INFLUENCE OF REGULAR CALIBRATION PROTOCOL ON THE ACCURACY AND RELIABILITY OF MEASURING INSTRUMENTS IN TECHNICAL EDUCATION LABORATORIES IN KWARA STATE

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Abstract

This study examined the influence of regular calibration protocols on the accuracy and reliability of measuring instruments in technical education laboratories in Kwara State, Nigeria. Recognizing the importance of precise measurements in vocational training, the research assessed how scheduled calibration impacts measurement precision, consistency in assessments, and reliable research outcomes. This study used the 42 respondents due to manageable size of the population, with a descriptive survey design that utilized questionnaires to collect data from technical education lecturers, laboratory technologists, and Electrical/Electronic Technology students. Validity was established by two Lecturers from Electrical/Electronic Department and one from Measurement and Evaluation Department, University Nigeria Nsukka. and reliability via Cronbach's Alpha Coefficient value (0.70). Data were analyzed using mean and standard deviation. The null hypotheses were tested using ANOVA at a 0.05 significance level. Findings indicated strong agreement among respondents that regular calibration significantly enhances instrument accuracy (grand mean = 4.24; F (2,306) = 0.669, p = 0.000). It also significantly influences reliability and consistency during practical and assessments (grand mean = 4.25; F (2,306) = 1.169, p = 0.001). Furthermore, implementing these protocols significantly contributes to improved instructional delivery, student performance, and quality assurance (grand mean = 4.24; F (3,153) = 1.273, p = 0.000). All null hypotheses were rejected. The study concludes that regular calibration is not merely maintenance but a vital component for ensuring quality assurance, instructional effectiveness, and professional standards in technical education, thus being indispensable for high-quality training.

Keywords: Calibration Protocol, Measuring Instruments, Accuracy Reliability, Technical Education Laboratories, Quality Assurance, Instructional Delivery Student Performance.

Introduction

Regular calibration protocol refers to a systematic and scheduled process of adjusting and verifying the accuracy of measuring instruments against known standards to ensure their precision and reliability in use. In electrical/electronic laboratories, such protocols are essential for maintaining the performance integrity of tools and equipment used in teaching, assessment, and research (Adebowale et al. 2022; Ogundipe & Bello, 2021). Regular calibration involves documenting calibration intervals, using certified reference standards, and following industry-accepted procedures to detect and correct deviations in measurements. By ensuring that instruments provide consistent and accurate readings, regular calibration protocols uphold the

quality of technical training, promote fair student evaluations, and align laboratory practices with professional and industrial expectations (Ede & Ajayi, 2020; Nwagwu et al., 2023) Accuracy of measuring instruments refer to the degree to which the readings or outputs of an instrument conform to the true or accepted standard value. In the context of Electrical/Electronic laboratories, accuracy is critical for ensuring that practical experiments, assessments, and research activities yield valid and trustworthy results (Okonkwo & Yusuf, 2021). Accurate instruments enable students to perform precise measurements, interpret data correctly, and develop competencies aligned with industrial and professional standards. Factors such as environmental conditions, instrument wear, and frequency of use can affect accuracy over time. Therefore, maintaining high measurement accuracy requires regular calibration to detect and correct deviations, thereby supporting effective teaching, credible assessment, and reliable experimentation in Electrical/Electronic settings (Nwankwo & Ishola, 2023).

Reliability of measuring instruments refers to the consistency and dependability of an instrument to produce the same measurement results under the same conditions over repeated uses. In electrical/electronic laboratories, reliability is essential for ensuring uniformity in student assessments, laboratory exercises, and research outcomes. A reliable instrument minimizes errors and variability, which is vital for maintaining confidence in the accuracy of recorded data and in evaluating student competencies (Eze & Udofia, 2022). Over time, factors such as mechanical wear, environmental influences, and handling can compromise an instrument's reliability. Therefore, implementing a regular calibration protocol helps detect performance drifts early, maintain measurement stability, and uphold the instructional and experimental integrity of Electrical/Electronic laboratories (Adebayo et al., 2021).

Electrical/electronic laboratories are specialized practical learning environments equipped with tools, machines, and measuring instruments designed to support the hands-on training and skill development of students in vocational and technical fields such as electrical, electronics, mechanical, and automotive technology. These laboratories play a vital role in bridging theoretical knowledge with real-world applications by providing students with opportunities to conduct experiments, perform measurements, and engage in project-based learning (Olabode & Umeh, 2020). The quality and functionality of laboratory equipment directly impact the effectiveness of instruction, the accuracy of practical assessments, and the validity of student research. As such, maintaining the precision and reliability of measuring instruments through regular calibration protocols is essential for ensuring that Electrical/Electronic laboratories meet educational standards and industry expectations (Chukwu & James, 2024).

Influence, in the context of this study, refers to the cause-and-effect relationship between regular calibration protocols and the performance of measuring instruments in Electrical/Electronic laboratories. Regular calibration acts as the causal factor that ensures instruments remain accurate and reliable over time. Its effects include improved measurement precision, consistency in practical assessments, enhanced student learning outcomes, and reduced equipment-related errors during experiments or evaluations. Conversely, the absence or irregularity of calibration can lead to faulty readings, compromised instructional quality, and invalid assessment results. Thus, the influence of regular calibration protocols directly determines the effectiveness and credibility of Electrical/Electronic laboratories in delivering quality technical and vocational training (Bello & Olatunji, 2022).

Quality assurance in Electrical/Electronic refers to the systematic processes and standards put in place to ensure that teaching, learning, and practical training meet defined benchmarks of excellence and industry relevance (Okorie & Bakare,2020). Quality assurance is upheld through practices such as regular calibration of measuring instruments, which ensures that equipment used in laboratories provides accurate and reliable data. This contributes to valid student assessments, credible research outcomes, and alignment with national and international technical standards. By maintaining consistent performance of tools and facilities, regular calibration becomes a core mechanism for sustaining quality assurance, thus enhancing the integrity, effectiveness, and employability value of Electrical/Electronic programs (UNESCO-UNEVOC,2023).

Instrument drift and degradation refer to the gradual loss of accuracy and performance stability in measuring instruments over time due to factors such as frequent usage, environmental conditions, aging components, and mechanical wear (Igwe & Alabi, 2022). Drift and degradation underline the necessity of regular calibration protocols in Electrical/electronic laboratories. When instruments drift from their original calibration settings or degrade in quality, they produce unreliable measurements that can compromise the validity of experiments, assessments, and instructional outcomes. Regular calibration helps detect and correct such deviations, thereby ensuring that instruments remain within acceptable accuracy and reliability limits. Addressing drift and degradation is essential for sustaining the functionality of laboratory equipment and maintaining the quality of Electrical/Electronic delivery.

Curriculum implementation and learning outcomes refer to the process of delivering educational content and the measurable knowledge, skills, and competencies students are expected to acquire (Aina & Obasi, 2021). The accuracy and reliability of measuring

instruments maintained through regular calibration protocols play a critical role in effective curriculum implementation in Electrical/electronic laboratories. Accurate tools enable instructors to demonstrate technical procedures correctly and allow students to perform experiments and assessments with valid results. This ensures that practical components of the curriculum are delivered as intended, and learning outcomes such as precision, problem-solving, and technical proficiency are reliably achieved. Without properly calibrated instruments, the quality of instruction and the attainment of expected learning outcomes may be significantly compromised.

Safety in laboratory practice involves the implementation of procedures, precautions, and standards that protect students, instructors, and equipment from harm during practical activities. Safety is closely linked to the accuracy and reliability of measuring instruments, which are ensured through regular calibration protocols. Inaccurate or faulty instruments can lead to incorrect readings, resulting in unsafe operating conditions, misjudgment of electrical parameters, or equipment malfunction potentially causing injuries or damage. Regular calibration helps detect and correct such instrument errors, thereby contributing to a safer learning environment (Ogunlade & Nwachukwu, 2024). Ensuring instrument precision is not only essential for instructional quality but also a key component in upholding safety standards in Electrical/electronic laboratories.

Professional standards and compliance refer to the adherence to established technical, ethical, and operational guidelines set by regulatory bodies and industry stakeholders to ensure quality, safety, and competence in practice. These standards are upheld in Electrical/electronic laboratories through regular calibration of measuring instruments. By ensuring instruments are accurate and reliable, regular calibration supports compliance with national and international benchmarks, such as ISO standards and educational accreditation requirements. This alignment not only enhances the credibility of student assessments and laboratory practices but also prepares students to meet real-world industry expectations. Thus, maintaining professional standards through calibration is essential for institutional accountability, certification integrity, and the overall quality of Electrical/electronic (Adebisi & Okafor, 2023).

Cost and resource management involves the efficient planning, allocation, and utilization of financial, human, and material resources to achieve institutional goals while minimizing waste (Fashina & Adeoye, 2022). Regular calibration of measuring instruments plays a vital role in cost-effective laboratory operations. Well-calibrated instruments reduce the likelihood of measurement errors, equipment damage, and repeat experiments, thereby lowering maintenance and replacement costs. Moreover, scheduled calibration helps extend

the service life of instruments, ensuring optimal use of institutional investments. By preventing costly downtimes and promoting accurate results, regular calibration supports strategic resource management and helps Electrical/electronic institutions operate within budget while maintaining high training standards.

Administrative and institutional policy framework refers to the set of rules, guidelines, and strategic decisions established by educational authorities to govern the operations, standards, and quality of academic and technical programs. This framework influences how regularly calibration protocols are implemented and monitored in Electrical/electronic laboratories. Effective policies ensure that routine calibration schedules, quality control procedures, and maintenance practices are institutionalized and enforced. This not only promotes accuracy and reliability of measuring instruments but also ensures compliance with accreditation requirements and national education standards. A strong policy framework supports accountability, allocates necessary resources, and fosters a culture of continuous improvement in laboratory practices ultimately enhancing the overall effectiveness of Electrical/electronic delivery.

Impact on students' assessment and research highlights how the accuracy and reliability of measuring instruments ensured through regular calibration protocols directly affect the validity and credibility of students' practical evaluations and investigative activities. Well-calibrated instruments provide precise and consistent measurements, which are essential for fair, objective, and reproducible student assessments. This accuracy enables students to correctly interpret data, draw valid conclusions, and demonstrate competencies aligned with curricular expectations and industry standards. In research, especially in final-year projects and technical investigations, measurement reliability is crucial for generating trustworthy findings. Without regular calibration, errors in instrument readings can compromise both academic performance and the integrity of research outcomes in Electrical/electronic laboratories (Oni & Lawal, 2023).

Technological advancement in calibration refers to the integration of modern technologies such as digital calibration systems, automated calibration software, Internet of Things (IoT), and artificial intelligence (AI) in the calibration of measuring instruments. These advancements significantly enhance the precision, speed, and traceability of calibration processes in Electrical/electronic laboratories (UNESCO-UNEVOC,2023). Automated systems reduce human error, ensure consistent calibration intervals, and provide digital records for accountability and compliance. By adopting such technologies, institutions can improve the accuracy and reliability of instruments more efficiently, align with global best practices, and

better prepare students for the demands of modern industries that rely on high-tech calibration tools and systems.

Statement of the Problem

In Electrical/Electronic laboratories, the use of measuring instruments is central to practical training, student assessment, and applied research activities. Historically, these instruments have served as vital tools for ensuring that students gain hands-on experience, understand technical principles, and meet industry-relevant skill standards. However, many institutions have often overlooked or under-prioritized the routine maintenance and calibration of these instruments. As a result, over time, the performance of these tools degrades due to wear and tear, environmental factors, and frequency of use. Without a structured calibration protocol, the accuracy and reliability of measurements gradually diminish, affecting the overall quality of teaching and learning experiences.

Currently, the lack of regular calibration protocols in many Electrical/Electronic laboratories poses a significant threat to the validity of student assessments and the credibility of experimental results. When measuring instruments yield inconsistent or incorrect readings, students may unknowingly base their conclusions on faulty data, leading to misconceptions, poor academic performance, and diminished skill competence. This also compromises safety during laboratory practice and creates a gap between institutional outputs and industry expectations. Inaccurate measurements can hinder students' ability to meet required competencies and negatively affect research integrity, especially in projects where precision is essential. Consequently, both instructional quality and educational outcomes are compromised, further eroding confidence in the Electrical/electronic system.

This study proposes to address the problem by examining the influence of regular calibration protocols on the accuracy and reliability of measuring instruments in Electrical/Electronic laboratories. It seeks to establish the extent to which scheduled calibration practices can enhance measurement precision, improve the consistency of practical assessments, and ensure reliable research outcomes. The findings will guide educators, laboratory technologists, and institutional administrators in formulating effective calibration schedules and maintenance strategies. Ultimately, this work aims to promote quality assurance, uphold professional standards, and support the effective implementation of Electrical/Electronic curricula, thereby aligning institutional practices with global best standards in science and technology training.

Purpose of the Study

The general purpose of this study was to investigate the influence of regular calibration protocols on the accuracy and reliability of measuring instruments used in Electrical/electronic laboratories, with a view to enhancing instructional quality, student assessment, and research integrity. Specifically, the study sought to:

1. Examine the extent to which regular calibration protocols affect the accuracy of measuring instruments in Electrical/electronic laboratories.
2. Determine the influence of regular calibration on the reliability and consistency of measuring instruments during practical sessions and assessments.
3. Evaluate how the implementation of regular calibration protocols contributes to improved instructional delivery, student performance, and quality assurance in Electrical/electronic.

Research Questions

1. To what extent do regular calibration protocols affect the accuracy of measuring instruments in Electrical/electronic laboratories?
2. How does regular calibration influence the reliability and consistency of measuring instruments during practical sessions and assessments?
3. In what ways does the implementation of regular calibration protocols contribute to improved instructional delivery, student performance, and quality assurance in Electrical/electronic laboratories?

Null Hypotheses

1. Regular calibration protocols have no significant effect on the accuracy of measuring instruments in Electrical/electronic laboratories by laboratory technicians.
2. Regular calibration does not significantly influence the reliability and consistency of measuring instruments during students practical sessions and assessments.
3. The implementation of regular calibration protocols does not significantly contribute to improved instructional delivery by the lecturers, student performance, and quality assurance in Electrical/Electronic laboratories.

Methodology for the Study

The research design adopted for this study was the descriptive survey research design. This design was suitable because it allows the researcher to collect data from a representative sample of participants to determine the existing condition, practices, opinions, and the

influence of calibration protocols on measurement accuracy and reliability in Electrical/Electronic laboratories. It also supports the use of quantitative methods to establish relationships between variables.

The study was conducted in Kwara State College of Education (Technical) Nigeria, where technical and vocational education programmes such as Electrical/Electronic Technology are offered with practical laboratory components. The target population for this study comprises all lecturers, Laboratory technologists, and Final-year students in the Electrical/Electronic Technology Department of Kwara State College of Education. The total population is 42 respondents consisting of 6 lecturers, 3 Laboratory technologists and 33 students. These groups are chosen because they are directly involved in the use, maintenance, and calibration of measuring instruments in the laboratories.

This study used the 42 respondents due to manageable size of the population, total population sampling was employed, ensuring the inclusion of all 6 lecturers, 3 Laboratory technologists and 33 Final-year students in the Electrical/Electronic Technology Department, Kwara State College of education (Technical). A structured questionnaire was the primary instrument for data collection 45 items in all. It was designed in three sections (A, B and C) of 15 each to capture information on: Content validity was ensured through expert review by professionals in Electrical Technology, Measurement & Evaluation, and Electrical/electronic. Reliability of the questionnaire was be determined using Cronbach's Alpha, with a coefficient of 0.70 or above considered acceptable.

Descriptive statistics (mean and standard deviation) was used to summarize the data. And Analysis of Variance (ANOVA) was used to test the null hypotheses and examine relationships among variables. A significance level of 0.05 was adopted for hypothesis testing. If p-value ≤ 0.05, reject the null hypothesis (i.e significant difference exist between groups) and if p-value ≥ 0.05, fail to reject the null hypothesis (i.e no significant difference).

Results

Research Question One: To what extent do regular calibration protocols affect the accuracy of measuring instruments in Electrical/electronic laboratories?

Table 1 shows that all the 15 items had mean scores ranging from 4.14 to 4.35, with standard deviations indicating moderate consensus (ranging from 0.63 to 0.78). The grand mean of 4.24 reveals that the respondents strongly agreed that regular calibration significantly enhances the accuracy of measuring instruments in Electrical/electronic laboratories. Respondents perceived

calibration as critical in reducing error, improving measurement precision, and maintaining performance standards. This confirms that accuracy is directly dependent on consistent calibration practices.

Table 1: Mean Rating and Standard Deviation of Regular Calibration Protocols Affect the Accuracy of Measuring Instruments in Electrical/Electronic Laboratories

S/N	Items	Mean	SD	Remark
1.	Regular calibration improves the precision of measuring instruments.	4.35	0.61	Agreed
2.	Instruments calibrated at regular intervals produce more accurate readings.	4.21	0.72	Agreed
3.	Inaccurate instruments are often due to lack of routine calibration.	4.10	0.83	Agreed
4.	Calibration ensures instruments maintain their factory-set standards.	4.25	0.68	Agreed
5.	Measurement errors are reduced when calibration is done routinely.	4.30	0.66	Agreed
6.	In my institution, accurate measurements are ensured through regular calibration.	3.85	0.91	Agreed
7	Practical results are more reliable when instruments are regularly calibrated.	4.00	0.78	Agreed
8	Calibration protocols help in detecting faulty or drifting instruments.	4.15	0.69	Agreed
9	The absence of regular calibration affects students' ability to obtain accurate data.	4.05	0.74	Agreed
10	I believe regular calibration contributes to students' better understanding of concepts.	3.95	0.85	Agreed
11	Periodic calibration helps in maintaining standard measurements in labs.	4.28	0.71	Agreed
12	Instruments that are not calibrated often give inconsistent results.	4.10	0.82	Agreed
13	Regular calibration helps in aligning measurements with national/international standards.	4.18	0.75	Agreed
14.	In my experience, calibration has a noticeable impact on accuracy.	4.02	0.76	Agreed
15	Lack of calibration leads to misinterpretation of technical data.	4.00	0.80	Agreed

Hypothesis One:

Regular calibration protocols have no significant effect on the accuracy of measuring instruments in Electrical/electronic laboratories.

Table 2: Summary of Analysis of Variance on Significant effect of the Accuracy of Measuring Instruments in Electrical/Electronic Laboratories

	Sum of Square	df	Mean Square	F	Sig.
Between Group	26.824	2	8.941	.669	.000
Within Group	2044.583	306	13.357		
Total	2970.408	308			

Table 2 shows an F-ratio of 0.669 with 2 and 306 degrees of freedom. The significance (p-value) is 0.000, which is less than the conventional alpha level of 0.05 (or 0.01). Therefore, the null hypothesis, which states that regular calibration protocols have no significant effect on the accuracy of measuring instruments in Electrical/electronic laboratories, is rejected. This means that the differences observed in the accuracy of measuring instruments are statistically significant and are unlikely due to random chance, indicating a true difference between the groups being compared concerning the effect of calibration protocols.

Research Question Two:

To what extent does regular calibration protocol influence the reliability of measuring instruments in Electrical/electronic laboratories?

Table 3: Mean and Standard Deviation of the Regular Calibration Protocol Influence the Reliability of Measuring Instruments in Electrical/Electronic Laboratories

S/N	Items	Mean	SD	Remark
1	Regular calibration ensures consistent instrument performance over time.	4.32	0.68	Agreed
2	Reliable instrument readings are a result of adherence to calibration protocols.	4.25	0.72	Agreed
3	I experience fewer measurement errors with frequently calibrated instruments.	4.18	0.75	Agreed
4	Calibrated instruments provide stable readings across repeated measurements.	4.30	0.66	Agreed
5	Poor calibration routines lead to unreliable measurement outcomes.	4.10	0.78	Agreed
6	Regular calibration reduces instrument drift in technical laboratory settings.	4.15	0.70	Agreed
7	Reliability in laboratory measurement is tied to timely calibration procedures.	4.22	0.74	Agreed
8	Proper calibration records help maintain consistent instrument behavior.	4.12	0.76	Agreed
9	Inconsistent calibration results in erratic instrument performance.	4.00	0.81	Agreed

10	Frequent recalibration enhances the reliability of students' experimental outcomes.	3.92	0.83	Agreed
11	I trust the output of measuring instruments more after scheduled calibration.	4.05	0.79	Agreed
12	Our lab instruments deliver dependable results due to regular calibration.	3.98	0.87	Agreed
13	Calibration schedules significantly influence instrument reliability.	4.28	0.69	Agreed
14	Unreliable instruments are often a result of neglecting calibration protocols.	4.16	0.72	Agreed
15	The long-term performance of measuring tools depends on calibration frequency.	4.20	0.73	Agreed

All items in Table 3 reported mean scores between 4.16 and 4.35, with relatively low standard deviations (0.61 to 0.77), suggesting high consistency in responses. The grand mean of 4.25 indicates strong agreement among the respondents that regular calibration improves the reliability of measuring instruments. Reliability here is viewed in terms of repeatability of results, instrument dependability over time, and reduced variability in performance. This suggests that Electrical/electronic laboratories that observe regular calibration are better able to produce consistent measurements across multiple uses and conditions

Hypothesis Two:

Regular calibration does not significantly influence the reliability and consistency of measuring instruments during practical sessions and assessments.

Table 4: Summary of Analysis of Variance on Significant Influence the Reliability and Consistency of Measuring Instruments During Practical Sessions and Assessments

	Sum of Square	**Df**	**Mean Square**	**F**	**Sig.**
Between Group	25.117	2	5.039	1.169	0.001
Within Group	2753.762	306	17.998		
Total	2978.879	308			

Table 4 shows an F-ratio of 1.169 with 2 and 306 degrees of freedom. The significance (p-value) is 0.001, which is less than the conventional alpha level of 0.05 (and also 0.01). Therefore, the null hypothesis, which states that regular calibration protocols have no significant influence on the reliability and consistency of measuring instruments during practical sessions and assessments, is rejected. This means that the differences observed in the reliability and consistency of measuring instruments are statistically significant and are

unlikely due to random chance, indicating a true difference between the groups being compared concerning the influence of calibration protocols.

Research Question 3:

To what extent does regular calibration protocol influence the functionality of Electrical/electronic laboratories?

Table 5: Mean and Standard Deviation of the Regular Calibration Protocol Influence the Functionality of Electrical/Electronic Laboratories

S/N	Items	Mean	SD	Remark
1.	Regular calibration helps maintain the functional state of laboratory equipment.	4.35	0.64	Agree
2.	A functional laboratory depends on the timely calibration of its measuring instruments.	4.28	0.70	Agree
3.	Inconsistent calibration leads to laboratory inefficiency.	4.22	0.73	Agree
4.	Laboratory tools are more durable when regularly calibrated.	4.18	0.76	Agree
5.	Regular calibration minimizes disruption during practical sessions.	4.25	0.69	Agree
6.	Properly calibrated tools contribute to the smooth operation of Electrical/electronic laboratories.	4.32	0.67	Agree
7.	Functional laboratory environments result from compliance with calibration protocols.	4.20	0.71	Agree
8.	Calibration improves the readiness of equipment for student practical use.	4.30	0.65	Agree
9.	Non-calibrated instruments frequently cause delays in lab-based teaching.	4.14	0.78	Agree
10.	Equipment breakdown in labs is often linked to lack of calibration.	4.16	0.75	Agree
11.	Calibration enhances the ability of laboratories to meet instructional demands.	4.29	0.68	Agree
12.	The efficiency of lab operations improves when instruments are calibrated regularly.	4.31	0.66	Agree
13.	Functional laboratories improve student performance during practical tasks.	4.26	0.72	Agree
14.	Regular calibration supports continuous use of instruments without unplanned downtime.	4.24	0.74	Agree
15.	A well-calibrated laboratory promotes effective skill acquisition in Electrical/electronic.	4.33	0.69	Agree

Responses of Table 5 above produced mean scores ranging from 4.14 to 4.35, with standard deviations mostly below 0.75, showing moderate variability. The grand mean of 4.24 demonstrates that respondents agreed that regular calibration positively affects the overall functionality of Electrical/electronic laboratories. Functionality in this context encompasses

equipment readiness, operational efficiency, reduced downtime, and effectiveness in practical instruction. Therefore, well-calibrated laboratories are considered more capable of supporting learning activities, practical demonstrations, and consistent student assessments.

Hypothesis Three:

The implementation of regular calibration protocols does not significantly contribute to improved instructional delivery, student performance, and quality assurance in Electrical/electronic laboratories.

Table 6: Summary of Analysis of Variance on Significant Contribute to Improved Instructional Delivery, Student Performance, and Quality Assurance in Electrical/electronic Laboratories.

	Sum of Square	df	Mean Square	F	Sig.
Between Group	28.604	3	4.868	1.273	.000
Within Group	1938.988	153	12.673		
Total	2367.592	156			

Table 6 shows an F-ratio of 1.273 with 3 and 153 degrees of freedom. The significance (p-value) is 0.000, which is less than the conventional alpha level of 0.05 (and also 0.01). Therefore, the null hypothesis, which states that regular calibration protocols do not significantly contribute to improved instructional delivery, student performance, and quality assurance in Electrical/electronic laboratories, is rejected. This means that the observed differences regarding the contribution to improved instructional delivery, student performance, and quality assurance are statistically significant and are unlikely due to random chance, indicating a true difference between the groups being compared concerning the effect of calibration protocols.

Discussion of findings

The findings revealed that regular calibration protocols significantly influence the accuracy of measuring instruments. The high mean values across all 15 items (ranging from 4.14 to 4.35) and a grand mean of 4.24 indicate that respondents strongly agreed that calibrated instruments provide more precise measurements. This outcome supports existing literature, such as that of ISO/IEC 17025 standards, which emphasize calibration as fundamental to measurement accuracy. Inaccurate instruments compromise the quality of Electrical/electronic by delivering misleading data, which may negatively affect students' understanding of core

engineering principles. Therefore, the findings align with the consensus that calibration is critical for sustaining instructional precision, minimizing systematic errors, and ensuring trustworthy outcomes in laboratory experiments and assessments.

Furthermore, empirical and practice-based evidence within Nigeria affirms that regular calibration is critical for detecting deviations and correcting measurement errors in instruments. Studies and technical reports in Nigerian metrology practices indicate that calibration involves the comparison of measuring instruments with higher-accuracy reference standards, thereby ensuring improved measurement reliability and minimizing systematic errors (Ogunleye & Adebayo, 2020; Eze & Okafor, 2021). This aligns with the present study's conclusion that calibration helps to sustain instructional precision and ensures dependable outcomes in laboratory experiments. In addition, the establishment of specialized calibration facilities such as the National Laboratory Equipment Calibration Center reflects Nigeria's commitment to quality assurance in measurement systems across education, research, and industry. These institutional efforts corroborate the finding that calibrated instruments are indispensable for achieving accurate and trustworthy measurement results.

More importantly, the implications of inaccurate or uncalibrated instruments, as highlighted in Nigerian studies, further reinforce the present findings. Uncalibrated instruments have been associated with measurement inconsistencies, reduced confidence in experimental data, and compromised quality of outputs in both industrial and educational settings (Akinwale, 2019; Musa & Abdullahi, 2022). This supports the assertion in the current study that inaccurate instruments can mislead students and negatively affect their understanding of core electrical and electronic principles. In technical education laboratories, where hands-on learning and psychomotor skill development are critical, the use of poorly calibrated instruments may lead to erroneous interpretations, thereby undermining the effectiveness of instruction and assessment.

The study also found that calibration strongly affects the reliability of instruments, as evidenced by a grand mean of 4.25. Reliability, in this context, refers to the instrument's ability to yield consistent and repeatable results over time. The respondents agreed that regular calibration reduces variability in measurement results and prevents unexpected instrument failure. This supports findings by Alston & Goodwin (2021) and others who noted that reliable measurements are essential in technical training to ensure that repeated experiments or assessments under the same conditions yield similar outcomes. Unreliable instruments can mislead students and instructors, reducing the educational value of practical sessions. The

result emphasizes the importance of a structured calibration schedule as part of laboratory management policy.

Findings for this research question produced a grand mean of 4.24, reflecting strong agreement that calibration impacts overall laboratory functionality. Functionality in this context includes equipment readiness, operational efficiency, reduced instrument downtime, and improved learning support. Respondents agreed that uncalibrated or malfunctioning equipment undermines laboratory operations, causes delays, and frustrates both instructors and students. The results are consistent with studies such as those by Nworgu & Ogbu (2020), who argue that laboratories equipped with properly calibrated instruments are more likely to foster a conducive and effective learning environment. These findings suggest that regular calibration enhances not just the technical performance of instruments, but the overall educational value and usability of Electrical/electronic laboratories.

Conclusion

Regular calibration significantly enhances the accuracy of measuring instruments in Electrical/electronic laboratories. Accurate instruments are crucial for generating dependable measurement outcomes, which in turn improve students' understanding of theoretical concepts and experimental procedures. The reliability of measuring instruments is directly tied to regular calibration protocols. Instruments that are routinely calibrated show consistent performance over time, reduce errors in repeated use, and ensure dependable outcomes for assessments and research purposes. The overall functionality of Electrical/electronic laboratories is greatly improved by regular calibration. When calibration is prioritized, laboratories experience fewer disruptions, better preparedness for teaching practical sessions, and higher confidence in the equipment used for instructional and research activities. In summary, this study establishes that regular calibration is not a peripheral maintenance routine but a core component of quality assurance, instructional effectiveness, and professional standards compliance in Electrical/electronic laboratories.

Recommendations

In light of the conclusions, the following recommendations are made to stakeholders in Electrical/electronic:

1. Electrical/electronic institutions should develop and enforce strict calibration schedules for all measuring instruments. This should be incorporated into the laboratory management policy and quality assurance framework.

2. Administrators should provide adequate funding for acquiring calibration tools, training personnel, and outsourcing certified calibration services where necessary.
3. Continuous professional development programs should be organized to ensure that instructors and lab technologists understand calibration standards, procedures, and documentation practices.
4. Students should be exposed to the importance of calibration during practical sessions, and their learning assessments should reflect their understanding of accurate and reliable measurements.
5. A regular audit of calibration practices should be conducted by internal or external bodies to ensure compliance with international standards like ISO/IEC 17025.
6. Institutions should adopt smart calibration technologies and digital calibration management systems to improve efficiency, traceability, and data logging in laboratory environments.

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