helps them develop strong technical skills in circuit analysis. These methods not only improve measurement accuracy but also strengthen foundational knowledge, making students better equipped for advanced studies or practical applications in physics and engineering.

Franco (2024) emphasized the importance of properly managing and arranging measuring devices, especially ensuring a multimeter is set to the correct voltage mode and that test leads are securely connected. Using the highest voltage range first helps protect the device and ensures accurate results. Sheng et al. (2023) found that in educational settings, using voltmeters with various ranges helps demonstrate how sensitivity affects readings. This method enhances students' understanding of selecting the right tools, interpreting varying data and grasping measurement uncertainty. It also reinforces hands-on learning in voltage measurement. Overall, proper device setup and instructional strategies are crucial for accurate measurements and deeper educational engagement in voltage-related experiments.

Kornegay, Kornegay, Baney, Harvey and Kinyanjui (2022) highlighted the use of advanced methods like four-terminal (Kelvin) sensing for high-precision voltage measurements. This technique separates current supply and voltage measurement electrodes, eliminating lead and contact resistance effects, which is crucial for accurate low-resistance readings. It is particularly useful in evaluating semiconductors and non-linear components. The authors emphasized that best practices such as correct instrument setup, proper connections, and employing sophisticated techniques are essential for reliable measurements. Adhering to these principles enhances the accuracy of experiments and supports a stronger understanding of electrical phenomena, benefiting both students and professionals in physics and engineering contexts. Docter and Bastemeijer (2024) identified key challenges in accurately measuring voltage during circuit-based physics experiments. Measurement errors often arise from weak connections, corroded terminals, and contact resistance, which can cause fluctuations or inaccuracies. Even a voltmeter's high internal resistance may slightly affect sensitive or low-voltage circuits. Improper voltmeter placement such as connecting in series instead of parallel, can disrupt circuit function (Mwinisin, 2023). Human errors, including selecting the wrong scale or misreading analog meters, further complicate results. Environmental factors like electromagnetic interference and temperature shifts can also impact high-precision measurements. Addressing these issues requires careful circuit setup, proper instrument use and a strong understanding of both theoretical concepts and practical techniques in voltage measurement.

Measuring Electric Current (I)

Accurate measurement of electric current in physics experiments requires careful adherence to best practices to ensure both safety and precision. Ghimire and Waller (2025) emphasize the importance of selecting the appropriate measuring device, usually an ammeter or a multimeter set to measure current—and correctly connecting it in series with the component under test. This configuration ensures the meter measures the consistent current flowing through the circuit. Oluokun, Akinsooto, Ogundipe, and Ikemba (2025) highlight the necessity of checking the expected current range before connecting the meter to prevent damage or overloading. Mantovani et al. (2020) stress that calibration and zero-error verification are critical steps prior to measurement. Analog meters should be checked to ensure the needle rests at zero with no current, while digital meters require testing with a known current source for accuracy. Regular calibration using standard instruments provided by the laboratory or external services is essential to maintain measurement reliability and consistency across repeated or comparative experiments. Together, these guidelines form a comprehensive approach to achieving safe and precise current measurements in experimental physics.

Srinivas and Elango (2024) emphasize the importance of ensuring secure, low-resistance connections in circuits to avoid inaccurate readings caused by voltage drops. Loose wires, corroded terminals, or poor-quality connectors increase resistance, affecting current flow. Using proper terminals like banana plugs or crocodile clips and ensuring clean, tight contact points can minimize these issues. Additionally, shortening wire lengths helps reduce resistance and unwanted effects, especially in sensitive or AC circuits. Ikpe, Ekanem and Ikpe (2024) recommend careful observation and systematic

documentation of current fluctuations when adjusting resistances or voltage inputs. They advise against rapidly changing circuit configurations while meters are connected, as sudden current spikes may damage components. Allowing the circuit to stabilize for several seconds after each adjustment is crucial, as transient effects can produce fluctuating readings that do not represent steady-state conditions. These practices help ensure accurate, reliable measurements during practical circuit work.
Rana, Mamun, and Islam (2024) emphasize that prioritizing safety is crucial when measuring electric current. Students and professionals must know the maximum current ratings of their instruments and circuit components to avoid overheating, short circuits, or electrical fires. It is important to verify the measurement range and lead positions on multimeters, especially when switching between current, voltage and resistance measurements. Using fuse-protected meters and personal protective equipment further enhances safety during laboratory experiments.

Measuring electric current accurately in physics experiments presents several challenges affecting data reliability and understanding of electrical behavior. Zhang (2024) highlights the necessity of placing the ammeter correctly in series; improper setup can cause circuit failure or inaccurate readings. The internal resistance of measuring devices, although ideally minimal, can still affect delicate low-current circuits. Calibration errors and instrument limitations such as insufficient resolution or range also contribute to inaccuracies. Leone (2014) notes external factors like poor connections, unstable power supplies and electromagnetic interference can cause fluctuating readings. Additionally, students may inadvertently alter circuit resistance while connecting instruments, impacting current flow. These technical and procedural issues stress the importance of careful setup, correct instrument use and a strong grasp of circuit principles to ensure valid and reliable experimental results.

Determination of Resistance (R)

In a physics lab on electrical circuits, accurately measuring resistance requires carefully following a circuit schematic, ensuring correct series or parallel setups, verifying polarities and securing connections to avoid errors like contact resistance or open circuits (Jash et al., 2022). Using a clear circuit diagram helps prevent wiring mistakes that affect results. Selecting proper tools is also crucial; high-quality digital multimeters (DMMs) are preferred for measuring voltage and current to apply Ohm's Law ($R = V/I$) accurately, while analog meters have educational value but less precision (Jiao et al., 2019). Setting the multimeter to the correct mode and range is vital, with auto-ranging aiding ease and manual adjustment offering better control for precise resistance measurement. According to Nyamathulla and Dhanamjayulu (2024), calibrating the measuring instruments before starting the experiment is a crucial best practice. It is essential to verify and correct the zero error in voltmeters and ammeters and ensure the continuity of the test leads. Calibration ensures that any changes in the meter readings due to internal factors like temperature variations or worn components are accounted for. Furthermore, it is important to consider the internal resistance of the measuring instruments, especially in delicate setups. For example, attaching a voltmeter with high internal resistance in parallel ensures low current draw, preserving circuit operation, while an ammeter with low internal resistance in series reduces additional voltage losses.

Sheng et al. (2023) emphasized the importance of minimizing both systematic and random errors in resistance measurements. To achieve this, resistance should be measured multiple times under consistent conditions, and the average value should be used for accuracy. Environmental factors, such as temperature, can significantly influence resistance, especially in materials like metals, so experiments must be conducted in stable, uniform environments. The researchers also highlighted the benefit of using resistors with specified tolerance levels to reduce variability. Additionally, they advised limiting current to prevent resistor overheating, which can cause measurement errors. Performing multiple experiments and plotting voltage-current (V-I) graphs to calculate resistance from the slope was recommended as a more precise and reliable method than relying on single measurements. This approach helps ensure consistent, accurate resistance values by addressing potential error sources and applying careful experimental techniques.

Thorough documentation and careful analysis are essential for optimal resistance assessment in physics experiments. Students should systematically record all observations, including instrument settings, environmental conditions and measured values (Brandt, 2024). Incorporating uncertainties into final results helps provide a realistic range for measured resistance. Constructing well-labeled voltage-current (V-I) graphs and applying linear regression when needed to determine gradients allows verification of results. These practices not only yield more accurate resistance measurements but also deepen students' understanding of underlying physics concepts and experimental techniques.

Resistance measurement in circuits during lab work involves challenges that impact accuracy and reliability. Ikpe et al. (2024) highlight that both systematic and random errors may arise from measurement devices like voltmeters and ammeters due to limited accuracy, calibration errors, or internal resistance. Additionally, poor connections, variable contact resistance at terminals, and wire quality can cause inconsistent voltage and current readings. Mantovani et al. (2020) emphasize environmental factors such as temperature fluctuations, which notably affect resistance in metals. Students may also struggle to interpret readings correctly, maintain proper circuit configurations and apply Ohm's law effectively, especially with non-ohmic components.

These factors underscore the importance of meticulous experimental setup, repeated measurements, and thorough error analysis when assessing resistance. This article specifically aimed to evaluate the precision of student measurements using an Electronics Practical Workbench versus traditional laboratory setups, providing insights into improving resistance measurement practices in physics education.

Methodology

Some schools in Kenya encounter difficulties because of inadequate or obsolete laboratory apparatus. This constraint hinders students' capacity to conduct experiments efficiently, which may subsequently influence their performance. To tackle this problem, this research was carried out to evaluate the precision of measurements among students utilizing an Electronics Practical Workbench compared to those employing conventional laboratory setups. The research utilized a quasi-experimental design that included a pre-test and a post-test. The research involved two non-equivalent groups, comprising an experimental group and a control group that underwent different interventions. The experimental group was taught practical skills using an electronics workbench, while the control group gained practical knowledge through conventional teaching approaches. This research was carried out in Nairobi County, Kenya. From a article population comprising 98 physics teachers and 1,791 form three physics students chosen from 74 public secondary schools, a sample was taken of 23 schools, 29 physics teachers and 452 students. The research conducted two assessments (E1 and E2) on chosen physics subjects, with one given at the beginning and the other at the conclusion of the study; furthermore, it distributed the Questionnaires, Measurement Skills Learnt Checklist (MSLC), and Interview Schedules. Statistical methods, including the Mann-Whitney U Test and Ordinal Logistic Regression, were employed to analyze the quantitative data.

Results

This section showcases the outcomes from measuring voltage, electric current and resistance taken during a physics lab activity utilizing a series circuit configuration. The circuit included multiple dry cells, a light bulb, an ammeter, a voltmeter and a carbon resistor. Data were gathered during two distinct evaluations, E1 at the study's outset and E2 at its conclusion to analyze any variations or enhancements in measurement precision and comprehension over the article duration. The findings were recorded as shown in table 1.

Table 1: Measurement of current, potential difference and electromotive force with more than 1 dry cell connected in series at R=2.5 Ohms.

Quantity	Groups	Practical Exam.		2 Cells			3 Cells			4 Cells		
				2.85 - 2.94	**2.95 - 3.04**	**3.05 - 3.14**	**4.35 - 4.44**	**4.45 - 4.54**	**4.55 - 4.64**	**5.85 - 5.94**	**5.95 - 6.04**	**6.05 - 6.14**
Potential Difference, V (mV)	**Experimental**	**PPAE 1**	N	77	112	22	75	109	27	63	114	33
			%	36.5	53.1	10.4	35.5	51.7	12.8	29.9	54	15.6
		PPAE 2	N	6	201	4	10	187	15	14	186	10
			%	2.8	95.3	1.9	4.7	88.6	7.1	6.6	88.2	4.7
	Control	**PPAE 1**	N	69	122	51	75	127	39	83	123	35
			%	28.6	50.6	21.2	31.1	52.7	16.2	34.4	51	14.5

		PPAE 2	N	71	124	45	79	128	34	90	122	29
			%	29.5	51.5	18.7	32.8	53.1	14.1	37.3	50.6	12
Electromotive Force, (E – V) in mV	**Experimental**	**PPAE 1**	N	64	117	30	75	99	37	56	121	34
			%	30.3	55.5	14.2	35.5	46.9	17.5	26.5	57.3	16.1
		PPAE 2	N	11	193	7	12	188	11	17	183	11
			%	5.2	91.5	3.3	5.7	89.1	5.2	8.1	86.7	5.2
	Control	**PPAE 1**	N	66	126	49	87	110	44	81	113	47
			%	27.4	52.3	20.3	36.1	45.6	18.3	33.6	46.9	19.5
		PPAE 2	N	70	130	42	91	115	35	85	121	35
			%	29	53.9	17.4	37.8	47.7	14.5	35.3	50.2	14.5
				0.6-1.14	**1.15-1.25**	**1.26-1.34**	**1.65-1.74**	**1.75-1.84**	**1.85-1.94**	**2.26-2.34**	**2.35-2.45**	**2.46-2.54**
Current, I (A)	**Experimental**	**PPAE 1**	N	67	109	35	73	113	25	66	90	55
			%	31.8	51.7	16.6	34.6	53.6	11.8	31.3	42.7	26.1
		PPAE 2	N	9	198	4	12	186	13	17	178	16
			%	4.3	93.8	1.9	5.7	88.2	6.2	8.1	84.4	7.6
	Control	**PPAE 1**	N	71	120	50	73	131	37	79	129	33
			%	29.5	49.8	20.7	30.3	54.4	15.4	32.8	53.5	13.7
		PPAE 2	N	67	132	42	80	127	34	86	120	35
			%	27.8	54.8	17.0	33.2	52.7	14.1	35.7	49.8	14.5

Students conducted measurements of potential difference (p.d). The actual values of p.d. for 2, 3, and 4 dry cells set up in series fell within the reading ranges of 2.95-3.04V, 4.45-4.54V, and 5.95-6.04V. A rise in the number of students was noted in the experimental group between PPAE 1 and PPAE 2. The rise was 42.2%, 36.9%, and 34.2%, resulting in the p.d. reading values falling within the ranges of 2.95-3.04V, 4.45-4.54V and 5.95-6.04V respectively. Regardless of the amount of dry cells utilized in the circuit, the student count decreased by no less than 8.6% from PPAE 1 to PPAE 2 across the remaining reading ranges. In the control group, the research observed a rise in the number of students obtaining the p.d. reading values in the ranges of 2.85-2.94V, 2.95-3.04V, 4.20-4.39V, 4.40-4.54V and 5.85-5.94V. The noted rises were 0.9%, 0.9%, 1.7%, 0.4% and 2.9% respectively. Conversely, the student count fell from PPAE 1 to PPAE 2 by 2.5%, 2.1% and 2.5% for individuals who obtained the p.d. reading values within the ranges of 3.05-3.14V for 2 dry cells, 4.55-4.64V for 3 dry cells and 6.05-6.14V for 4 dry cells.

As the actual p.d. values were contained within the ranges of 2.95-3.04V, 4.45-4.54V and 5.95-6.04V, where the deviations were greater, the article observed that utilizing an electronics practical workbench impacted the accuracy of measurements. This is due to the potential decrease in students obtaining readings that deviate significantly from the true value, while simultaneously increasing the number of students receiving readings nearer to the true value. The treatment allowed a greater number of students in the experimental group to achieve readings nearer to the true value than those in the control group. The research highlighted that the electronics practical workbench affects measurement precision in physics experiments.

Students subsequently measured the electromotive force (emf) for the 2, 3 and 4 dry cells connected in series in a circuit; the actual emf values for the 2, 3 and 4 dry cells in series fell within ranges of 2.95-3.04V, 4.45-4.54V and 5.95-6.04V, respectively. The research observed an increase in the number of students in the experimental group obtaining emf reading values in the ranges of 2.95-3.04V, 4.45-4.54V and 5.95-6.04V by 36.0%, 42.2% and 29.4%, respectively. The difference was calculated and analyzed between the practical reports of PPAE 1 and PPAE 2. The count of students capable of reading emf values decreased by at least 10.9% across the other reading ranges.

In the control group, the research observed an increase in student numbers from PPAE 1 to PPAE 2 by 1.6%, 1.6%, 1.7%, 2.1%, 1.7% and 3.3% for students who achieved readings within the ranges of 2.85-2.94V, 2.95-3.04V, 4.20-4.39V, 5.85-5.94V and 5.95-6.04V. On the other hand, the student count decreased by 2.9%, 3.8%, and 5.0% in the reading ranges of 3.05-3.14V, 4.55-4.64V and 6.05-6.14V respectively. In this instance, the research demonstrated that EPW affects the precision of reading voltage values from the voltmeter. This was validated as additional students obtained measurements with slight variations from actual values for various dry cells connected in series during the practical tasks performed in this research.

The students also conducted ammeter readings while performing the physics practical activities. The actual currents for 2, 3 and 4 dry cells connected in series fell within the ammeter reading ranges of 1.15 - 1.25A, 1.75 - 1.85A and 2.35 - 2.45A respectively. As shown in table 4.3.2, the experimental group saw an increase of 42.1%, 34.6% and 37% in the number of students able to read ammeter values for 2, 3 and 4 dry cells arranged in series within the ranges of 1.15-1.25A, 1.75-1.85A and 2.35-2.45A respectively. These represented the percentage change comparison from PPAE 1 to PPAE 2. The count of students in the experimental group receiving the readings in various ranges for any number of dry cells arranged in series decreased by at least 5.6%. In the control group, the count of students able to obtain ammeter readings within the ranges of 1.15 - 1.25A, 1.75 - 1.85A and 2.35 - 2.45A also rose by 5.0%, 3.1% and 1.2% respectively. The quantity decreased by not less than 1.3% across other present reading intervals.

Given that positive changes were noted in the experimental group during students post-treatment, the electronics practical workbench appeared to impact measurement accuracy, as more students in the groups registered readings with minor deviations from the true values. A linear regression analysis was subsequently performed to assess the relationship between the accuracy in reading current values, potential difference values and practical report scores. Additional factors assessed in the practical report included mean scores prior to and following treatment, standard deviations from actual values or mean scores and the extent to which accuracy influenced the learners' practical report scores. Results were documented as shown in tables 2.

Table 2: Descriptive statistics on practical report mean score and average pd readings for 2 and 3 cells arranged in series.

	Group	N	Practical Report Mean Score				Std. Deviation			
			PPAE 1		PPAE 2		PPAE 1		PPAE 2	
Practical Report Scores	Experimental	211	15.37		27.99		8.44		6.38	
	Control	241	15.33		15.49		3.59		3.32	
			1 Cell	2 Cells	1 Cell	2 Cells	1 Cell	2 Cells	1 Cell	2 Cells
Potential Difference (p.d.)	Experimental	211	1.438	2.94	1.49	3.005	0.085	0.071	0.054	0.041
	Control	241	1.43	2.97	1.45	2.98	0.09	0.072	0.78	0.076

According to table 3, the mean scores for practical reports among students in both the experimental and control groups prior to the treatment were fairly similar; specifically, 15.37 for the experimental group and 15.33 for the control group. A variation was noted among the students in the experimental group post-treatment. The students achieved a mean score of 27.99 on their practical report, while their peers in the control group obtained a mean score of 15.49. This suggests that the use of the workbench influenced the accuracy of reading values, resulting in the higher scores seen in the experimental group post-treatment. Simultaneously, the standard deviation from the true value decreased by a greater margin (2.06 units) for students in the experimental group compared to the control group, which saw a reduction of 0.27 units. This showed that the treatment enhanced accuracy by helping students achieve scores nearer to the average value.

A comparable pattern was noted when the pd mean value was calculated. Prior to treatment, the mean pd values for students in the experimental and control groups were roughly comparable at 1.44 and 1.43V, respectively. Nonetheless, following treatment, the mean pd value was greater for the students in the experimental group compared to those in the control group, with a difference of 0.05V. The research found that the pd mean value from the experimental group (1.49V) was more precise than that of the control group students (1.45V), since the actual value is 1.48V. The research also highlighted a significant decrease in standard deviation within the students in the experimental group, leading to more precise readings at PPAE 2. This was opposed to the increase in standard deviation among students in the control group at PPAE 2.

A similar trend was noted for the pd readings when two cells were employed in the practical work. Students in both the experimental and control groups achieved roughly the same average pd readings for two cells connected in series, as noted prior to treatment, with a pd reading difference of 0.03V between the groups. This contradicted the results following treatment, where the experimental group exhibited a mean pd reading of 2.96V, while the control group showed a mean pd reading of 2.93V. This showed a greater level of accuracy in the students of the experimental group compared to those in the control group. This was validated with the deviation units from the actual value in both groups. The research noted enhanced accuracy in obtaining readings for both groups, particularly among students in the experimental group, who achieved a mean pd reading of 2.96V, differing from the true value by 0.01 units. The research evaluated the relationship between precision in measuring potential difference and the average scores of practical reports. The discovery was documented as shown in table 4.

Table 4: Correlation between accuracy of pd readings and practical report mean scores.

			PPAE 1 Practical Report Scores		PPAE 2 Practical Report Scores	
		Group	1 Cell	2 Cells	1 Cell	2 Cells
Pearson Correlation	Potential Difference (pd) reading	Experimental	0.049	0.028	0.63	0.56
		Control	-0.011	0.012	0.047	0.018
Sig. (1-tailed)	Potential Difference (pd) reading	Experimental	0.247	0.341	0.0001	0.001
		Control	0.214	0.426	0.232	0.393

According to the results presented in table 4, the correlation between the accuracy of pd readings for one cell and practical report scores among students in the experimental group prior to treatment was .049, whereas for students in the control group, it was negatively at -.011. By the end of treatment, this showed a positive improvement, with correlations of .63 and .047 for students in the experimental and control groups, respectively, indicating a greater increase in the experimental group. Following treatment, the statistical analysis revealed a statistical significant finding concerning the accuracy of pd readings compared to practical report scores [P-value = .0001] within the experimental group of students. This is due to the P-value (.0001) being lower than the significance level (.05). Consequently, the intervention affected practical report scores by the precision of reading p.d. values. These results were opposite to those observed in the control group of students. A comparison of the results before and after the study indicated that there was no statistical significance at either the beginning or the conclusion of the research study.

A comparable pattern was noted with values for two cells set up in series, where the Pearson correlation between reading accuracy and practical report scores was .028 and .012 for the experimental and control group students, respectively, prior to treatment. At this stage, the correlation between pd readings and practical report scores showed no statistically significant outcomes among students in both groups, as the p-values exceeded .05 for students in both groups. The outcomes varied in the post-treatment, particularly in the experimental group; the research noted positive correlations in both groups, but the experimental group exhibited a higher correlation value of .56. There were also notable results regarding the accuracy of reading pd values for two cells and practical report scores among students in the experimental group. No such notable result was seen among students in the control group. This indicated that the use of EPW for reading values in practical tasks affects the accuracy of the readings, leading to improved mean scores in practical reports.

Discussion

The noted rise in the number of students achieving potential difference (p.d.) readings within the defined ranges for 2, 3 and 4 dry cells in the experimental group emphasizes the success of the intervention between PPAE 1 and PPAE 2. The increases of 42.2%, 36.9% and 34.2% respectively indicate a better comprehension or advanced measurement abilities, possibly due to greater exposure to circuit concepts or practical experience (Brown & Tsai, 2017). This enhancement is consistent with discoveries by Chen et al. (2019), who observed that active participation in lab experiments greatly enhances students' understanding and precision in electrical measurements. Moreover, the steady decline of at least 8.6% in student numbers beyond the target reading ranges further reinforces the idea that focused instruction or repeated practice can enhance students’ accuracy and consistency in performing voltage measurements (Feyzioglu, Akpinar & Tatar, 2018). The capability to obtain measurements within narrower intervals indicates a positive trend towards mastering experimental skills, highlighting the significance of iterative, scaffolded learning in scientific education (Zhang, Guan & Hu, 2024).).

In contrast, the control group exhibited only marginal increases in student counts within certain lower p.d. ranges and slight decreases in higher ranges from PPAE 1 to PPAE 2, with rises ranging from 0.4% to 2.9% and declines of approximately 2-2.5%. This pattern may indicate a plateau effect where students, without additional intervention or enhanced instructional methods, show limited improvement in measurement accuracy over time. Such findings are consistent with prior studies by Brosnan, Moeyaert, Brooks Newsome, Healy, Heyvaert, Onghena and Van den Noortgate, (2018) who emphasized that passive learning environments often lead to stagnation in skill development. Moreover, the subtle changes suggest that standard classroom procedures might be insufficient to significantly impact students’ experimental competencies, especially in precise measurement tasks like voltage determination (Rivers, 2021). Together, these results highlight the crucial role of active, targeted pedagogical strategies in elevating student performance in physics laboratories, underscoring a need for curricula that incorporate frequent, guided practice and immediate feedback to foster deeper understanding and skill acquisition.

The findings showing a notable enhancement in practical report scores for the experimental group correspond with previous research highlighting the effect of experiential teaching methods on student achievement. The average score rose from 15.37 to 27.99 for the experimental group, unlike the control group’s slight variation, indicating that utilizing a workbench improves students’ involvement and comprehension of practical measurements. This aligns with discoveries by Ali, Ullah and Khan, (2022) who showed that interactive lab instruments promote enhanced conceptual understanding and increase precision in experimental activities. In a similar vein, Donkin, Askew and Stevenson, (2019) emphasized that hands-on interventions with immediate feedback greatly enhance student confidence and precision in scientific measurements. The significant decrease in standard deviation within the experimental group strengthens the idea that organized practical experiences yield more reliable and accurate results, aligning with the findings of Mazzone, et. al., (2020) who noted diminished variability in student performance following the implementation of simulation-based training. Moreover, the improved precision corresponds with Canhoto and Murphy, (2016) who discovered that experiential learning tools diminish measurement errors by encouraging active learning and enhanced cognitive integration.

The enhanced accuracy in potential difference (pd) measurements after treatment in the experimental group provides strong proof of the workbench’s effectiveness in enhancing technical skills essential for physics education. The closeness of the average pd value to the true voltage of 1.48V post-treatment (1.49V for the experimental group compared to 1.45V for the control group) signifies a significant enhancement in measurement precision. These outcomes align with the research of Hussain, Wahsh and Wahish, (2024), who reported notable enhancements in students’ accuracy of electrical measurements after the implementation of interactive tools. Additionally, the decrease in standard deviation for the experimental group highlights a rise in the control group, emphasizing how guided practical interventions help reduce experimental error (Pogrow, 2019). This phenomenon aligns with findings by May et. al., (2019), who associated organized hands-on experiences with improved accuracy and dependability in laboratory tasks. The results indicate that hands-on involvement enhances students’ grasp of measurement concepts, reinforcing Hussain et. al., (2024) conclusions about the beneficial impacts of experiential learning on accuracy in scientific data gathering.

The findings related to the implementation of two cells in series during practical work further support the advantages of the experimental treatment in improving measurement precision. Before treatment, the similarity in average pd readings among the groups indicates similar baseline abilities; however, the post-treatment difference, with the experimental group reading nearer to the true value (2.96V vs. 2.93V), illustrates the effectiveness of the workbench in enhancing practical skills.

This result aligns with the study by Steger, (2020), which indicated that hands-on handling of electrical components enhances students' conceptual comprehension and measurement precision. Moreover, the noted reduction in deviation units for the experimental group supports the findings of Routray, (2025), who indicated that interactive lab environments enhance precision in electrical experiments. The link between elevated practical report scores and enhanced accuracy backs theoretical models that highlight the combination of cognitive and procedural understanding in science education (Rivers, 2021). These results collectively emphasize the educational importance of using experiential learning tools to improve both theoretical comprehension and practical skill effectiveness.

Conclusion

This research article focused on assessing the accuracy of student measurements with an Electronics Practical Workbench compared to conventional laboratory configurations, offering perspectives on enhancing resistance measurement techniques in physics teaching. Accuracy and precision are closely related to how close the practical measurement values are to the actual values, which EPW has shown to guarantee in real-world applications. It minimizes the bias faced by secondary schools without physical physics labs, those with labs but inadequate practical resources and those that have both but struggle with problems such as broken, malfunctioning or completely non-operational equipment, resulting in increased expenses for ongoing repairs and maintenance. EPW thereby promotes students' academic achievement by minimizing these hurdles, allowing them to be more accurate in measurements during hands-on tasks.

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Ethical pledge: The researchers confirm that the all data collected was responsibly handled and accurately documented without manipulation of any kind or bias

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