

**ELECTRONICS PRACTICAL WORKBENCH TECHNOLOGY AND ITS INFLUENCE
ON FORM THREE PHYSICS STUDENTS' ACADEMIC ACHIEVEMENT IN NAIROBI
COUNTY-KENYA**

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A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment for the Requirement
for the award of degree of Doctorate of Philosophy in Science Education-Physics Option of
Masinde Muliro University of Science and Technology

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PLAGIARISM STATEMENT

I affirm that this thesis is my own creation and has not been submitted for a degree at any other university. Every source of information and quotations utilized has been recognized and cited appropriately.

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I dedicate this PhD thesis to God, the wellspring of all wisdom, strength and purpose. In every challenge, uncertainty and victorious moment, His grace has upheld me, directing my steps and illuminating the way ahead. During uncertain times, His presence provided calmness; in times of success, His blessing was my happiness. This endeavor is a modest tribute and I attribute all glory and honor to Him, who enables everything.

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ABSTRACT

Physics is taught both theoretically and practically, with practicals accounting for 40% of the total marks in the Kenya Certificate of Secondary Education. High accuracy and precision are essential for success in these practical assessments. This study explored the effectiveness of the Electronics Practical Workbench (EPW), a software that simulates analog and digital circuits in enhancing learning outcomes compared to traditional methods. Using a quasi-experimental research design with both experimental and control groups, involving pre-test and post-test with non-equivalent groups, the study examined four objectives. The study was guided by Multimedia Learning Theory (MMLT) established by Richard Mayer in 1997 posits that multimedia learning theory comprises three components that enhance students' learning effectiveness. The first objective was to determine the difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method. The second objective was to examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills such as observation, measurement and communication among students taught using workbench and those taught conventionally. The third objective was to examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally. The fourth objective was to determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods. Each objective was comparatively dealt with between EPW and conventional methods of teaching practical work. Out of a population of 67 public secondary schools and 1,639 form three physics students, 21 schools were sampled by stratified simple random sampling while 452 form three physics students were sampled purposively. Some of the conventional practical teaching methods in physics include lecture, demonstration, collaborative learning, guided inquiry and case study. The experimental group used EPW, while the control group followed conventional methods during practical session. Instruments used to collect data included achievement tests, observation checklists, attitude questionnaires, focus group discussions and interviews, all validated by experts and tested for reliability. Quantitative data was analyzed using the Mann-Whitney U Test and Ordinal Logistic Regression, while qualitative data were subjected to thematic analysis. Findings revealed that EPW significantly improved students' accuracy in measurement, enhanced their science process skills and practical skills with each the p-value below significant level of .05, this led to better practical scores. Students also developed more positive attitudes toward physics practicals when taught using EPW. The study concludes that EPW can be an effective tool in secondary school physics education, supporting both skill development and academic performance. It recommends that Educational policymakers, through the MoE and KICD, should develop a national strategy to integrate EPW into secondary school physics by providing software, infrastructure and Continuous Professional Development CPD training for teachers, ensuring equitable access to quality practical experiences and standardized physics skill development nationwide.

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ACRONYMS

ADPQ:	Attitude Developed towards Physics Questionnaire
BSPS:	Basic Science Process Skills
CBC:	Competency Based Curriculum
CBE:	Competency Based Education
CDF:	Constituency Development Funds
CPW:	Computer Practical Workbench
EMF	Electromotive Force
FDSE:	Free Day Secondary Education
FGD:	Focus Group Discussions
IBL:	Inquiry-Based Learning
KCSE:	Kenya Certificate of Secondary Education.
KNEC:	Kenya National Examination Council.
LATF:	Local Transfer Authority Funds
LED:	Light-Emitting Diodes
MMLT:	Multimedia Learning Theory
NACOSTI:	National Commission for Science, Technology and Innovation
NGO:	Non-Governmental Organizations
PAT:	Physics Achievement Test
Pd:	Potential difference
PPAE:	Physics Practical Achievement Examinations
PPP:	Public Private Partnerships
PPPA:	Physical Physics Practical Apparatuses
PTCT:	Performance Test on Chosen Topics.
SEPU:	Science Equipment Production Unit
SMASE:	Strengthening of Science and Mathematics Education
SMASSE:	Strengthening of Mathematics and Science in Secondary Education.
SSL:	Science Skills Learnt
SSLC:	Science Skills Learnt Checklist
STEM:	Science, Technology, Engineering and Mathematics
TEL:	Technology-Enhanced Learning
TSC:	Teachers Service Commission
UNESCO:	United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

INTRODUCTION

1.1. Chapter Overview

This chapter provides the background to the study, statement of the problem, purpose of the study, research objectives, research hypothesis and significance of the study, scope and limitations of the study. This chapter also provides the conceptual framework, theoretical framework and an operational definition of terms as used in the study.

1.2. Background to the Study

Science involves seeking and applying knowledge to understand the natural and social environment through systematic, evidence-based inquiry. It plays a vital role in human life by equipping individuals with the skills and reasoning needed to make informed and meaningful life decisions (Mrisho et. al., 2023). In school settings, active learner-centered laboratory approaches are essential for nurturing scientifically competent students who can think critically and apply their knowledge beyond the classroom. The hands-on nature of laboratory activities enhances students' mastery of scientific concepts and promotes the development of key skills such as scientific reasoning, observation and problem-solving. Through active participation in experiments and investigations, learners engage at higher cognitive levels, strengthening their ability to connect theory with practice and cultivate a deeper understanding of science.

Physics is a fundamental subject in secondary education, essential for enhancing students' comprehension of the natural environment, scientific thinking and problem-solving skills. It lays the groundwork for higher education in science, technology, engineering and mathematics (STEM) disciplines, while preparing students with analytical and critical thinking abilities useful

in daily life and future professions (Qotrunnada, 2022). Teaching physics successfully nurtures curiosity, hands-on abilities and an understanding of scientific concepts, all of which are vital for informed choices and creativity. In Kenya, teaching physics holds significant value as it corresponds with national objectives of enhancing scientific understanding, technological skills and sustainable progress. Through the combination of theoretical understanding and hands-on skills, high school physics develops students' capacity to implement concepts in real-life scenarios, improving academic achievement and equipping them to face the demands of a swiftly changing technological world (Muge & Waiganjo, 2025).

The Electronics Practical Workbench (EPW) represents an innovative and practical teaching strategy in physics by providing a virtual, interactive, and heuristic learning environment that closely mimics real laboratory experiences. As highlighted by Alessandrini (2023), EPW allows students to create, manipulate and analyze electronic circuits without the need for physical components, breadboards, or instruments, using intuitive click-and-drag functions. The platform automatically performs calculations, generates graphs and provides instant feedback on changes to circuit parameters, enabling students to focus on understanding underlying physics concepts rather than being constrained by manual computation or limited laboratory resources. This integration of visualization, simulation, and immediate analysis aligns with modern pedagogical approaches that emphasize active, student-centered learning, offering a level of precision, accuracy, and engagement that is often difficult to achieve in conventional physics labs. Furthermore, EPW enhances practical and conceptual understanding by enabling students to perform experiments digitally while simultaneously observing the relationships between experimental setups and theoretical principles (Lucas & Vicente, 2023).

In Japanese high schools, physics practical work is an integral part of science education and is often characterized by a balance between traditional hands-on experiments and modern technological integration. Teachers frequently use electronics-based laboratory equipment and simulation tools to help students visualize and test complex physical phenomena, allowing them to move beyond rote learning toward experiential understanding. However, many schools still rely on conventional methods such as manual circuit assembly and basic measurement tools, which can limit precision and engagement (Tassilova et. al., 2025). The introduction of an electronics practical workbench (EPW), similar to those used in advanced laboratories, offers a modernized approach that enhances the traditional method by providing real-time data analysis, interactive components, safer and more efficient experimentation. By integrating such technology, as seen in progressive Japanese classrooms, students can better connect theoretical concepts to real-world applications, leading to improved motivation, deeper conceptual understanding and more positive attitudes toward physics.

Physics hands-on activities play a crucial role in advancing technology, enhancing cultural development and improving financial understanding (Majid et. al., 2025). In addition to fostering innovation, these activities also nurture vital values such as love, responsibility and unity among students (Prayogi & Verawati, 2024). To achieve quality results in science education, students need to have robust technological skills, hands-on abilities and a positive attitude toward learning. Nonetheless, as highlighted by Habibulloh et. al., (2024), numerous educational systems continue to depend predominantly on traditional laboratory methods that may not keep pace with the swift evolution of science and technology. Hands-on physics activities incorporating contemporary tools and digital technologies can better prepare learners to utilize

their knowledge and abilities in novel and unfamiliar situations, promoting flexibility and creativity in a rapidly changing scientific environment.

In Sweden, high school physics instruction showcases a harmonious blend of conventional experimental techniques and contemporary, technology-based learning. Swedish schools frequently prioritize inquiry-driven laboratory activities in which students create and execute experiments to investigate real-world uses of physics principles (Kotsis, 2024). Utilizing sophisticated laboratory interfaces, sensors, and data loggers enables students to capture and evaluate results with greater precision, enhancing their conceptual comprehension and analytical reasoning. Certain schools still rely on traditional equipment for fundamental circuit experiments and mechanical demonstrations, which, although useful, might restrict involvement and accuracy. The EPW's combination of electronic components, sensors and simulation capabilities reflects Sweden's focus on technological knowledge and sustainable education. This combination of conventional and digital hands-on approaches enhances creativity, build confidence and promote more favorable attitudes toward physics, in line with Sweden's educational emphasis on inquiry, innovation and lifelong learning.

In Tunisia, physics education in high schools stresses theoretical knowledge and hands-on learning; however, numerous schools struggle with inadequate lab resources and obsolete equipment. Like other contexts, practical physics sessions in Tunisia frequently depend on conventional demonstrations and hands-on experiments (Ndiokubwayo, 2024). This is essential for basic understanding but may limit students' involvement and accuracy in measurements. Numerous laboratories face challenges with aging or inadequate equipment, resulting in errors and diminished enthusiasm among students. Incorporating technologies into Tunisian physics

classrooms begun many years ago and has assisted much in addressing these limitations by offering contemporary, digital solutions that improve experimental precision and data collection (Marcel et. al., 2024). The technology allows students to visualize and modify electronic circuits, accurately measure physical quantities and efficiently analyze results, reflecting Tunisia's recent educational reforms that focus on integrating technology in STEM education. Through the integration of traditional hands-on techniques with technology, Tunisian students can foster enhanced conceptual comprehension, better practical skills and a more favorable outlook on physics as an engaging, technology-oriented field.

In Rwanda, the focus of high school physics education is increasingly on enhancing students' practical and problem-solving abilities; however, numerous schools still encounter difficulties due to insufficient or outdated laboratory apparatus. Conventional practical techniques, although beneficial for establishing basic comprehension, frequently subject students to measurement mistakes and inaccuracies arising from mechanical flaws and deterioration in standard equipment, problems akin to those noted by Twahirwa and Twizeyimana, (2020). To tackle these challenges, Rwanda's competency-based curriculum promotes the use of digital technologies and contemporary laboratory systems to enhance accuracy and involvement in science education. Integrating technology into Rwandan physics labs complements this educational transition by facilitating precise, real-time data collection and analysis, thereby diminishing systematic and human errors. This digital advancement aids teachers in overseeing student performance, as noted by Reyes et al. (2024), while also fostering greater conceptual comprehension, enhanced report writing, and increased student motivation. Integrating technology with traditional experimental methods, Rwandan schools can connect conventional practices with contemporary innovation, enhancing both technical skills and favorable attitudes towards physics.

In Uganda, practical physics work in high schools is still a key part of science education, yet numerous schools still depend largely on traditional methods using manual measurements and sequential procedures. Although these conventional methods assist students in grasping fundamental experimental arrangements, they frequently restrict creativity and conceptual investigation because of obsolete or inadequate lab equipment. Incorporating technology into physics laboratories in Uganda presents a novel approach to these issues by minimizing rote memorization and enabling students to concentrate more on grasping the fundamental physics concepts. This corresponds with Gumisirizah et. al., (2023) finding that digital physics labs allow students to predict, experiment and confirm results instantly. Equipped with capabilities like digital data gathering, automatic graph creation and experiment visualization, the technology can improve the precision and effectiveness of hands-on tasks.

In Kenya, high school physics practical activities are a vital part of the science curriculum, aimed at fostering students' scientific inquiry, critical thinking and problem-solving abilities. However, many schools continue to face challenges such as inadequate laboratory resources, limited teacher support and reliance on traditional instructional methods, which often restrict students' opportunities for meaningful hands-on experimentation (Musasia et. al., 2012). The integration of an electronics practical workbench (EPW) into physics laboratories offers a practical solution to these challenges by providing an interactive and reliable platform for conducting experiments, troubleshooting equipment and identifying potential sources of error. This aligns with Iyamuremye et al. (2023), who emphasized that practical skills are best developed through active engagement with laboratory tools. Combining conventional approaches EPW enables students to interpret results more accurately and appreciate the dynamic nature of science, as noted by Wang

et al. (2023). Furthermore, collaborative practical tasks using the workbench promote teamwork and communication among Kenyan students, ultimately enhancing their scientific competence and nurturing more positive attitudes toward physics.

In the Kenyan context, where practical work contributes 40% of the national physics examination, the workbench provides an equitable and scalable solution to challenges such as limited laboratory space, outdated equipment, and large class sizes. By supporting experiential and visual learning, EPW ensures that students acquire essential science process and practical skills, while also fostering analytical thinking, problem-solving and deeper comprehension of physics phenomena. Thus, the workbench not only serves as a practical tool but also embodies an innovative teaching strategy that integrates technology with curriculum objectives to improve students' academic achievement and conceptual mastery.

EPW allows students to conduct experiments related to electric circuits. In general, experiments related to electric circuits make up at least 50% of the practical physics in KCSE. The practical work at KCSE includes high school physics concepts like thermal expansion, heat transfer, simple circuits, magnetism, electric current's electromagnetic effect, sound, current electricity, work, energy, power and machines, heating effect of electric current, heat quantity, mains electricity, electromagnetic induction, cathode rays and cathode ray tubes, along with electronics.

Therefore study investigated the differential influence of using an electronics practical workbench (EPW) and conventional methods in physics practical work on students' academic achievement in physics practical work.

In Nairobi, practical work in secondary school physics is essential for enhancing scientific reasoning, enriching students' grasp of the nature of science and encouraging teamwork and proficiency in fundamental scientific concepts. However, numerous schools in the city still face challenges with overcrowded labs, restricted access to contemporary tools and the steep expenses of up keeping traditional equipment. For meaningful learning outcomes, lab activities should be organized effectively, include scientific methods and promote student reflection and dialogue. Muge and Waiganjo, (2025) observed that traditional educational systems alone cannot fully provide all scientific experiences. Incorporating technology into physics classrooms provides an affordable and creative approach by enhancing traditional techniques with digital accuracy and immediate data assessment. This synergy allows students to perform precise experiments, participate in cooperative inquiry and utilize scientific reasoning more effectively, thus changing physics practical activities into a more engaging, efficient and conceptually rewarding experience.

Traditional teaching methods in physics practical work, although essential, possess various limitations that hinder effective learning and the development of skills in students. These conventional methods frequently depend on hands-on experiments, displays and sequential steps that prioritize repetition instead of grasping the concepts. In numerous situations, including Japan, Sweden, Tunisia, Rwanda, Uganda and Kenya, obsolete or insufficient laboratory tools have resulted in consistent measurement inaccuracies, poor precision and a lack of student involvement. Crowded laboratories and lack of teacher assistance further diminish chances for personal experimentation and inquiry-driven learning.

Traditional methods in practical work also find it challenging to keep up with current technological progress, hindering students' ability to connect theoretical concepts to practical applications or to cultivate advanced scientific reasoning and analytical abilities. Consequently, students might turn into passive watchers instead of engaged contributors to the scientific process. These constraints underscore the necessity of supplementing conventional practical approaches with technological tools such as the Electronics Practical Workbench (EPW), which provides digital accuracy, instant data evaluation and interactive simulations to improve involvement, precision, and understanding of concepts in physics education.

The study contributes to achieving the objectives of teaching physics in secondary schools, as well as national and global development goals. By comparing the effectiveness of the electronics practical workbench (EPW) with conventional teaching methods, the study promotes the development of scientific inquiry, accuracy and practical competence which are some of the key aims of physics education. It enhances learners' acquisition of science process and practical skills, fostering innovation, problem-solving and critical thinking; these are some of the essential for technological advancement. By improving students' attitudes toward physics, the study aligns with Kenya's educational and industrialization goals under Vision 2030 and supports global agendas such as the UN Sustainable Development Goals (SDGs) on quality education (SDG 4) and industry, innovation and infrastructure (SDG 9). Ultimately, it provides evidence-based insights for integrating digital technologies in education, bridging skill gaps and preparing learners for participation in a knowledge-driven economy.

In conclusion, fostering scientific reasoning skills, deepening the comprehension of the nature of science, enhancing collaboration and boosting mastery of scientific concepts are among the

functions of science lab experiences. To achieve these, laboratory activities must be structured to yield clear learning results, feature effective sequences, including use of scientific processes and integrate student reflections, discussions and experiences in science. Carli and Pantano, (2023) observed that all experience in science may not be fully attained through schooling systems alone. Therefore, by integrating an electronics practical workbench, science practical learning experiences become more cost-effective.

1.3.Statement of the Problem

Practical activities in physics education are vital as they enable students to interact directly with scientific phenomena, deepening their grasp of theoretical concepts through experiential learning. It cultivates key abilities like observation, measurement, experimentation, data analysis and problem-solving, all of which are important for scientific understanding. Moreover, practical activities encourage curiosity, critical thinking and positive perspectives on learning, equipping students for advanced education and careers in STEM fields.

Physics is a hands-on science subject that is most effectively learned through practical work. In Kenya, physics practical work constitutes approximately 40% of the national secondary school summative assessment, with experiments related to electric circuits making up approximately 50% of this practical component. Effective teaching of practical work is therefore critical for developing students' accuracy, science process skills and practical skills, which are essential for both academic success and future careers in physics. However, despite the recognized importance of practical activities, Kenyan secondary schools face persistent challenges in providing adequate physics laboratory experiences.

These challenges include insufficient laboratory space, limited and outdated apparatus, and rising costs associated with purchasing, maintaining and replacing equipment, particularly for national examinations where circuit-specific tools are required (Chepkirui & Njoroge, 2024; Wekwe et al., 2024). Many laboratories operate with obsolete or poorly functioning instruments, leading to systematic and human errors during experiments. Additionally, increasing student enrollment worsens difficulties in organizing practical sessions, often resulting in rushed or overcrowded laboratory activities. Consequently, students may experience inaccuracies, incorrect interpretations, improper use of SI units and errors in graph plotting, which restrict their understanding of physics concepts and compromise the achievement of hands-on science learning outcomes (Mboya, 2023). These limitations may further influence students' attitudes toward physics, affecting their subject choices in higher grades. This study, therefore, sought to investigate the impact of using an electronics practical workbench (EPW) approach on students' achievement in physics practical work, aiming to address the shortcomings of conventional methods and enhance practical learning outcomes.

1.4. Purpose of the Study

This study aimed to examine the effect of utilizing an electronics practical workbench (EPW) on students' academic achievement in physics practical work in secondary schools in Kenya. The study specifically sought to investigate the impact of the EPW on students' accuracy in measurements, development of basic science process skills and practical skills, as well as their attitudes toward physics, tackling the ongoing issues of inadequate laboratory resources, obsolete equipment and overcrowded labs. There is limited empirical evidence in Kenya on how digital alternatives such as the Electronics Practical Workbench (EPW) can address the challenges of

conventional circuit-based practical work and improve the effectiveness of physics laboratory teaching. A study conducted by Amuh, (2024) on perceptions of junior high school students on integrated science teachers' attitudes and competencies in using laboratory resources revealed that many Kenyan schools lack functional physical labs and up-to-date apparatus, limiting hands-on physics practical work in conventional mode. Although studies like effects of virtual laboratory-based instruction on the frequency of use of experiment as a pedagogical approach in teaching and learning of physics in secondary schools in Kenya (Okono et., 2023) show virtual labs increase experimental teaching approaches in Kenya but they do not deeply explore how well virtual setups replicate the accuracy, apparatus interaction and human-error dynamics of traditional circuit-based physics practicals involving proper SI unit use, instrumentation calibration and wiring errors.

By providing a digital, interactive and reliable platform for conducting experiments, the study sought to determine whether the EPW could reduce systematic and human errors, enhance accuracy in practical tasks and support learners in connecting theoretical concepts to hands-on applications. Furthermore, the study aimed to assess whether the use of EPW ultimately enhances overall performance in both practical and national examinations, thereby offering a viable solution to the limitations of conventional practical teaching methods.

1.5. Rationale of the study

Physics practicals form a critical component of secondary school education in Kenya, accounting for approximately 40% of the Kenya Certificate of Secondary Education (KCSE) practical assessment marks. Despite this, conventional practical teaching methods such as demonstrations and guided inquiry often face challenges in ensuring high accuracy, precision and skill

acquisition among students. This represents a significant gap, as insufficient practical competence can negatively impact students' overall academic performance. The study addresses this gap by examining the effectiveness of the Electronics Practical Workbench (EPW), a software-based simulation tool, in enhancing accuracy in measurements, acquisition of science process skills, practical skills and enhancement of attitudes toward physics. By comparing EPW with conventional methods, the study provides empirical evidence on whether technology-assisted instruction can improve the quality of physics practicals, which has been inadequately explored in the Kenyan context.

The rationale for focusing on Nairobi County and Form Three physics students is due to the large and diverse population of students and schools, making the findings applicable to varied learning environments. This research is important to multiple stakeholders such as teachers who can adopt more effective methods to improve student engagement and outcomes, policymakers through the Ministry of Education (MoE) and the Kenya Institute of Curriculum Development (KICD) can make informed decisions on curriculum enhancement and technology integration, and students benefit directly from improved practical competencies. The study also contributes to knowledge by empirically testing the application of Mayer's Multimedia Learning Theory (MMLT) in physics practical instruction, offering insights into how multimedia tools can enhance skill development and learning outcomes. Furthermore, it has practical relevance by suggesting strategies for equitable access to quality practical experiences, aligning with national curriculum objectives that emphasize competence in both theoretical understanding and practical skills in science education.

1.6. Research Objectives

The study was guided by the following objectives:

- (i) To determine the difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method.
- (ii) To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills among students taught using workbench and those taught conventionally.
- (iii) To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally.
- (iv) To determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods.

1.7. Research Hypotheses

H₀₁: There is no significant difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method.

H₀₂: There is no significant effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills among students taught using workbench and those taught conventionally.

H₀₃: There are no significant effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally.

H₀₄: There is no significant influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods.

1.8. Significance of the Study

This study is important because it demonstrates how integrating the Electronics Practical Workbench (EPW), a digital simulation tool, can significantly improve students' accuracy, science process skills, practical abilities and attitudes toward physics compared to conventional methods. The findings contribute to educational knowledge by providing empirical evidence that technology-enhanced practical learning can effectively complement or even surpass traditional hands-on approaches, especially in resource-limited contexts. For teachers and learners, EPW offers a flexible, safe and engaging platform to conduct experiments, reinforcing conceptual understanding and boosting confidence in practical work. Schools will benefit through improved student performance and reduced costs associated with physical laboratory materials. Curriculum developers can use these insights to embed virtual labs and simulations within the physics curriculum, aligning learning outcomes with 21st-century competencies. Finally, policy makers and the Ministry of Education (MoE) gain evidence to support policies promoting digital learning tools, teacher training and equitable access to technological resources, ultimately enhancing the quality and consistency of science education across Kenya.

The utilization of EPW fosters self-motivation in learners, encourages innovation, transformative teaching, and a technology-based learning method, as it allows students' intelligence and talents to improve when effective teaching and learning strategies are established. Unlike conventional practical work approaches, which often rely on manual measurements, limited apparatus and

step-by-step procedures that may restrict creativity and precision, the EPW enhances students' engagement by providing interactive simulations, real-time feedback, and automated data analysis. Using EPW can significantly improve students' science process skills, demonstrating their acquisition of fundamental scientific knowledge, as physics and natural sciences are fields grounded in credible experimental evidence, critique and logical decision-making (Prayogi et al., 2024). In their future fields of specialization, students can apply the knowledge and skills gained from physics practical work using the electronics workbench to address scientific challenges in real-life situations, bridging the gap between theory and practical application more effectively than traditional methods.

1.9.Scope of the Study

The study took place in the sub-counties of Dagoretti North, Embakasi Central, Embakasi South, Kibra, Mathare and Westlands within Nairobi County. It involved specific secondary schools in the County. The schools must have had a computer lab by then, that is properly equipped with operational computers and essential physics experimental equipment and tools. The schools must have had electricity or backup generators to supply power during outages. The students carried out practical work involving electric circuits related to three chosen physics topics or strands including cells and simple circuits, current electricity and electronics. The set of physics topics was derived from KNEC's examination analysis reports for 2018, 2019, 2020 and 2021, which pinpointed the three topics that had low scores over the four successive academic years particularly in practical section. The study was done in term 2 of the year 2022.

The practicals conducted involved Ohm's Law verification, series versus parallel circuits for cells and bulbs, electromotive force (EMF) and terminal voltage. The research evaluated basic

science process skills including observation, measurement and communication taking into account levels of accuracy among physics students. It also included practical skills like setting up experiment, manipulation and writing laboratory reports. The independent variables were practical teaching methods involving use of EPW and conventional methods, while the dependent variables included the accuracy level in measurement, acquisition of basic science process skills, enhancement of practical skills and the students' attitudinal change towards physics due to the teaching method used during specific practical work. The study administered a physics practical achievement exam, conducted both at the start and the term. It also included a science process and practical skills observation checklist, questionnaire for students and a focus group discussion for students. Quantitative data was analysed both descriptively and inferentially, whereas qualitative data was analyzed using thematic methods.

1.10. Limitations of the Study

Quasi-experimental research designs may have not permitted random assigning of participants to experimental or control groups, specifically students, which could introduce specific risks to internal validity. This was minimized by increasing the random selection of schools to take part. The researcher adhered closely to the data collection protocols while providing treatment to the experimental group.

Some school principals showed limited cooperation by not permitting their seasoned teachers of physics to serve as research assistants or to conduct lessons outside the planned physics classes. In these situations, the researcher prearranged and ensured that lessons occur as planned in the usual teaching sessions' time and by experienced physics teachers of the sampled schools. Some participants disliked the elements of utilizing computers for practical tasks, the use of content document analysis for references and the use of observation checklist or the existing laboratory

equipment and its condition. This could be because of lack of trust in researchers' intentions and suspicions of concealed motives which could occur in certain schools. Consequently, this could have led to reluctance of respondents to disclose sensitive information or to present situations in an exaggeratedly positive light. This could have become a limiting factor, as the respondents might have cultivated a habit of inflating or deflating their answers to the questions in a manner, they consider favorable. To reduce this, data was gathered and verified using various research tools, including content document analysis and observation checklists among others.

1.11. Assumption of the Study

The researcher believed that the sample size was a good representation of the target population, the students had not interacted with the specific practical work within the selected topics. The researcher presumed that the research assistants had received training in computer proficiency, allowing them to effectively manage teaching and learning via an electronic practical workbench which is a computer-based software.

1.12. Theoretical Framework

This study was guided by four interconnected theories: Multimedia Learning Theory (MMLT) introduced by Mayer (1997), Constructivist Learning Theory by Piaget (1988), Experiential Learning Theory by Kolb (1989) and the Technological Pedagogical Content Knowledge (TPACK) model developed by Mishra and Koehler (2006). These theories together illustrate how utilizing the Electronics Practical Workbench (EPW) improves students' learning, abilities and perspectives in physics practical work over traditional methods. The framework suggests that EPW combines cognitive, experiential and technological aspects of learning, enabling learners to actively build knowledge through various modes of engagement, interaction and reflection (Singh & Agarwal, 2023). Conversely, traditional practical methods that depend

heavily on instructor demonstrations and tactile engagement with equipment offer beneficial yet restricted chances for cognitive adaptability practice and prompt feedback because of material and situational limitations.

Mayer's Multimedia Learning Theory (MMLT) states that learning becomes more efficient when learners acquire information via various modalities, visual, auditory and kinesthetic, rather than relying solely on verbal communication (Gilakjani, 2012). The experimental group utilizing EPW gains from this dual-channel processing by interacting with visual simulations, hearing verbal instructions or audio feedback and handling digital components. This integration enhances comprehension of abstract physics concepts by minimizing cognitive overload and encouraging active mental structuring of information. On the other hand, the control group using traditional practical methods mainly handles information via single channels, typically verbal or visual, which may impede understanding of abstract concepts like electronic circuit behavior. Consequently, MMLT supports the argument that EPW enhances learners' understanding, memory and involvement through the cognitive synergy fostered by multimedia learning settings.

The Constructivist Learning Theory, Experiential Learning Theory and TPACK framework enhance this theoretical basis by detailing how teachers and learners engage in these settings. Constructivism highlights that students actively create their own knowledge by engaging in exploration, reflection and teamwork (Rob & Rob, 2018). In the EPW, students engage in free experimentation, evaluate results, and link new concepts to prior knowledge, aligning with the principles of discovery and social learning proposed by Piaget and Vygotsky. Kolb's Experiential Learning Theory enhances this by illustrating how EPW facilitates the four learning stages: concrete experience, reflective observation, abstract conceptualization and active

experimentation, via ongoing virtual experimentation and immediate feedback. Ultimately, TPACK emphasizes the teacher's responsibility in combining technology with pedagogical practices and subject matter expertise to ensure that EPW usage is meaningful and educationally effective. The control group gains from traditional practical practical teaching methods focused on practical skill development, whereas the experimental group underwent a more enriched, technology-augmented learning experience that promotes critical thinking, creativity and scientific reasoning, results that correspond with 21st-century educational objectives.

1.13. Conceptual Framework

This is a framework that illustrates how dependent variables were adjusted to achieve the dependent variable and research aim by associating them with the research goals.

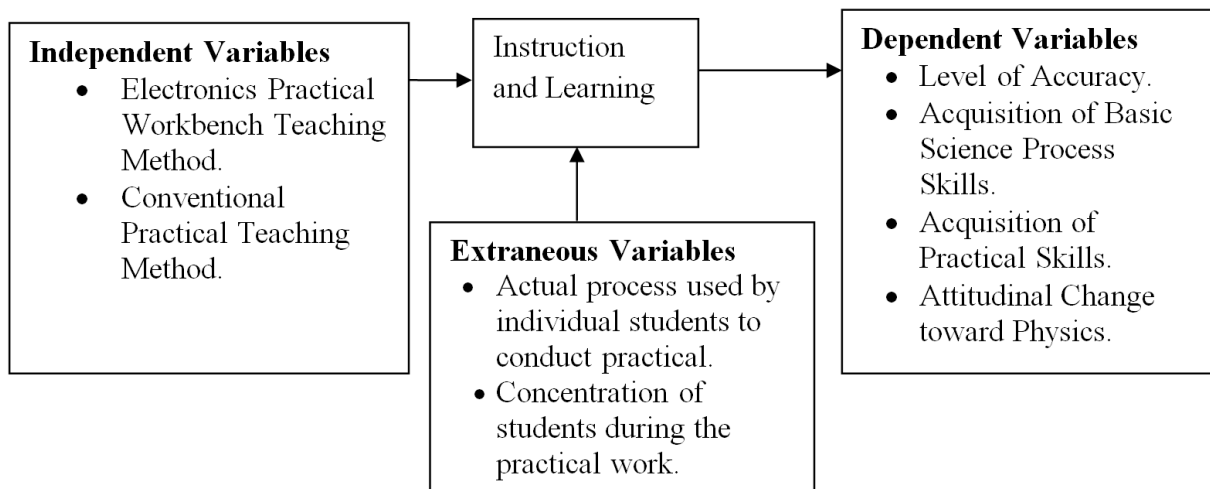


Figure 1.1. Conceptual framework of the study; (Source: Self, 2020).

Figure 1.1 shows a framework which demonstrates that the independent variables, that is, use of electronics practical workbench and traditional practical teaching method in teaching and learning physics practical work. The study focused on changes in dependent variables, including

the accuracy levels in measurement, reading and recording data, acquired science process skills and practical skills, students' attitudinal change and the comparative academic performance. These were observed when the independent variables were manipulated by adopting the teaching methods to different groups of students. The actual process in practical work and focus differs among students. These variables were regulated by establishing standardized procedures, guidelines and instructions to guarantee that the use of diverse processes is limited. Adopting random assignment of group of students to the varying conditions of the independent variable assisted in managing students' focus during the practical work.

1.14. Operational Definition of Terms

Academic Achievement: This refers to the results of physics practical work regarding the accuracy of writing practical reports and the degree to which the student has met other practical objectives.

Accuracy in measurement: This refers to how close a measured value is to the true or accepted value of the quantity being measured.

Attitude Change: This refers to the modification of a learner's perceptions regarding physics through practical work.

Conventional Practical Teaching Method: This refers to a physics practical teaching method passed down through generations, thought to be the most effective approach in physics practical activities. In the context of this study, it involves the application of usual physical experimental equipment.

Differential Effect: It refers to the difference in academic achievement or learning outcomes that arises when comparing students who perform physics practicals using the Electronics Practical Workbench with those who use the conventional practical method.

Experimental Skills: These are practical abilities required to design, conduct, analyze and interpret scientific experiments effectively and accurately.

Gain: The difference between the mean score of the post-test and the mean score of the pre-test.

Electronics Practical Workstation: This is a software designed for computers which is used to carry out physics electronics practical experiments.

Electronics Practical Workstation Method: This is a computer-based approach to performing physics electronics experiments using specialized simulation software.

Performance: This refers to students' success regarding academic achievement, skill development and positive attitudinal change towards physics.

Practical Skills: It refer to the abilities and competencies that enable a learner to effectively perform experimental activities, including the correct setting up of apparatus, manipulating and handling instruments safely and recording, analyzing, and reporting experimental results in a clear and logical manner.

Practical Work: This is a hands-on learning through experiments or activities that relates theoretical knowledge to real-world situations through practical work.

Science Process Skills: These are a collection of transferable abilities, including the capacity to observe effectively, measure and communicate information using appropriate scientific language.

CHAPTER TWO

LITERATURE REVIEW

2.1.Introduction

Physics practicals are traditionally conducted through interactive laboratory sessions where students carry out experiments using actual equipment and materials with the teacher's assistance. This method corresponds with the aims of physics education specified in the national curricula, which encompass enhancing students' comprehension of scientific ideas and principles, encouraging problem-solving and analytical thinking skills and promoting hands-on abilities essential for scientific investigation and technological use. In traditional practical lessons, teachers usually showcase experimental techniques, then students either work alone or in small teams to assemble equipment, collect data, document findings and evaluate outcomes. This approach seeks to assist students in linking theoretical concepts to real-world events, enhance the accuracy in measurements, foster curiosity, creativity and collaboration.

The teaching and learning of physics in secondary schools encounter various obstacles that impede students' comprehension and performance. Many schools face insufficient laboratory facilities and equipment, restricting chances for hands-on experiments crucial for acquiring practical skills. Crowded classrooms hinder personalized attention and a lack of qualified physics educators results in excessive workloads and dependence on theoretical teaching instead of engaging or hands-on approaches. Intricate abstract ideas in physics frequently dishearten students, particularly when they aren't connected to practical applications (Okono et. al., 2023). Restricted availability of digital educational tools and resources, especially in rural regions,

additionally enlarges the learning divide. The medium of instruction, English, may pose a challenge for certain students, hindering their understanding of specialized terminology. Additionally, unfavorable perceptions of physics, commonly seen as challenging or suitable only for gifted students, diminish motivation and involvement. Ultimately, excessive curriculum demands and a focus on test preparation limit teachers' creativity and opportunities for hands-on involvement, hindering the development of profound conceptual comprehension and passion for the subject (Qotrunnada, 2022).

There is an increasing demand for effective and creative teaching techniques in physics practical sessions to connect theoretical concepts with real-life applications, thus improving students' comprehension, involvement and ability to solve problems (Prayogi & Verawati, 2024). Conventional methods that depend largely on teacher demonstrations and restricted lab resources frequently do not offer learners adequate hands-on experiences and chances for inquiry-based education. Creative approaches, like the use of digital simulations, virtual labs and interactive resources, allow students to see abstract ideas, test hypotheses in a safe environment and obtain instant feedback, enhancing their grasp of concept (Mashami et. al., 2023). These methods also address various learning preferences, visual, auditory and kinesthetic, making physics easier to understand and more fun. In addition, integrating contemporary technology into hands-on teaching fosters creativity, critical thinking, and teamwork, which are vital skills for students in the 21st century. In the end, embracing practical and creative approaches guarantees that physics education stays pertinent, interesting, and successful in cultivating scientifically literate and technologically skilled individuals

Electronics Practical Workbench (EPW) is an interactive software tool designed to simulate analog and digital electronic circuits, providing a virtual environment for conducting physics practical work (Twahirwa et. al., 2020). In the context of physics education, EPW enables students to design, test and analyze electrical and electronic experiments without the limitations of physical laboratory resources. It allows learners to connect virtual components such as resistors, capacitors and transistors, measure voltage and current using simulated instruments and observe circuit behavior in real time. By integrating visual, auditory and kinesthetic learning experiences, EPW supports deeper conceptual understanding of abstract physics concepts like current flow, resistance and circuit laws (Kotsis, 2024). Its use promotes accuracy, safety and flexibility, allowing students to repeat experiments multiple times, explore ‘what-if’ scenarios and receive immediate feedback. Consequently, EPW serves as an innovative and cost-effective complement to traditional laboratory work, enhancing students’ practical skills, confidence, and interest in physics while fostering active, technology-enhanced learning.

This chapter focuses on the relevant literature where electronics practical workbench, physics academic achievement, methodologies for physics practical instruction and practical activities used in teaching physics are addressed. Others are science process skills, practical skills, attitude change in physics and summary of the chapter.

2.2. Electronics Practical Workbench and Academic Achievement

Electronics Practical Workbench (EPW) is a software tool designed for teaching and learning practical tasks that engages students in observing or handling experimental objects and materials through a computer. It plays a crucial role in the science learning process, resulting in enhanced academic performance, better concept comprehension and a favorable shift in attitude towards

science. Instructions for practical work contain extensive information requiring learners to split their focus between written content and tools, potentially leading to cognitive overload (Margolis, 2023). Cognitive overload refers to the impact on the cognitive processing system that arises when carrying out a specific task, particularly when the volume and complexity of information surpass the limits of working ability (Moko et. al., 2023).

Traditional practical teaching approaches in physics are vital for fostering creativity, innovation and critical thinking, as they provide authentic, hands-on experiences that bridge theoretical knowledge with real-life applications. According to Kumari et. al., (2024), students' scientific creativity and innovation depend on their critical thinking, communication, and collaboration skills, competencies that are effectively developed through laboratory-based activities. In conventional physics practicals, learners actively engage with tools, instruments, and materials, promoting observation, experimentation, and inquiry. Kotsis (2024) emphasizes that such engagement is crucial for linking observable phenomena to scientific concepts. Through this process, students are encouraged to evaluate hypotheses, refine ideas, and construct new understandings based on evidence and reasoning.

Stavrou and Piki (2024) highlight that traditional practical experiences extend beyond academic benefits, offering broader economic and social advantages by fostering self-efficacy and preparing students for technology-oriented careers. Similarly, Kotsis (2024) asserts that hands-on physics education enhances conceptual understanding and supports student-centered learning by encouraging exploration and self-directed inquiry. Complementing these perspectives, Amanat et. al., (2024) note that practical experiments enable students to move beyond rote memorization toward developing analytical skills, interpretation and evaluation of experimental results.

Boonprakong et al. (2023) further argue that such experiences strengthen causal reasoning and deepen comprehension of scientific variables.

Margolis, (2023) points out the danger of cognitive overload resulting from switching between instructions and tool utilization, while Moko, et. al., (2023) expands the critique by stressing the cognitive system's constraints in processing intricate or abundant information. Mohamed's examination is applicable to real-world situations, emphasizing practical educational environments, while Moko, et. al., (2023) offers a theoretical basis that elucidates the mental pressures students encounter. Collectively, their viewpoints indicate that successful instructional design should harmonize content presentation and cognitive capability, though Mohamed could enhance his approach by integrating additional cognitive theory, while Moko, et. al., (2023) may bolster her argument by relating her ideas to particular learning contexts.

Computers can host a range of softwares or programs that serve as components of problem-solving instruments. The Electronics Practical Workbench (EPW) is one example of such a program. The workbench allows users to create both digital and analog simulation circuits. The user is able to choose and combine specific components shown on the screen to construct a circuit. Kang and Temkin, (2022) hinted out that the display offered by EPW consists of four sections, with the majority allocated for the workspace. On the same display, there are scrollable dialogue boxes featuring virtual tools and equipment. The workbench features a graphical user interface that may necessitate the use of a mouse for pointing or selection purposes. To link two or more elements, a wire is pulled between them.

The wires can be generated automatically by pointing, clicking and dragging from the tip of an already inserted component to a different one. It features both analog and digital parts that are

distinct and can function independently. Analog components include Light-Emitting Diodes (LED), other various diodes, both direct and alternating current sources, resistors, transformers, capacitors, amplifiers and inductors. Additional test tools include voltmeter, oscilloscope, ammeter and multimeter among others. Digital components include electronic gates, adders, flip-flops and testing devices such as generators and multimeters. Salutina et. al., (2024) referred to the electronics practical workbench as an aid for instructors of digital circuits. It serves to validate the experiment or circuits. If a circuit fails to function, it might be a defective configuration that can be recognized and fixed promptly.

While Kang and Temkin, (2022) emphasize the user interface layout of the EPW, highlighting the dominance of the workspace and integration of virtual tools, Salutina, et. al., (2024) focus more on its pedagogical utility, particularly in troubleshooting and circuit validation. The former centers on structural and design aspects beneficial for user interaction, whereas the latter views the workbench as a functional educational aid, prioritizing instructional effectiveness. Together, the studies offer complementary insight, one from a usability perspective and the other from an instructional standpoint, but neither fully explores how these design elements directly impact learning outcomes or user engagement.

Creativity and innovation in science are among ways of generating original and valuable ideas employed by students who are ready to tackle science-related issues and operate in science related fields. Creativity and innovation demand critical and inventive thinking, along with abilities to engage in good communication and collaboration. These abilities can be enhanced through hands-on experience in science and are also crucial for people in everyday life (Darbellay, 2024).

An effective physics lab allows a student to link observable phenomena with hands-on experiences and scientific principles that guide their precise observations (Ghimire, 2024). By doing this, many students can evaluate their concepts and hypotheses, which is essential for developing problem-solving techniques and helping them grasp various scientific concepts. Physics practical activities provide a notable economic impact in various sectors, stimulate growth and generate highly skilled employees, fostering individual self-efficacy (Wahab et al., 2024).

Darbellay, (2024) highlight the wider cognitive and social skills developed through practical science, connecting them to real-life relevance, whereas Ghimire, (2024) concentrate on the educational benefits of physics labs in enhancing conceptual comprehension via observation and experimentation. Wahab et al. (2024) instead depict physics practicals as economically and professionally revolutionary, emphasizing their importance in workforce development and self-efficacy. Collectively, these viewpoints enhance each other, demonstrating that hands-on science education fosters knowledge while also promoting societal and personal growth in various areas.

Physics is a hands-on science that is not only inspiring and enjoyable but also enhances students' observational skills, encourages deeper inquiry and aids them in forming new insights and vocabulary. Conducting suitable physics experiments and investigations is crucial for improving learning, enhancing performance in the subject, clarifying and solidifying physics concepts (Kotsis, 2024). Additionally, Kotsis pointed out that by engaging in practical learning experiences in science, specific beneficial results can be recognized. This likewise encourages student-focused teaching methods and allows students to depend on the evidence.

Amanat et. al., (2024) noted that engaging in hands-on science practical tasks offers students comparable experiences and encourages them to think critically by looking for meanings behind the observed occurrences rather than simply memorizing the correct details. It similarly promotes evaluating the observed incidents and their results. Boonprakong et. al., (2023) observed that when students conduct their own experiments, they gain greater familiarity with the occurrences and the variables at play. It encourages cause and effect reasoning, so when these benefits are successfully utilized, they enhance academic achievement in physics.

The three scholars, Kotsis, (2024), Amanat et. al., (2024) and Boonprakong et. al., (2023), all highlight the importance of practical experimentation in physics instruction, yet they tackle it from varying perspectives. Kotsis, emphasizes the importance of experiments in reinforcing conceptual comprehension and fostering evidence-driven and learner-focused education. In contrast, Amanat et. al., 2024 prioritizes critical thinking and meaning construction, whereas Boonprakong et. al., (2023) highlights the importance of causal reasoning development and understanding experimental variables as essential components of academic achievement.

2.3.Methodologies for physics practical instruction

One of the teaching approaches used in physics education is Project-based instruction, which focuses on student learning through real-world application. It enables students to engage more actively than in a conventional classroom setting. It is most effective for advanced learners who are able to work alone. In this setting, the physics instructor prepares students for self-directed tasks. Following a fundamental overview of each concept, students will need to explore that project (Chaiyasit et. al., 2023). The second teaching method is demonstration that depends on presenting new and related information to students in an accessible manner.

The approach is most suitable for students following a standard science curriculum, as it introduces new and complex concepts in a conventional and recognizable way. The teacher will need to create content on every concept. This comprises a graphic work or digital note sheet, for the student that provides information both verbally and visually, serving as an essential component of teaching. Graphic work enables students to engage with the instructor and develop their personal comprehension of each idea, the experiences and resources (Charlot, 2023).

Chaiyasit et. al., (2023) highlight the importance of student independence and practical problem-solving in project-based learning, while Charlot, (2023) favor a more organized approach through demonstrations, placing greater emphasis on teacher-directed explanations and visual supports. Project-based learning encourages independence and enhances understanding in advanced students, but it can be difficult for those requiring more support, a gap that the demonstration method effectively fills by providing structured, clear content suitable for typical learners. Both approaches foster engagement, yet differ in their techniques: project-based learning stimulates active exploration and creativity, while demonstration guarantees consistent comprehension through clear visuals and verbal explanations.

The third teaching method is experiential learning though engaging students in hands-on activities that assist students in gaining a solid grasp of the physics behind experimental measurements and obtaining proficiency with various instruments. This enables the learner to gain directly from a dynamic and varied learning environment. Students who develop physics concepts in physics through hands-on activities tend to retain the information more effectively, experience a feeling of success upon completing the task and can easily apply that knowledge to different learning contexts (Chen et. al., 2024).

Although practical activities enhance involvement and understanding of concepts, there is a lack of comparative research assessing how this approach measures up against other evidence-supported teaching methods in physics education. The results highlight student contentment and the use of knowledge but overlook possible limitations like resource limitations or differing student learning styles that could impact the method's success. While the research emphasizes better retention via experiential learning, it would gain from longitudinal data to assess if these improvements last over time and in various academic environments

When practical multiple teaching methods are adopted, there is a greater likelihood that the information will be retained in memory for effective recall. Managing exceptional students often proves to be challenging with conventional teaching methods since they actively engage in the learning process rather than merely observing (Adeoye et. al., 2024). The hands-on activities enhance gaining of information and experiences, resulting in better retention. Students participating in labs and such activities are empowered in their learning process (Yao, 2023). Active learning often encourages children who may not excel academically or lack interest in school to be engaged. They ultimately engage in taking in information that they do not receive through conventional show me or tell me approaches (Swargiary, 2023).

The results highlight a significant deficiency in traditional teaching approaches, which frequently do not meet the needs of exceptional students who need greater interactive involvement to succeed academically. The study shows that hands-on and active learning methods greatly improve retention and empower learners, prompting educators to reconsider passive teaching strategies. The research highlights the importance of diverse instructional techniques in promoting deeper cognitive links, indicating that a universal approach is inadequate for

successful education. The study collectively challenges conventional referred to as show me or tell me methods as outdated, especially for disengaged or underachieving students who gain more from hands-on and interactive learning settings.

Hands-on learning experiences in science promote learner-focused teaching approaches and enable students to rely on evidence. Chen et. al., (2024) observed this but did not assess the accuracy of the report writing during the practical activities. Adeoye and the team overlooked the educational materials, particularly the physics laboratory equipment used in physics experiments during practical work. Some of these physical practical equipment and materials are obsolete, while others need regular repairs and maintenance. These are some of the challenges that this study sought to address by utilizing the electrical workbench as an effective tool for physics practical work. Chen et. al., (2024) emphasize the importance of experiential learning in promoting evidence-based and student-centered education, yet they neglect to assess the precision of students' report writing in practical activities.

The research overlooks an essential factor in applied science education by not taking into account the condition and significance of the physics lab instruments utilized. The writers fail to consider how outdated or poorly kept resources can greatly impede the effectiveness of experiential learning in physics education. While the implementation of the electrical workbench seeks to overcome these constraints, the research could have been improved with a more detailed evaluation of the tools and resources essential for hands-on learning.

Swargiary, (2023) concluded that when students conduct their own experiments, they gain greater familiarity with the events and variables involved. It encourages cause and effect reasoning; thus, when these benefits are efficiently utilized, they enhance academic achievement

in physics. This is a fact, however, in order for practical work to successfully enhance academic performance in physics, the final outcome is reflected in the written practical reports, which require precise data collection. This might not be accomplished with defective practical equipment in our school physics labs. The Electronic Practical Workbench will consequently tackle most of the erroneous experiences that physics students typically encounter during practical sessions.

Although Adeoye et. al., (2023) emphasize the importance of experiential learning in promoting evidence-based and student-centered education, they neglect to assess the precision of students' report writing in practical sessions. The research overlooks an essential element of hands-on science education by not taking into account the state and significance of the physics lab instruments employed. The authors disregard the effect of old or inadequately maintained resources, which can greatly impede the efficiency of practical learning experiences in physics education. While the implementation of the electrical workbench seeks to overcome these limitations, the research might have been enhanced through a more thorough evaluation of the tools and resources essential for hands-on learning.

The electronic practical workbench has emerged as a modern alternative to traditional laboratory setups, designed to overcome many of these challenges. It integrates digital tools and sensors to improve measurement precision, enhance visualization of physical phenomena and facilitate accurate data recording. By minimizing the reliance on physical apparatus that require frequent maintenance, the EPW ensures consistent experimental conditions and reliable outcomes. According to recent studies, the EPW provides a dynamic and interactive learning environment that aligns with evidence-based and student-centered pedagogies (Chen et al., 2024). It allows

learners to visualize abstract concepts digitally, conduct experiments with high accuracy and generate immediate data feedback. This not only enhances understanding but also improves the accuracy of students' practical reports, a challenge often overlooked in conventional setups (Adeoye et al., 2024). Furthermore, the EPW supports inclusivity by catering to students with different learning styles, offering simulations and guided modules that scaffold independent inquiry.

Conventional practical teaching methods cultivate essential experimental and observational skills through direct manipulation of physical apparatus, encouraging tactile learning and real-world engagement. However, they are limited by equipment reliability, high maintenance costs and variability in results. In contrast, the Electronic Practical Workbench offers accuracy, efficiency and adaptability, enabling educators to simulate complex experiments that may otherwise be constrained by resources or safety concerns. Both traditional and electronic practical approaches play vital yet complementary roles in physics education. Conventional methods strengthen tactile skills, observation, and experiential reasoning, whereas the Electronic Practical Workbench addresses equipment-related challenges and enhances precision and engagement through digital interactivity. A blended instructional model that combines both approaches may therefore represent the most effective strategy for advancing physics practical education in contemporary classrooms. Some of the commonly used conventional practical teaching methods are described in the following sections.

2.3.1. Demonstration

The term demonstration originates from the Latin word 'demo,' which means 'to read.' It wasn't until the 16th Century that the term was utilized to refer to the oral teaching provided by an

instructor in front of a group of students (Al-Hassan, 2018). This approach is merely one of the various teaching techniques implemented in science education in many schools. It is appropriate and typically with a big group of students. Many demonstrations feature a form of visual support, like a slideshow, a document, an image or a video. Certain educators might utilize a whiteboard or chalkboard to highlight key concepts during their instruction processes (Astalini et. al., 2019).

The historical development of the term demonstration emphasizes its strong ties to oral teaching, but its current application goes well beyond simple reading, pointing to the necessity of re-evaluating its present educational significance. Although demonstrations are frequently used in science education, an overreliance on this approach can restrict student involvement, particularly when interactive and experiential learning opportunities are neglected. Regular use of visual tools like slideshows or videos improves understanding, yet the impact of these tools largely relies on the instructor's skill in relating them meaningfully to the topic. While suitable for large groups, using demonstration alone may not fully meet varied learning needs, requiring a more balanced and multimodal teaching strategy.

Demonstration involves teaching by using examples or conducting experiments. A science educator might demonstrate a concept by conducting an experiment for the learners. A demonstration can be used to establish a fact by using a mix of visual proof and related reasoning. Demonstrations are parallel to written narratives and examples in that they enable students to connect personally with the information being presented (Chi, 2018). Information demonstrated becomes personally meaningful.

Demonstrations enhance student engagement and strengthen memory associations as they link facts to their practical applications in the real world (Kanphukiew & Nuangchalerm, 2024). In

the process of learning through demonstration, students can grasp the concepts more effectively. Demonstration frequently takes place when learners struggle to link theories to real-world applications or when they find it difficult to grasp how theories are applied (Maroungkas et. al., 2023).

A teacher not only illustrates particular learning concepts in the classroom but also engages in classroom demonstrations to enhance their teaching strategies, which may or may not be demonstrative in nature (Bhaumik et. al., 2024). This research finding effectively highlights the value of demonstration as a teaching method that bridges theory and practical application, emphasizing enhanced engagement and memory retention. However, it somewhat lacks empirical evidence or specific data to support the claims about effectiveness, relying mostly on general statements and secondary sources. The inclusion of diverse references adds credibility, but the explanation could benefit from clearer differentiation between demonstration as a teaching strategy and other instructional methods mentioned, like written narratives. Overall, while the conceptual overview is solid, a more rigorous analysis or case study data would strengthen the argument and practical implications.

Kamugisha et. al., (2024) noted that demonstrations are practical and most effective, particularly in larger class sizes. This is acceptable when there is sufficient equipment for every student or a greater ratio of available equipment to the learners' performing demonstrations in groups. Nonetheless, a few of the devices for demonstrations could be defective. Majority of presentations in a demonstration incorporate various visual aids, including slideshows, Word documents, images or films, which can be addressed by EPW. For illustration, Haug and Mork, (2021) noted that the impact of classroom demonstration by instructors involves a shift in

viewpoint regarding interactions with 21st Century learner. This may alter the students' view on deciding to studying physics, especially as they advance to higher grades from form 2 or grade 9.

The research highlights the practicality and effectiveness of demonstrations in larger classes, but its emphasis on equipment availability may overlook challenges in resource-limited settings. Mentioning defective devices points to potential disruptions, yet the study lacks strategies for mitigating such issues. The integration of diverse visual aids is well-noted, though the role of EPW could be better explained to clarify its unique contribution. Finally, linking demonstrations to shifts in student attitudes is insightful, but the claim would benefit from more empirical evidence to support its impact on physics learning motivation across grade levels.

2.3.2. Class practical work

The purpose of introducing students to hands-on experiments is to enhance their overall and particular skills in conducting scientific investigations. It also improves their practical skills in managing experimental instruments. Practical experimentation is a crucial component of the research cycle in scientific investigations (UNESCO, 2019). This lays the groundwork for the development and enhancement of predictions, which is a one of the basic science process skills in scientific processes. It guarantees that students acquire not just the body of scientific knowledge, but also the methods through which it has been created (Acharya, 2024). The aim of an experiment generally revolves around assessing the validity of the hypotheses formulated from theories. In typical scenarios, students are often provided with the experimental design and procedures, then they are instructed to perform the experiment by adhering closely to the provided guidelines (Eckerd et. al., 2021).

The researchers clearly emphasize the significance of experiential learning in cultivating both broad and targeted scientific abilities, stressing the importance of practical tool usage and the scientific method. Nonetheless, their results indicate a somewhat narrow perspective, highlighting that students generally adhere to established experimental designs, potentially limiting chances for creativity and more profound inquiry. Although they emphasize the importance of experimentation in confirming hypotheses and developing scientific understanding, there is scarce dialogue on how open-ended or student-designed experiments might further improve critical thinking. Ultimately, the analysis would gain from discussing how experimentation can transcend procedural tasks to promote greater autonomy and creativity in scientific inquiry.

During experiments, the instructor provides assistance and guidance to students while advising them on their experimental methods (Werth et. al., 2023). The students must infer the hypotheses under examination from the provided experimental design to gather data, make precise measurements during the experimental tasks to assess and analyze the experiment in a written report (Tan, 2022). Practical sessions enable students to showcase, apply their knowledge and abilities of 'how to do something' while accomplishing the learning objectives independently. This cannot be accomplished through written evaluations like open-ended questions or multiple-choice items. Hands-on experiments can be expanded to include an examination of practical skills, paired with concise instructions and engaging questions about theories (Kelley, 2021).

The researchers collectively highlight the value of hands-on experimentation for deepening student learning and skill development, emphasizing instructor guidance and student autonomy. However, Werth et al., (2023) might underestimate the potential for varying degrees of instructor

influence, which could affect student independence. Tang, (2022) focus on hypothesis inference and data accuracy but do not address how students' prior knowledge impacts their ability to interpret experimental designs. Kelley, (2021) convincingly argue for practical assessments over written tests, though integrating theory with practice may require careful balance to avoid cognitive overload.

2.3.3. Conducting Experiments in Physics Laboratories

In physics classes, skills like manipulation, inquiry, investigation and communication are developed through hands-on activities (Kotsis, 2024). These encompass making observation, identifying the problem or a challenge, developing a hypothesis, testing the hypothesis, gathering data, organizing data into tables, analyzing the data, drawing a conclusion and communicating the findings. Cognitive skills including critical thinking, problem-solving, application, synthesis, evaluation, creativity and decision-making are also employed throughout the lesson (Yusuf et al., 2024). Attitudinal conducts like curiosity, perseverance, satisfaction, agreement and cooperation between students and the instructor are also nurtured (Grieco, 2022).

The application of laboratory methods for teaching and learning has turned into a custom among science instructors and students. On one hand, they recognize the significance of using laboratory methods in science education, but on the other hand, they merely offer 'poor service' regarding its real application. Physics teachers generally do not consider it practical to make laboratory work the focal point of their teaching (Kotsis, 2024).

These results offer an extensive summary of how physics teaching incorporates hands-on experiences to cultivate a diverse array of skills, spanning practical handling to advanced cognitive functions, which is essential for well-rounded education. The study appears to neglect

the extent to which these skills are applicable to real-world problem-solving outside the classroom setting. Although traits such as curiosity and cooperation are rightly emphasized, the issue of inadequate implementation and insufficient focus on laboratory activities by educators (Kotsis, 2024) reveals a notable disparity between theory and practice. Upcoming studies need to investigate approaches to close this divide, making certain that the recognized advantages of laboratory techniques are completely utilized in real educational settings. An investigation into the use of EPW seeks to bridge this gap.

Some physics instructors often express dissatisfaction regarding insufficient materials and equipment for conducting practical activities. Simultaneously, it is possible that these materials and tools could be available in the school laboratory's storage, with a teacher unaware of their presence. Consequently, many physics educators often conduct many demonstrations that might be more instructor-focused; however, students must engage in inquiry-based learning to truly value the essence, teaching and learning strategies employed in scientific processes (Ouyang, 2023). Through participation in hands-on learning experiences, learners will acquire skills, concepts, attitudes, cognitive abilities and comprehension of the essence of science. Consequently, demonstrations harm the physics students over the long run (Buzuzi, 2024). There are numerous methods for conducting class experiments. These consist of rotational experiments, group experiments and individual experiments.

A rotational experiment aims to determine how the mind identifies objects in the surroundings. It starts with forming a mental picture of an object and then mentally turning the object in three dimensions until a comparison can be conducted. The learner subsequently determines if the objects are identical or not and then conveys the decision (Tian et. al., 2024). It additionally

entails transitioning from one experiment to the next, ensuring that all experimental activities are addressed by the conclusion of the learning session. In a group experiment, a specific number of learners are organized into groups and tasked with conducting different experiments based on the apparatus and other materials available. This approach assists them in creating ideas for experiments by directing their thinking from broad to detailed. It likewise prompts students to formulate several hypotheses prior to carrying out an experiment (Pesovski et. al., 2024).

The researchers emphasize significant problems in physics education, particularly the gap between existing resources and teachers' awareness, which may restrict hands-on learning experiences. Ouyang, (2023) accurately highlight the importance of inquiry-based learning instead of teacher-centered presentations to promote enhanced student involvement and comprehension. Buzuzi, (2024) reinforce this by stating that excessive dependence on demonstrations could impede the long-term growth of scientific skills in students. Furthermore, Tian et. al., (2024) and Pesovski, (2024) offer effective strategies like rotational and group experiments that promote active learning and critical thinking; however, additional studies could investigate the implementation of these techniques and their effects on varied learner populations.

Learner-centered education aims to tailor both the content and methods to suit the learner (Darmaji et. al., 2018). This includes personal experiments in which students create observations and thoughts based on a tangible experience. Then, abstract ideas are created that direct new behavior. These activities can be tailored to suit the shared learning preferences of each learner to support everyone. It further promotes the comprehensive use of various senses, enabling a greater number of learners, including those with disabilities, to learn effectively (Jax et. al.,

2019). Practical science is inspiring, ignites students' curiosity and aids them in grasping theoretical concepts by directly encountering phenomena. There are two primary categories of practical classroom work: experiments for experience and experiments for investigation.

The research experiment allows students to acquire knowledge by obtaining empirical evidence. Senses serve as the main source of empirical evidence and are fully utilized (Angraini et. al., 2024). High school physics laboratory activities offer hands-on experience with phenomena, serve as a foundation for the organized growth of students' concepts and act as a testing site for evaluating the predictive strength of their reasoning. The laboratory exercises should be structured to stimulate students' thinking, allowing them to gain skills and self-assurance in their scientific learning journey (Jumini et. al., 2024).

These researchers collectively emphasize the value of learner-centered, sensory-rich practical education in science, which effectively bridges theory and experience. However, while the importance of tailoring activities to individual or shared learning preferences is highlighted, the challenge of balancing customization with curriculum standards is underexplored. The focus on sensory engagement and hands-on experiments rightly promotes inclusivity, yet specific strategies for diverse learners, especially those with disabilities, need further elaboration. Finally, although the role of laboratory work in building conceptual understanding and reasoning is well supported, more attention could be given to assessing the long-term impact on students' scientific thinking and motivation.

By engaging in routine laboratory tasks, the students will be capable of measuring physical quantities with suitable precision. They can identify factors that may influence the reliability of their measurements. The students will be capable of handling the materials and equipment they

use in hands-on activities. Laboratory activities provide learners with the chance to articulate their observations and measurements clearly. Thus, it becomes simple for them to represent information using suitable verbal, pictorial, graphical and mathematical forms. They will be capable of making conclusions and reasoning based on their observations. By engaging students in laboratory class experiments, they gain the capacity to logically support their conclusions and forecasts. They will actively engage with their classmates and instructor in a collaborative intellectual venture (Kustijono et. al., 2018).

The findings by Kustijono et. al., (2018) present a comprehensive view of the benefits of laboratory activities in developing students' practical and analytical skills. However, the claims could be strengthened by providing empirical evidence or specific examples demonstrating how precision in measurements and reasoning skills improve over time. The emphasis on collaboration is valuable, but more insight into how group dynamics impact learning outcomes would add depth. Lastly, while the description highlights positive outcomes, potential challenges such as varied student engagement or resource limitations are not addressed, which could affect the generalizability of the results.

Parmar et. al., (2024) discovered that students can achieve meaningful learning during laboratory activities when given the chance to handle equipment and materials while collaborating with peers in an environment that allows them to explore solutions to problems that captivate their interest. For a student to develop the practical and cognitive skills related to learning physics, it is crucial that they are completely involved in laboratory activities. This necessitates adequate equipment and lab stations for groups of two or three students in the laboratory.

The quantity of students and laboratory stations in a classroom should be low enough for the teacher to oversee the safety of the students' activities and to have adequate time to engage actively with each lab group (Werth et. al., 2023). School administration must guarantee equal access to lab activities with suitable supervision for every student, including measures to adapt activities for students with disabilities. When suitable, lab activities ought to incorporate equipment and phenomena that connect to the students' world, including toys, sports gear, tools and household objects.

The Ministry of Education Report (2018) affirmed that by 2014, one of the government's long-term priorities was to guarantee equitable and affordable access to basic education. To accomplish this, various strategies are implemented, including forming strategic partnerships with private sectors, non-governmental organizations (NGOs), faith-based groups and other collaborators in providing infrastructure. The infrastructure comprises a science lab, practical tools and digital gadgets like laptops for first-grade students.

Parmar et. al., (2024) highlight the significance of experiential, cooperative learning in labs for effective participation and skill enhancement in physics. Nonetheless, the dependence on suitable tools and limited group sizes as pointed out by Werth et. al., (2023) might pose difficulties in resource-constrained schools, possibly restricting the practical use of the study. The appeal for equal access and inclusive oversight is admirable but lacks specific strategies on how to adequately assist students with disabilities in varied educational environments. Although the Ministry of Education's initiatives to enhance infrastructure via partnerships are encouraging, the report fails to specify how these actions directly affect everyday lab learning experiences or tackle inequalities in various regions.

Certain challenges related to laboratory and laboratory equipment investment identified by (Al-Worafi, 2024).) prompted the government to prioritize this matter over others, which included insufficient laboratories and lab equipment, as well as a lack of workshops for tutors in science, languages and technical subjects. The limited workshops that were held were predominantly theoretical in nature. Additional issues included subpar standards for laboratory constructions, inadequate maintenance of laboratory apparatus and disorganized investments in science projects.

The communities, committees from local transfer authority funds (LATF), constituency development funds (CDF) and other key stakeholders are increasingly establishing new schools for economic, social and political reasons. Most of the buildings have only classrooms and offices, lacking science laboratories. When a science practical is to be held, many schools transform the classrooms into a science laboratory that lacks the necessary features of a proper lab. Some of these schools lack even the fundamental science lab equipment and students first encounter real laboratory tools during exam periods. A substantial limited investment has been made in providing science laboratories and science kits in secondary schools to familiarize students with scientific equipment before the national examination period. The lack of adequate guidelines regarding the use of existing equipment and digital devices, as well as their maintenance and overall safety in handling, constitutes some of the challenges

Ludwig et. al., (2021) observed that experiments in physics laboratories involve making observations, identifying issues, formulating hypotheses, testing them, collecting data, tabulating the data, analyzing it and drawing conclusions. Achieving meaningful academic success necessitates precision in the processes of data collection, recording, tabulation and analysis.

Amanat et. al., (2024) noted that several physics instructors often express concerns about insufficient materials and equipment for conducting practical activities. Simultaneously, it is conceivable that these materials and equipment could be secured in the school laboratory storage, with a teacher unaware of their presence. As a result, many physics instructors often conduct numerous demonstrations that may be more focused on the teacher, but students must engage in inquiry-based learning to fully understand the essence, teaching and learning strategies employed in the scientific process. In his situation, EPW will tackle the problems of insufficient equipment and the instructor's demonstrations.

Ansah et. al., (2024) discovered that the quantity of students and laboratory stations in a classroom should be limited so that the teacher can oversee the safety of the students' actions and have enough time to engage actively with each laboratory. EPW, on the other hand, will offer every learner a chance to be safer than when using the physics lab apparatus and equipment. As per the 2018 report from the ministry of education, school administration is required to provide equal access to laboratory activities with suitable supervision for every student, including adjustments made for students with disabilities. To accomplish this, a digital or virtual lab is necessary, which can be fulfilled through the use of EPW.

Based on Keyan Competency Based Education (CBE), the researcher observed that transformative physics practical teaching approaches that align with CBE are required. Some of the approaches include Inquiry-Based Learning (IBL) which is a student-centered approach that encourages learners to pose questions, develop hypotheses and carry out investigations to draw conclusions. In a physics practical context, students can be guided through EPW to explore physical phenomena through experimentation rather than following predetermined procedures.

This aligns with CBE by fostering critical thinking, problem-solving and scientific inquiry skills, allowing learners to progress based on their demonstrated understanding rather than time spent in class.

The second approach is Project-Based Learning (PBL) which involves students working on extended, real-world physics problems or experiments that require planning, execution and analysis. In line with these tasks, learners can use EPW to design and build a model of an electric circuit, such as a solar-powered device, integrating concepts like energy transformation and circuitry. This method is in line with the use of EPW and supports CBE by emphasizing mastery of complex skills, collaboration and the application of knowledge in authentic contexts.

The third approach is Technology-Enhanced Learning (TEL) which involves integrating simulation tools and virtual labs allows students to conduct experiments that may be difficult to perform in traditional school settings due to cost, time or safety constraints. In this case EPW comes in through simulations which enable learners to manipulate variables and observe outcomes in real time. This approach supports CBE by providing accessible, flexible opportunities for practice and skill acquisition, reinforcing learning at the individual's pace.

2.3.4. Applications of Physics SEPU and Micro Kit in Physics Practical Work

In secondary school physics, practical work is carried out through laboratory experiments, demonstrations, field trips and excursions. The innovativeness and creativity of teachers can also bring forth new methods of practical application through research. In Kenya, such innovations encompass physics micro-kits, notably specialized Science Equipment Production Unit (SEPU) kits that feature portable basic experiential tools for use in inadequately equipped physics laboratories, along with straightforward improvisations (Adam et. al, 2017).

The Kenya Vision 2030 identifies Science, Technology and Innovation as a foundation for the social and economic development. The national development blueprint recognizes the role of Science and Technology in development as new knowledge expected to boost wealth creation, social welfare and international competitiveness. With increased unemployment and the need to provide skills that will enable the youths to be self-employed and compete in the global job market, there has been increased need to promote science as the avenue through which self-sustaining skills can be imparted. As a result, the government, with the support of other stakeholders has increasingly given the construction of science laboratories, science rooms, provision of laboratory equipment and science kits priority mainly in public secondary schools. Lopes et. al., (2024) shed light that laboratories and science rooms refer to the buildings that are designed and fitted with tools and equipped with chemicals that are necessary for effective teaching of science subjects.

Laboratory equipment, apparatus and science kits are those tools that facilitate the effective teaching and learning of science plus other skills-oriented subjects. Improvement of infrastructure including computer laboratories, installation of electricity lines or solar power in all schools in phases was thought to make it possible to be prioritized by the government. There has been provision of School Equipment Production Unit (SEPU) to schools, parents' mobilization of funds through Parents Associations (PTAs) development projects, Local Authority Government through Constituency Development Funds (CDF), Public Private Partnerships (PPP) especially in primary schools, secondary schools and to some extent Special Needs Education (SNE) and Accelerated Christian Education (ACE) learning centers (Mboya, 2023). Despite these investments in construction of school laboratories and purchase of

laboratory equipment, there is still a big gap that requires continued and expanded investment to ensure quality learning in all the schools.

The performance of sciences in secondary schools has been improving since the introduction of laboratory equipment grants in 2003 in secondary schools and the introduction of the Strengthening of Science and Mathematics Education (SMASE) initiative. However, this gain is currently hampered by the increase in enrolment of secondary schools following the introduction of Free Day Secondary Education (FDSE) in 2008. In addition, the current GoK laboratory and equipment grants does not comprehensively cover schools for learners with special needs and excludes ACE learning centers and primary schools (Munyasia, 2021).

Currently, efforts are being made to utilize virtual science laboratory that rely on the interplay of the computer and the internet (Ayoubi, 2018). According to Oyoubi, every effort should be made to create interest in the students in order to study physics. Whereas the above efforts can be lauded, this study will concentrate on exploring the role that traditional laboratory experiments teaching method and electronics practical workbench as method of teaching and learning practical in improving physics academic achievement, acquisition of science process skills and change of attitude in learning physics amongst form two students.

Physics Laboratory should be equipped to help physics students to carry out Physics experiments covering several topics. Lab experiments focus on conceptual understanding, with an emphasis on relevance and historical development. Physics is specific and avoids unnecessary technical development. It emphasizes on physical concepts, analyzing aspects of many everyday phenomena and guiding readers carefully through mathematical derivations. It also provides a wealth of interesting information, from the history of the science, to connections with real world

phenomena in science and engineering to common sense advice and insight on the intuitive understanding of scientific phenomena. The Micro kits form a full set of apparatus required and is like a mini-laboratories. The kits are cost effective safer than conventional laboratory equipment and materials. Each kit is compact, can be reused and is unbreakable. In addition, the small quantities of chemicals used make the methodology environmentally sound (Mnyango and Hlangothi, 2024).

The pedagogical importance of this practical science education tool for capacity building in scientific thinking is high. Students learn to ask questions about the natural world, set up experiment to answer their questions, observe and record results and then draw conclusions. Shivolo, (2024) agreed that teaching of scientific thinking can be achieved with this methodology in contexts where no laboratory facilities are available. The micro science approach not only helps to develop scientific thinking in students but also provides developed and developing countries alike with new teaching tools. These micro-kits promote practical science experimentation using micro science as an advocacy tool amongst policy makers. They improve science curricula by inclusion of hands-on experimentation for a better understanding of science. This increases the interest of young people in science so as to promote gender equality, scientific literacy and the choice of a scientific career. It also promotes capacity building for science education and enhances development of scientific thinking and experimentation for pupils (Tsiouri et. al., 2024).

This is a free online interactive learning and teaching tool. It involves visual display of the learning and teaching activities, simulations and animations. The teaching of physics is clearly enhanced by the use of demonstrations. Visual examples of abstract concepts aid in their

mastery. Demonstration illustrates the physics scientific methods and relates experimental observations to scientific theories. Demonstrations are usually done by the teachers. However, the follow up discussions on the purpose of the demonstration are usually counterproductive. In many cases the demonstration is derived from mostly irrelevant cultural settings with the attendant equipment disasters (Shivolo, (2024). Demonstrations are like a whole class practical; they activity involve the students in observing or manipulating real objects and materials just like whole class practical. Demonstrations can be made more effective by proper planning and having clear learning objectives in mind. An effective demonstration should promote good observation skills, stimulate thought, arouse curiosity, present aspects of complex concepts on a concrete level and most important, be the basis for class discussion (Jax et. al., 2019).

Demonstrations provide an opportunity to engage students in a different way to other types of lesson activity; in particular, they can provide an opportunity to insert some drama and entertainment into your lessons. Developing interest in science through emotional engagement is possible during class demonstrations. There is a very wide range of positive emotions which teachers can foster through the way they teach science. It can promote curiosity, intellectual joy of understanding, sense of imagination, amusement and amazement. This helps in developing positive emotional responses in the classroom and also helps to cultivate effective relationships between the teacher and the pupils. In some situations, it may be more appropriate and indeed more effective to carry out a demonstration instead of carrying out a class practical where students have done practical initially; in this case the students have traditionally observed the happenings in lessons where they individually or in pairs used the apparatus to identify and solve problems (Veldkamp et. al., 2020).

Visibility is very important; the teacher must make sure that students can see the demonstration. If they cannot all see the teacher and the demonstration or hear you clearly, the lesson will not be effective. The teacher should pay attention to size and lines of sight and carry out the demonstration from the most appropriate position in the classroom, which is not necessarily the front of the class. The teacher should ensure that no part of his/her body obscures students' view. The teacher can make small demonstrations easier to see by using a video connected to your whiteboard (Rojas, 2023). The teacher should prepare students to observe what the/she wants them to see with effective discussion beforehand. During the demonstration, learners' attention should be brought to the things the teacher wants them to see. Repetition is necessary, if possible, the teacher should repeat the demonstration; this will allow the teacher to draw attention to things students may have missed first time (Devis et. al., 2024).

Laboratory equipment, apparatus and science kits are those tools that facilitate the effective teaching and learning of science plus other skills-oriented subjects as was observed by Kanphukiew et. al., (2024) which fine with physics practical work however the equipment and the apparatus must be adequate and non-faulty as can be achieved by use of EPW. They observed that even though there has been provision of (SEPU) to schools, funds mobilized by PTA's, county governments' support through CDF, PPP especially in schools, there is still a big gap that requires continued and expanded investment to ensure quality learning in all the schools and this can be supported by EPW. Most laboratory equipment does not support learners with special needs whereas EPW will cater for learners living with different disabilities. This is because through computer, the volume can be adjusted for learners with hearing impairment while an LCD projector can be used to magnify the details of the content.

During the literature review, the researcher noted that the use of Physics SEPU kits and Micro Kits in physics practical work has presented some significant weaknesses, particularly in terms of equipment durability and precision. Many of the SEPU and Micro Kit components are made from low-cost materials intended to make them affordable and widely accessible, but this often results in fragile or easily damaged apparatus. For example, connectors, resistors and power sources may wear out or malfunction after limited use, compromising the accuracy and consistency of experiments. This fragility not only disrupts learning but also increases maintenance costs and reduces the lifespan of the kits.

Another key limitation is the restricted scope of experiments that can be conducted using these kits. While SEPU and Micro Kits are designed to cover basic principles such as electricity, mechanics and optics, they often lack the flexibility or range of components required for more complex or advanced experiments (Charlot, 2023). This constraint limits students' ability to explore physics concepts deeply or to engage in inquiry-based learning that encourages creativity and critical thinking. As a result, the learning experience may become overly guided and theoretical rather than practical and exploratory.

Some of the accuracy and calibration of instruments included in the kits may be of the substandard by fading shortly especially when not safely utilized and stored appropriately. For instance, measuring devices such as voltmeters or ammeters in the Micro Kits may not be sensitive enough for fine measurements, leading to systematic errors and incorrect conclusions.

Systematic errors involve improper use of equipment, as well as internal and external built-in instrumental errors like zero error (Mwamba et. al.,(2019). The challenges can also arise from human mistakes, which include errors made during an experiment that can compromise

calculations based on certain data, such as parallax errors which is a shift in the perceived location of an object viewed from two different angles, faulty arithmetic, incorrect setup of equipment, inaccurate observation techniques and failure to select the proper physics apparatus for a specific experiment.

Additional human mistakes comprise incorrect identification of axes, labeling of graphs, imprecise plotting of points on a graph, finding and connecting optimal points, failure to appropriately select scales and interpret graphical data, erroneous writing of conclusions and practical reports (Amanat et. al., 2024). Detecting and rectifying systematic errors might be challenging when utilizing the commercial mechanical physics lab apparatus. In this instance, the error can be identified and reduced through thorough comparison of the results acquired in specific experiments with independently gathered comparable standard values. This can be accomplished by incorporating different tools and methods, utilising processes established in the values already acquired, acknowledged and fine-tuned until the desired result is achieved.

The processes of identifying and correcting errors are still laborious and time-consuming, which may not be conclusively accomplished during a practical session if they arise. These inaccuracies hinder students' development of precise experimental skills and reduce the reliability of their data. Teachers may also struggle to demonstrate proper scientific methodology when the tools themselves cannot support it, thereby weakening the overall educational value (Okam, 2017).

In some instances, there are pedagogical and logistical challenges associated with using these kits effectively. In many classrooms, there is a shortage of kits relative to the number of students, resulting in overcrowded groups and limited hands-on time for individuals (Munyasia, 2021). Additionally, some teachers may lack the training or confidence to integrate the kits

meaningfully into their lessons, leading to underutilization or misuse. Without proper instructional support and curriculum alignment, the intended benefits of practical work such as reinforcing theoretical knowledge and building problem-solving skills are significantly diminished (Mutembei, 2024).

Wekwe et. al., (2024) provided an extensive summary of hands-on activities in secondary school physics, emphasizing the impact of innovations such as SEPU micro-kits and micro science methods in Kenya. Their focus on how these kits tackle infrastructural issues, particularly in inadequately equipped laboratories is significant, as these tools offer affordable, portable and eco-friendly options compared to traditional lab equipment. This is in harmony with Kenya Vision 2030's emphasis on science and technology as essential catalysts for socio-economic growth. Despite recognizing the potential of these kits to promote scientific reasoning and skills, the results could gain from more extensive empirical evidence regarding the effects of these tools on long-term learning results, particularly in comparison to conventional lab environments or new virtual laboratories (Chepkirui, (2024).

Omwoyo, (2024) noted that the studies accurately highlight important shortcomings of the SEPU and Micro Kits, including concerns about durability and limited experimental range. These shortcomings influence both the dependability of experiments and the quality of the students' practical experiences. The delicate and inaccurate nature of devices such as voltmeters or resistors restricts students' chances for deeper investigation and might unintentionally steer practical learning towards memorization or abstract tasks. The debate surrounding systematic and human errors in the management and interpretation of experimental data highlights a significant issue: unreliable or insufficient tools can undermine scientific integrity and obstruct

skill enhancement. Nonetheless, the discussion might be strengthened by offering more specific suggestions on achieving a balance between cost-effectiveness and longevity or by examining additional strategies (like combined use with virtual labs) to address these limitations (Kangangi, 2017).

Ultimately, the researchers underscore significant pedagogical and logistical challenges, especially shortages of kits, overcrowded classrooms and insufficient teacher training that hinder the effective utilization of these practical tools. This acknowledgment of actual obstacles demonstrates a sophisticated comprehension of educational environments. Although the challenges are clearly outlined, the conversation could be enhanced by suggesting specific solutions, such as scalable teacher professional development, policies for equitable resource allocation or integration frameworks that connect micro-kits with curricula and assessment methods. Additionally, the rising implementation of virtual labs is mentioned briefly but could be expanded upon as a supplementary or alternative method to address these challenges and improve students' involvement and comprehension of physics.

3.3.5. Knowledge Gap on Accuracy in Measurement

Although the Electronics Practical Workbench (EPW) is recognized for its educational benefits, a significant knowledge gap exists in understanding how its interface design affects students' accuracy in measurements. While prior studies (Chaiyasit et al., 2023) discuss cognitive overload in general, they do not empirically link specific EPW features, such as dialog boxes, component arrangement, and multitasking between instruction and application, to students' cognitive stress and measurement precision. Moreover, few studies have addressed how the accuracy of data collected through EPW compares to traditional methods, or how repeated use influences long-

term retention of measurement skills. Additionally, assessment and feedback mechanisms for practical tasks are underdeveloped (Ouyang, 2023), leaving a gap in understanding how structured feedback affects students' precision and the quality of their practical reports.

2.4.Science Process Skills

Science process skills are the fundamental abilities that enable learners to engage in scientific inquiry, investigation and problem-solving. They are the mental and physical actions scientists and students use to observe, explore and understand natural phenomena. Although it requires a great deal of preparation time, once a system is developed, the experimental method of teaching makes the teaching fun. If the students are learning and having fun doing it, they gain knowledge and skills more (Mokhtar et. al., 2023). The observations and results can be used to gain understanding of physics concepts. Science process skills necessary for the world of work are systematically developed. Without this approach, the students rely on memory and abstract thought; two methods which restrict learning for most students. When the students conduct experiments, students develop their critical thinking skills, inferring, measuring, communication, classification and predicting skills as well as discovery of scientific concepts (Gizaw & Sota, 2023). It involves hands-on learning where students are motivated to learn more and improve their practical skills. Learning by well planned activities and experiences in a well-engineered program is considered a good instructional approach (Sahdan and Abidin, 2017).

Veronika et. al, (2017) considered practical work as a way of engaging the learner in observing or manipulating real or virtual objects and materials; this is where EPW comes in handy. Appropriate practical work enhances students' experience, understanding, skills and enjoyment

of science. Practical work enables the students to think and act in a scientific manner. Practical work in physics helps them develop familiarity with apparatus, instruments and equipment.

Science process skills have been described as mental and physical abilities and competencies which serve as tools needed for the effective study of science and technology as well as problem solving, individual and societal development. These science process skills include observing, measuring, classifying, communicating, predicting, inferring through using number, controlling variables, hypothesizing, formulating models, designing experiment and interpreting data (Pascoe et. al., 2018). Science process skills are classified into two categories that; basic and integrated process skills. Basic science processes are important for science learning and concept creation at the lower level of learning in secondary schools (Panadero, 2017). According to Panadero noted that more difficult and integrated science process skills are more appropriate at the secondary and tertiary school levels for the formation of models, experimenting and inferences. Hence both basic and integrated science process skills are relevant and appropriate at the senior secondary schools' level of education in Kenya.

Science process skills are taught as part and parcel of the physics curriculum which are cognitive and psychomotor skills needed in problem solving. They are skills which scientists utilize in identification of problems, objective inquiry and data collection, transformation of data, its interpretation and communication. These skills can be acquired and developed through science practical activities. The skills form part of the aspect of science learning which remains after cognitive knowledge has been forgotten. Students using science process skills show an indicator of transfer of scientific knowledge. Practical work is not just putting the apparatus together when seen but it needs planning, designing a problem, creating a new approach and procedure. It also

involves putting familiar things together in the new arrangement. This means that creativity knowledge exhibited by students in practical class enables them to manipulate some of practical equipment (Mwamba et. al., 2019).

Murugan and Osman, (2018) identified science process skills to be observing, measuring, classifying, communicating, predicting and inferring by using number, controlling variables, hypothesizing, formulating models, designing experiment and interpreting data. In order to acquire the skills identified by Murugan and Osman, accuracy of the physics practical apparatus is key. Observations, measuring, classifying, for example good, poor and bad conductors, inferring and interpreting data require a high level of accuracy and precision which may not be effectively achieved by the normal practical apparatus we have in our laboratories. This is a gap that can be bridged by EPW.

Based on the researcher's literature review on Basic Science Process Skills (BSPS), the skills such as observing, classifying, measuring, predicting and inferring, are foundational to effective scientific learning and inquiry (Parmar et. al., 2024). While Physical Physics Practical Apparatuses (PPPA) are essential tools in circuit-based practical activities, their complexity can sometimes overshadow the acquisition of these core skills. Students may become preoccupied with assembling components correctly such as connecting wires, resistors and power supplies rather than focusing on the scientific reasoning or observational skills the activity aims to develop. In such cases, the mechanical aspects of setting up the apparatus can dominate the learning process, leaving little room for nurturing basic science process skills. In this case EPW may intervene and minimizes the timeframe for setting up such apparatus and promotes consultation, negotiation or coordination on the concepts to be developed.

Circuit-based experiments often assume a level of prior knowledge and manual handiness that students may not yet possess. For example, understanding how to read circuit diagrams or use multimeters correctly requires a combination of abstract thinking and technical proficiency. If students struggle with the apparatus, their attention is diverted from observing phenomena or drawing conclusions based on evidence (Prayogi et. al., 2024). As a result, instead of exploring concepts like current flow or resistance through inquiry and experimentation, students may resort to rote following of instructions, missing opportunities to engage with process skills like hypothesis formulation or data interpretation. To minimize this, EPW comes with ready tasks of clicking and reading manual on how to design and use the circuits effectively.

Practical teaching methods are vital to effective physics education, as they connect theoretical concepts with practical applications. Conventional approaches, including demonstrations, project-oriented teaching, and practical lab activities, have historically been utilized to enhance conceptual comprehension and skills acquisition. Nonetheless, new technologies like the Electronic Practical Workbench (EPW) are progressively being investigated to tackle the challenges linked to traditional laboratory methods, especially regarding resource limitations, data precision and student involvement. Conventional teaching techniques highlight student involvement via organized and concrete learning opportunities. Chaiyasit et. al., (2023) define project-based instruction as a method that encourages active learning and self-directed problem-solving, enabling students to investigate practical uses of physics principles. This approach boosts creativity and independence, especially in advanced students who are capable of handling self-directed initiatives. Similarly, Charlot (2023) highlights teaching through demonstrations, offering organized explanations of intricate concepts with the help of visual and verbal tools.

This method supports students adhering to regular curricula, guaranteeing transparency and uniformity via teacher-directed teaching.

Although project-based learning encourages autonomy and profound comprehension, it can pose difficulties for students requiring additional support. Demonstrations, conversely, guarantee understanding but can restrict chances for investigation and creativity. Chaiyasit et al. (2023) and Charlot (2023) highlight that both approaches increase engagement but have different emphases; project-based learning fosters creativity, while demonstrations promote clarity and accessibility. Practical physics experiments have historically been key to student-focused learning. Chen et al., (2024) assert that these activities aid students in understanding experimental measurements, enhance their skills with instruments, and foster long-term retention. Similarly, Adeoye et al., (2024) along with Yao (2023) emphasize that students involved in hands-on laboratory activities gain better conceptual comprehension and a feeling of success, which enhances their motivation. Nonetheless, these conventional laboratory activities frequently rely on antiquated or inadequately maintained tools, potentially impacting data precision and restricting the overall learning process (Chen et al., 2024; Adeoye et al., 2024).

Additionally, Swargiary (2023) notes that engaging in practical work enhances causal reasoning and supports greater academic success in physics. However, precise data collection and report writing are essential for practical work to effectively improve learning outcomes. When laboratory instruments are faulty, students might generate inaccurate results, compromising the learning goals. Consequently, although traditional practical approaches promote experiential learning, they frequently face obstacles due to equipment constraints, maintenance problems, and variations in measurement precision.

Traditional experimental techniques have been acknowledged as successful in developing essential scientific process skills like observation, measurement, classification, prediction and inference (Gizaw & Sota, 2023). By engaging actively in laboratory experiments, students not only gain theoretical knowledge but also cultivate cognitive adaptability and psychomotor skills. Mokhtar et. al., (2023) state that while the experimental method requires considerable preparation time, it fosters an enjoyable and captivating atmosphere that boosts students' motivation and comprehension of physics principles. In the same vein, Sahdan and Abidin (2017) highlight that well-organized and practical learning experiences are essential for successful skill development. Hands-on activities enable students to handle actual materials and tools, assisting them in absorbing the principles of scientific reasoning. Veronika et al. (2017) contend that this involvement with real-world issues enables students to reason and behave in a scientific manner.

Mwamba et. al., (2019) elaborate that conventional hands-on activities promote creativity by planning, designing, and modifying known tools to address issues, thus enhancing integrated process skills like hypothesizing, experimenting and data interpretation.

The advancement of scientific process skills in traditional environments relies significantly on the precision and quality of laboratory equipment. Murugan and Osman (2018) emphasize that precise measurement and observation are essential for skills such as classifying, inferring and interpreting data; however, these frequently fail in schools that use outdated or poorly kept equipment. Incorrect measurements, delicate parts or unsecured links can hinder learning, leading to frustration and reducing students' trust in their scientific findings. As a result, the physical handling of equipment can sometimes eclipse cognitive involvement, with students prioritizing circuit assembly over questioning and reasoning.

The EPW has developed into a contemporary teaching instrument aimed at addressing the limitations of traditional equipment. It merges simulation, automation and real-time data analysis, enabling students to perform experiments accurately and with minimized setup time (Veronika et al., 2017). By reducing mechanical errors and ensuring consistent measurements, EPW facilitates the precise observation, measurement, and deduction required for mastering scientific process skills. In contrast to conventional setups that typically demand considerable manual skill and previous technical expertise, the EPW offers organized digital assistance that improves conceptual comprehension. It provides engaging tutorials and ready-made circuit templates, allowing students to concentrate on scientific reasoning, developing hypotheses, testing assumptions and analyzing results, rather than on the technical difficulties of setting up equipment. Consequently, students interact more profoundly with the fundamental process skills.

Physical limitations of the apparatus itself can inhibit exploration. Poorly maintained or inadequate equipment can produce inconsistent results, which may confuse students rather than foster critical thinking. Inaccurate readings, loose connections or fragile components can lead to frustration and disengagement, especially if students cannot discern whether errors emerge from their setup or the equipment (Mihindo et. al., 2017). This undermines confidence in their observations and measurements and discourages the iterative experimentation necessary to develop skills like analyzing procedures.

The structure of many circuit-based practical lessons may not encourage open-ended exploration or problem-solving. When tasks are overly guided or outcomes are predetermined, students are not required to predict outcomes, design experiments or interpret unexpected results or key aspects of science process skills. In such environments, practical work becomes a demonstration

rather than an investigation, limiting the potential for students to engage deeply with the scientific process. To truly develop basic science skills, students need opportunities to make decisions, test ideas and reflect on findings, at some point elements often constrained in tightly controlled circuit-based practicals using physical apparatus alone (Ludwig et. al., 2021).

2.4.1. Knowledge Gap on Science Process Skills

Existing literature inadequately evaluates how EPW enhances essential science process skills such as observation, measurement, and communication. Although EPW supports interactive circuit validation (Kang & Temkin, 2022), research has primarily emphasized functionality rather than the development of problem-solving and analytical abilities over time. There is limited empirical evidence on whether simulated troubleshooting and repeated engagement in virtual experiments improve students' conceptual understanding and process skills compared to conventional approaches. Furthermore, there is insufficient focus on how students communicate their findings, interpret data and engage in scientific reasoning during EPW-based learning activities (Rojas, 2023), highlighting a gap in understanding how virtual labs foster scientific literacy and cognitive skill development.

2.5. Practical Skills

These are doing skills or abilities to perform a task. They include setting up experiments, manipulation of experimental equipment and writing laboratory reports. According to Bao and Koenig, (2019) students should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in an environment appropriate to and reflect the demand of learners. These activities should allow learners to use their knowledge and understanding of physics in planning, carrying out, analyzing

and evaluating their work. By having these practical skills, it is expected that learners will be able to use and be familiar with standard laboratory equipment which is deemed suitable at their levels. This should be effective throughout their experiences of carrying out their practical activities.

Once learners have acquired these skills, they should be able to demonstrate and describe ethical, safe and skillful practical technique process. They should be able to select appropriate qualitative and quantitative scientific methods to apply as found out by Al-Hassan, (2018). Setting up experiments, reading scales of equipment, manipulation of experimental data and writing laboratory reports should not be a major problem to them. They should be able to take measurements with appropriate precision and accuracy. The process of result analysis, interpretation, explanation and evaluation should be simpler to the learners (Oymak & Bekiroghu, 2017). In contrary Mwamba et. al., (2019) noted that most of physics students have recorded difficulties in setting up experiments, reading scales of equipment, manipulation of experimental data, evaluation, result analysis, data interpretation, explanation and writing up laboratory reports electronics related Kenyan to high school subjects. This study will therefore test EPW as a practical teaching and learning method which can offer a solution to such challenges. This therefore has been translated to source of low academic achievement in physics final examination; KCSE (Kenya National Examinations Council, 2021).

As mentioned by Murugan and Osman, (2018) that practical skills include setting up experiments, reading scales of equipment, manipulation of experimental data and writing laboratory reports. These are challenging activities to most students. Setting up experiments particularly electronics; where circuits are involved. Parallel and series circuits connection

processes is a challenge to most students during experiments. Some of the connecting wires tend to be quite loose, some joints have rusted. These challenges can be addressed by EPW. This is supported by Kumar, (2018) who noted that most of physics students have recorded difficulties in setting up experiments, reading scales of equipment, manipulation of experimental data, evaluation, result analysis, data interpretation, explanation and writing up laboratory reports on electronics related to Kenyan high school subjects.

The researcher noted that, despite the widespread use of physical equipment in physics education, many students continue to struggle with mastering essential experimental skills, particularly in circuit-based practical activities. One core reason is the limited exposure and hands-on time that students receive with the equipment. In many schools, especially those with large class sizes and limited resources, students may only get a few minutes of direct interaction with a circuit setup (Rojas, 2023). This time constraint which can be minimized by use of EPW, prevents deep engagement and hinders their ability to practice and internalize key skills such as assembling circuits correctly and systematically troubleshooting issues when circuits do not work as expected.

Students often approach practical sessions with a focus on obtaining the correct result rather than understanding the process. This results-oriented mindset leads them to follow instructions mechanically without comprehending the underlying principles. When reading scales on instruments such as ammeters and voltmeters, for instance, students may record values without appreciating factors like instrument accuracy or zero error. The lack of emphasis on conceptual understanding in practical contexts reduces their ability to independently interpret measurements and draw meaningful conclusions (Salutina et. al., 2024).

Reyes et. al., (2024) hinted inadequate scaffolding of experimental design skills may be detected among some students. In many cases, students are given highly structured procedures that leave little room for them to make decisions or engage in critical thinking. As a result, they do not develop the ability to plan experiments or modify procedures in response to unexpected outcomes which can be addressed by use of EPW. This is limited of individual student independence limits their ability to manipulate experimental data meaningfully, such as selecting appropriate units, plotting graphs correctly or recognizing patterns and anomalies in results.

The assessment and feedback mechanisms in practical work are often underdeveloped. Unlike when the EPW is used, students may not receive detailed feedback on their laboratory reports or data handling techniques, which leaves them unaware of their mistakes or areas needing improvement. Writing a good lab report requires not only reporting results but also explaining the rationale, analyzing sources of error and relating findings to theory. Without targeted instruction and consistent evaluation, students may see lab reports as a formality rather than a learning tool, further weakening their skill development (Mwamba, 2019).

Teachers themselves may lack adequate training or support to effectively guide students in circuit-based experiments using physical practical equipment especially when they may be faulty. Okam et. al., (2019) hinted that some instructors may focus more on theoretical aspects of physics due to time constraints which is one of the aspects that prompted the researcher to carry out this study by using EPW or curriculum demands, thus spending less time reinforcing practical skills. Additionally, outdated or malfunctioning equipment can make the learning process frustrating and unproductive. All of these factors combine to undermine the potential

benefits of using physical practical equipment in helping students acquire the full range of experimental skills necessary for scientific inquiry.

Conventional experimental teaching in physics highlights practical engagement with actual equipment and tools. Bao and Koenig (2019) state that students cultivate important experimental and investigative skills by participating directly in laboratory tasks that involve planning, conducting, and evaluating experiments. When effectively executed, these activities enhance learners' comprehension of safe, ethical and proficient practical methods (Al-Hassan, 2018). Pupils acquire skills in choosing suitable scientific techniques, measuring precisely, handling data and composing clear laboratory reports (Oymak & Bekiroghu, 2017). Nonetheless, evidence shows that numerous students find it difficult to achieve these skills in traditional environments. Mwamba et al. (2019) state that physics students often encounter challenges in configuring experiments, interpreting instrument scales, managing experimental data, and composing reports, particularly in activities related to electronics. Comparable results from Murugan et. al., (2018) emphasize that building circuits, managing delicate parts and ensuring precise measurements continue to be major obstacles. Elements like weak or corroded connections, poor equipment upkeep and restricted access to lab tools additionally hinder the development of accurate manipulation skills.

The limitations of time and resources in packed classrooms hinder personal practice. Students frequently get little practical experience, restricting their capacity to diagnose issues or explore on their own. Consequently, they might adhere to instructions in a rote manner without grasping the logic underpinning their actions. This focus on results compromises conceptual comprehension and restricts creativity in designing experiments and solving problems. Moreover, underdeveloped feedback and assessment mechanisms lead to students seldom getting

comprehensive advice on enhancing experimental precision or lab reporting. Educators encounter difficulties in enabling successful hands-on activities. In numerous resource-constrained schools, teachers emphasize theoretical teaching rather than hands-on lab activities because of a lack of materials or time (Bao & Koenig, 2019). As a result, numerous students finish the physics program with limited skills in organizing experiments, effectively handling instruments or thoroughly recording outcomes.

The EPW has developed into a contemporary teaching resource aimed at addressing the difficulties posed by traditional lab configurations. According to Veronika et al. (2017), experiential learning includes working with real or virtual tools to involve students in genuine scientific exploration. The EPW demonstrates this concept by providing a digital simulation setting that imitates physical experiments, incorporating automated measurement and analysis tools. The EPW improves hands-on skill development by minimizing setup duration and offering students reliable, flawless equipment. This enables them to concentrate on essential experimental skills, correctly assembling circuits, adjusting variables, documenting observations and analyzing results, free from the distractions of faulty equipment or setup issues. Students can continuously practice creating and evaluating electronic circuits, which strengthens procedural knowledge and boosts confidence.

In contrast to conventional approaches that typically limit exploration to set procedures, the EPW facilitates interactive experimentation and provides instant feedback. Students are able to create, evaluate, and adjust their experimental configurations instantly, noting how alterations impact the collected data. This process aids in honing analytical skills and enhances their grasp of measurement precision, uncertainty, and sources of error. Additionally, by streamlining data

entry and chart creation, the EPW enhances report writing efficiency, allowing students to concentrate on data analysis and theoretical links instead of manual calculations or formatting tasks.

In settings where educators and pupils encounter restrictions in equipment availability or technical skills, the EPW functions as a leveling instrument, guaranteeing that each learner can actively participate in hands-on experiments. It offers an organized educational platform that combines conceptual grasp, procedural skill and analytical reasoning, which are all essential elements of scientific proficiency.

The results from Bao and Koenig (2019), Al-Hassan (2018) and Kamar (2018) establish a strong basis for the significance of enhancing students' practical abilities via carefully designed experimental and investigative tasks. These researchers appropriately highlight that for students to successfully plan, implement and assess experiments, the setting must support practical involvement. Nonetheless, although the theoretical basis is solid, these studies might ignore the practical limitations encountered in numerous classrooms, particularly in under-resourced environments like Kenyan high schools, where scarce lab time and insufficient materials obstruct the optimal implementation of these teaching methods. The belief that students will inherently acquire precision, ethical awareness and analytical skills solely from participating in experiments may not be accurate without structured support and tailored assistance.

This is clearly observed when comparing these hopeful perspectives with the more realistic insights of Oymak and Bekiroghu, 2017 alongside Mwamba et. al., (2019). These researchers emphasize the ongoing challenges students face in acquiring fundamental experimental skills, particularly in electronics-related tasks. Problems like defective wiring, corroded parts and the

mechanical adherence to instructions without comprehension show that learning practical skills is much more intricate than what previous researchers have proposed. The suggestion to implement EPW as an organized, potentially digital or blended approach to address these issues is a positive solution. Nonetheless, its effectiveness depends on tackling systemic problems like equipment quality, instructor training and student-to-equipment ratios, aspects that the existing literature does not adequately address.

Establishing experiments, adjusting laboratory instruments, and composing lab reports are vital skills that allow students to implement theoretical understanding in practical settings (Bao & Koenig, 2019). They are referred to as practical skills that demonstrate the capability to design, implement, evaluate, and document scientific research efficiently. Cultivating these skills is essential for students' comprehension of physics principles and their readiness for higher education and scientific professions. Although conventional laboratory techniques continue to be the basis for developing these skills, new technological tools like the EPW are being investigated as creative options to address constraints observed in standard practical settings.

Additionally, the more detailed examination in the final section of the literature highlights notable educational deficiencies, including inadequate scaffolding and limited feedback systems during practical sessions. The tendency of students to seek the correct answer without understanding the conceptual methods behind measurements, along with instructors potentially lacking training or favoring theory over practical application, indicates a significant disconnection between curriculum goals and classroom experiences (Lopes et. al., 2024). EPW is suggested as a possible link, but to be effective, it needs strong teacher support, ongoing student involvement and improved assessment approaches. These results suggest a wider consequence:

effective practical skill development demands more than just equipment access or a novel teaching model; it needs a comprehensive reevaluation of how experimental science is taught, assessed and supported.

2.5.1. Knowledge gap practical skills

While studies acknowledge the benefits of hands-on experiments for skill development (Darbellay, 2023; Darbellay, 2024), there is a lack of research on how EPW compares to traditional labs in fostering practical skills such as experimental setup, manipulation, and accurate report writing. Existing literature often treats practical activities mechanically, focusing on task completion without linking performance to broader conceptual understanding (Chaiyasit et al., 2023). Additionally, the role of teacher preparedness, instructional assistance and resource availability in supporting students' practical skill acquisition remains underexplored (Ansah et al., 2024; Charlot, 2023). Finally, hybrid or integrated teaching strategies that combine virtual and hands-on approaches to strengthen manipulation skills and scientific reporting are minimally investigated, particularly in resource-limited settings like Kenyan secondary schools, indicating a clear research gap in bridging practical competence with academic performance.

2.6. Attitude Change towards Physics

A general assessment of the physics context in Kenyan secondary schools indicates that the subject is often regarded as an incidental or supplementary subject (Kustijono et al., 2018). Among the students, physics is regarded as a subject that is seen as conceptually challenging and only suitable for exceptionally talented and gifted individuals. As stated by Guy and Lownes (2015), these factors are linked to students' perceptions of physics and the approaches used to teach it. Students' interests and attitudes might significantly influence those studying physics.

This may affect the student's performance in the subject and their selection of the subject at form three levels.

A favorable outlook on physics can be encouraged by providing an effective learning setting, improved teaching techniques and engaging firsthand experience with the scientific process. Fernandez-Rio et. al., (2017) suggested that students ought to be exposed to self-directed learning strategies to enhance their self-efficacy and confidence in managing science-related tasks. They observed that attitude influences learning in physics and it is widely recognized that a negative attitude towards a subject hinders learning. Thus, assisting students in cultivating favorable attitudes towards physics ought to be regarded as a crucial aspect of science education.

The students' enthusiasm and disposition towards physics has been a subject of global attention. It is seen as an important indicator of their academic performance in science. Consequently, physics is regarded as challenging, which is clear from the number of students enrolling in it in Kenyan secondary schools, particularly in forms three and four. In his study, Kangangi (2017) noted that students do not study enough physics at home because most parents already perceive physics as a challenging subject. Therefore, the physics instructor needs to be more impactful in teaching and inspiring students to learn physics, especially during their time at school. Interest is regarded as one of the key motivational elements in learning and development.

Through natural sciences, students recognize the significance of science in their lives and careers, although there is a notable decline in their enthusiasm for studying these subjects. Factors influencing students' attitudes toward science include gender, age, educational level such as elementary, secondary and high school, type of school which are public or private, academic performance in sciences and social self-image (Kizilcec et. al., 2017). Additional factors consist

of the family's socio-economic standing such as education level of parents, their occupations and monthly earnings, instructional techniques, parental attitudes towards sciences, students' cognitive skills, their interest in specific career paths and societal perceptions of science and scientists (Mihindo et. al., 2017). As stated by Mihindo and other scholars, students' attitudes are viewed as an essential element in enhancing their competencies in natural sciences and mathematics, encompassing their motivation, interest and sense of self-efficacy.

Chi, (2018) noted that fostering a positive attitude towards physics can be achieved by providing a conducive learning environment, effective teaching methods and active, quality engagement with the scientific process. In light of this observation, the present study will implement EPW as a strategy for teaching and learning in physics practical sessions and assess its impact on students' attribute and academic performance in physics compared to traditional teaching and learning methods.

The researcher observed that despite the integration of physical apparatus in circuit-based practical activities, many students still exhibit a negative attitude toward physics. One core reason is the abstract nature of many physics' concepts. While practical activities are intended to bridge theory and application, some students often struggle to link what they observe in experiments to the underlying principles. For instance, seeing a bulb light up in a circuit does not necessarily lead to a deep understanding of current, voltage or resistance. Without strong conceptual grounding, the hands-on experience may feel more like a mechanical task than a meaningful learning opportunity (Kooloos et. al., 2020).

Some students have negative prior experiences and mindset towards the subject. Many students come into physics with preconceived notions that it is difficult, math-heavy and only suited for

specific students (Kizilcec et. al., 2017). These attitudes often originate from earlier educational experiences or societal stereotypes. If students already feel intimidated by the subject, then practical work may not fully change the attitude fully no matter how well the practical is designed. This can make the students feel physics physical practical devices as just like another hurdle rather than an engaging tool for understanding. This mental block can diminish their motivation to fully engage with experiments. Therefore, a motivating factor such as use of EPW which involve digital manipulative skills should be adopted improve their attitudes towards the subject.

The design and delivery of practical lessons can play a significant role. If circuit-based activities are overly guided or lack room for exploration and inquiry, students may not develop a sense of curiosity or ownership over their learning. When practicals are reduced to following instructions with little explanation or problem-solving, students may see them as tedious or disconnected from real-life applications. Effective learning through practicals requires thoughtful integration with theory and opportunities for students to hypothesize, test and reflect on outcomes (Kelley, 2021).

Resource limitations can hinder the impact of using physical apparatus. In many schools, the equipment may be outdated, insufficient in quantity or poorly maintained. This can lead to frustrating experiences where students are unable to properly complete tasks or where only a few students get hands-on experience while others remain passive. In such scenarios, the intended benefits of practical learning are diminished and students may associate physics with inefficiency and confusion rather than engagement and clarity (Kim, 2024). In this case, the EPW may come

to handle the situations involving outdated, insufficient in quantity or poorly maintained practical equipment.

Assessment practices can also influence student attitudes. If the evaluation of physics learning focuses heavily on written exams and theoretical problems, students may undervalue the importance of practical activities (Vignal et. al., 2023). They might see them as supplementary rather than central to their understanding and performance in the subject. Without proper reinforcement of the value of experimental work through assessments and classroom discussions, students are less likely to appreciate or enjoy the hands-on aspects of physics education.

Students' perceptions of physics greatly influence their motivation, involvement and achievement in the field. In numerous Kenyan secondary schools, physics is frequently seen as abstract, challenging, and appropriate only for top-performing students (Kustijono et al., 2018). These views have led to decreasing enrollment and poor performance, especially at the senior secondary level. Guy and Lownes (2015) state that these attitudes are strongly linked to the teaching methods employed and the learning contexts created. Thus, choosing effective teaching approaches, whether through traditional hands-on techniques or contemporary digital resources like the EPW, significantly influences students' views on physics.

Conventional physics practical teaching in Kenyan classrooms typically depends on teacher demonstrations and strict laboratory exercises that allow minimal scope for inquiry and exploration. Consequently, numerous students perceive physics as reliant on formulas and detached from real-life situations. Kangangi (2017) states that students seldom participate in self-directed physics study at home, a trend bolstered by parents viewing the subject as inherently challenging. This establishes a loop of diminished enthusiasm and evasion behaviors.

Traditional instructional hands-on activities aim to connect theory with actual situations. When successfully executed, these activities can cultivate curiosity and respect for the field by enabling learners to witness principles at work. Chi (2018) contends that practical involvement, paired with proper direction, can enhance a more favorable perspective on physics. Nonetheless, in numerous situations, these advantages are diminished by structural limitations like restricted laboratory resources, oversized class sizes, and antiquated or malfunctioning equipment (Mihindo et. al., 2017).

In these settings, students frequently find practical lessons to be frustrating. Defective equipment, inadequate material supplies, and hurried classes restrict students' chances for significant engagement. Rather than feeling motivated, students might experience anxiety or disengagement, viewing hands-on tasks as boring or unclear. Additionally, when evaluations emphasize theoretical tests rather than hands-on investigation, students often neglect the importance of practical education. This strengthens the belief that physics is a theoretical and unreachable field, thus diminishing their internal drive (Omwoyo, 2024).

Another constraint of traditional practical teaching is its procedural inflexibility. This involves excessive structured circuit-based tasks, where learners adhere to directions without chances for making choices, diminish curiosity and independence. Consequently, students might carry out experiments mechanically without grasping the fundamental physics principles. This reduces the desired motivational impact of hands-on work and reinforces the belief that physics is solely about finding the correct answer.

The EPW offers a different teaching method that incorporates digital interactivity into experiential education. In contrast to traditional equipment, the EPW allows students to perform virtual or electronically supported experiments with precision, reliability and instantaneous feedback. By alleviating technical obstacles like defective circuits or restricted access to tools, EPW enables students to concentrate on conceptual comprehension and exploration, instead of mechanical setup difficulties (Chi, 2018).

EPW promotes active participation via interactive simulations and real-time visualization of outcomes, boosting students' sense of autonomy and interest. Fernandez-Rio et. al., (2017) highlight that learning environments that are technology-enhanced and self-guided improve students' self-efficacy and assurance in managing scientific activities. The digital platform of EPW fosters exploration without the worry of damaging tools or incurring expensive mistakes, which can alleviate stress and enhance a more favorable emotional bond with physics.

EPW supports various learning styles and offers chances for individualized pacing, enabling students to redo experiments until they grasp the concepts. This is in accordance with modern constructivist principles, as students actively create meaning instead of just passively watching. By doing this, EPW converts practical sessions into captivating, solution-oriented activities that are applicable, reachable and fun, elements proven to enhance attitudes toward science education (Hoang et al., 2024). Through the incorporation of visual simulations and real-time feedback, EPW further enriches students' understanding of the accuracy and reasoning in physics. It connects theoretical concepts with measurable results more efficiently than old physical configurations. Consequently, students view physics as accessible and relevant to everyday situations, aiding in transforming feelings from fear to interest.

The results shared by Omwoyo, (2024) emphasize an ongoing and systemic problem in physics education at Kenyan secondary schools: the view of physics as an exclusive and unattainable subject. This viewpoint is strongly linked to unproductive teaching techniques and the absence of engaging, relevant instructional approaches. The researchers accurately highlight that students' perceptions of the subject are greatly influenced by their in-class experiences, including the methods used for teaching and evaluation in physics. Although it is praiseworthy that the literature highlights the necessity for more engaging, student-focused methods like self-directed learning strategies, there is a persistent belief that merely enhancing teaching practices will inevitably change ingrained attitudes. This neglects the larger sociocultural and institutional factors that also play a role in students' dislike of physics.

Furthermore, the different observations from Kangangi (2017) and others regarding insufficient home-based support highlights the importance of community and parental impact, yet the proposed solution frequently remains too focused on the teacher. Although enhancing teachers' ability to inspire is a key suggestion, the results downplay the importance of engaging families and communities in transforming views on science. Likewise, the impact of elements like gender, socio-economic status and school type, emphasized by Hoang et. al., (2024). Strategies such as EPW, likely indicating a digitally enhanced practical learning approach, show potential, but if broader inequities and mindset issues are not tackled, their effectiveness could be constrained or temporary. Educational reforms need to focus on making physics captivating in the classroom while also aiming to clarify the subject socially and culturally.

In the end, a thorough analysis of the design and implementation of practical activities reveals a core problem in modern teaching techniques: practicals often prioritize procedures over exploration. Incorporating EPW could offer a modern and appealing alternative to outdated and

underfunded physical arrangements, but there's a risk of perceiving it as a universal remedy. Poorly executed digital tools may reflect the same passivity that learners experience with traditional methods. Emphasizing authentic inquiry, thorough assessment and connections to real-world scenarios is crucial for the effectiveness of these changes (Jumini et. al., 2024). Therefore, while the proposed solutions, ranging from improved teaching techniques to technological innovations, are well-intentioned, their effectiveness relies on extensive systemic change, teacher training, infrastructure investment and continuous engagement with students' actual experiences inside and outside the classroom.

2.6.1. Creating Interest in Physics Practical

The education process should include simulations, displays, conferences and activities to help clarify certain physics concepts. Visual demonstrations of abstract ideas should be utilized to exemplify the scientific methods in physics and to help students connect experimental findings to Tytler et. al., (2020). Experiential learning often encourages children who are either not academically gifted or have yet to demonstrate interest in school to engage. This method ultimately results in acquiring knowledge that wouldn't be obtained through conventional show me, tell me techniques. Hands-on activities foster scientific mindsets, enhance problem-solving abilities and boost conceptual comprehension. Hands-on activities in physics aid in gaining experience with tools, devices and gear, as well as enhancing practical skills.

Skills are cultivated for interpreting various scales, direct experience is acquired and theoretical concepts are made tangible. Msimango et. al., (2024) agree with his findings that naive and scientifically basic concepts are questioned when practical activities are employed for learning. Knowledge about scientific phenomena can be inferred. Hands-on activities foster enthusiasm and curiosity for studying physics. Students generally acquire knowledge more effectively in

hands-on courses where they can handle tools and devices to understand the material. Rossoni et. al., (2024) considered practical work to be the process through which materials and equipment are thoughtfully combined.

Educators who adopt experiential learning in science appear to acknowledge specific favorable results and support student-centered teaching methods. Students participating in a practical science program will retain the information more effectively, experience a sense of achievement upon completing tasks and find it simpler to apply that knowledge to different learning contexts. When multiple learning approaches are utilized, such as hands-on learning, the likelihood of information being retained in memory for regular retrieval increases. Students participating in labs and activities gain empowerment in their learning journey.

The advantages of experiential learning center on students who may not be as academically gifted or have not demonstrated enthusiasm for science. This approach often encourages these kinds of students to engage and ultimately grasp knowledge that I think they wouldn't acquire from typical show-and-tell techniques. Interactive teaching methods make learning enjoyable (Gambari et.al, 2017). Through engaging in and experiencing science, students enhance their critical thinking abilities while uncovering scientific concepts. This self-discovery remains with students for their entire lives, even as memories diminish (Kustijono et. al., 2018)

According to Jax et al. (2019), visual representations of abstract ideas should be employed to demonstrate scientific methods in physics and to help students connect experimental findings to scientific theories. The EPW serves as a virtual illustration of abstract concepts that can help shift learners' perspectives on practical physics tasks. Using practical equipment during lab sessions has posed difficulties for certain physics students. This tends to diminish their self-

esteem in learning the topic, as noted by Stylos et. al., (2023) who stated that students should be introduced to self-learning techniques that will enhance their self-efficacy and confidence in managing science-related tasks. This is the point at which EPW begins to control mechanical mistakes and certain human errors encountered during hands-on tasks.

Based on the researcher's observations, an electronics practical workbench offers a versatile and engaging alternative to traditional physics apparatus for teaching circuit-based practical activities. The workbench is equipped with components like breadboards, power supplies, multimeters, resistors, capacitors and function generators, allowing students to construct and test various electronic circuits hands-on. Unlike static physical apparatus used in physics labs, which often focus on demonstrating fixed concepts, the workbench may provide an open-ended platform for experimentation and creativity (Ansah et. al., 2024). This flexibility may capture students' interest more effectively by allowing them to build real-world applications such as alarms, amplifiers and sensor-based systems.

The interactivity of an electronics workbench may stimulate curiosity and deepens conceptual understanding. When students build and troubleshoot circuits themselves, they could develop a stronger grasp of voltage, current, resistance and other foundational electrical principles (Alessandrini, 2023). Rather than passively observing the behavior of a system, they may become active participants in creating and exploring it. This process should enhance their problem-solving skills and may foster a sense of ownership and achievement, which can make physics feel more relevant and rewarding.

The workbenches introduce students to tools and techniques used in modern technology fields, bridging the gap between theoretical physics and engineering. By simulating real-world

scenarios such as designing a circuit for a temperature sensor or creating a simple logic gate system, students may see how physics principles apply in careers such as robotics, telecommunications and embedded systems (Lopes et. al., 2024). This career-connected learning may boost motivation, especially for students who may not initially be interested in abstract physics concepts but are drawn to practical, hands-on work.

Integrating electronics workbench into the physics practical work may support differentiated learning as recommended by CBE. Students can work at their own pace, design personalized experiments and collaborate in teams to solve open-ended challenges. Teachers can guide students through foundational experiments before allowing them to branch out into creative projects. This approach may not only sustain interest but also cultivates collaboration, critical thinking, innovation and skills essential for success in both academics and future professions (Stylos et. al., 2023).

The results from Lopes et. al., (2024), paired with insights from Dare and Roehrig (2016), make a strong argument for including experiential learning in physics instruction. Their focus on simulations, practical activities and visual demonstrations is in harmony with recognized educational theories such as constructivism, which suggests that learners build knowledge through their experiences. These strategies seem especially successful in involving students who have difficulty with conventional learning approaches or perceive abstract physics ideas as unreachable. Nevertheless, although their support for active learning is justified, the conversation would gain from more definitive proof of lasting retention and observable academic progress, instead of anecdotal or broad claims regarding engagement and understanding.

The work of Gambari et al. (2017) and Kustijono et al. (2018) expands on this experiential base by emphasizing the motivational and cognitive advantages of interactive science education. Their results emphasize the importance of self-exploration and emotional engagement in education, especially for students who are underachieving or lack interest. Although this viewpoint is crucial for meeting the varied needs of learners, it assumes that every student will equally benefit from experiential learning, which may not be the case. Certain learners gain more from organized, theoretical methods and the study could improve by recognizing this variability and offering strategies for integrating various techniques in inclusive classrooms.

The incorporation of an electronics practical workbench (EPW), as mentioned by Jax et al. (2018) and Fernandez-Rio et al. (2017), enhances the dialogue by emphasizing resources that connect theoretical understanding with practical usage. The EPW presents an engaging, student-focused method that improves technical skills and fosters enthusiasm for STEM professions. This advancement is especially beneficial for harmonizing physics education with 21st-century competencies and workforce demands. However, possible constraints must be taken into account, including resource accessibility, teacher development and the danger of becoming overly dependent on technology to fill fundamental conceptual voids (Lucas et. al., 2023). In general, the workbench model shows significant promise for varied and effective learning, but its execution should be directed by thorough educational planning.

2.6.2. Electronics Practical Workbench as Innovative Teaching Styles

Practical work involves students engaging in activities where they either observe or handle actual objects or materials, either on their own, at individually or in small groups or by watching demonstrations from the teacher. Hands-on activities can inspire learning by igniting curiosity

and pleasure. It also imparts laboratory skills and improves the understanding of scientific concepts. It provides an understanding of the scientific method and enhances proficiency in its application. It fosters scientific traits like open-mindedness and objectivity (Pascoe et. al., 2018). Practical work activities are most effectively learned and comprehended when they are arranged in a sequence from familiar to unfamiliar, starting with the less complex and progressing to the more complex. Ongoing assessments must be conducted prior to, during and following the lesson.

A facilitator model of teaching can be utilized, which often highlights student-centered learning. In this method, significant responsibility is assigned to the student to take the initiative to fulfill the requirements of different learning tasks (Panaredo, 2017). The group activities and delegator teaching methods often assign control and responsibility for learning to individual students or groups. The instructor frequently allows students to select how they create and execute their intricate learning projects, functioning in an advisory capacity (Mwamba et. al, 2019). The transition from a teacher-focused approach to a child-centered, activity-based method of teaching science is essential, as it fosters and enhances the child's spirit of inquiry. An effort to ensure that students are thoroughly informed and comprehend how scientists operate, while also equipping and readying them for potential careers in science and technology, fosters the enhancement of process skills.

It is important to recognize that for science education to be significant and applicable, it should appropriately represent the essence of science. In other words, it should be focused on processes while also highlighting the outcomes of science. It should encourage emotional responses to science and emphasize attitudes like honesty, open-mindedness, critical thinking, curiosity, patience in judgment and humility (Marszalek et al., 2019). These define scientists and the

scientific endeavor. Science process skills are characterized as cognitive and physical abilities and competencies that act as essential tools for the effective exploration of science and technology, along with problem-solving and individual and societal advancement.

The results of Pascoe et al. (2018) highlight the cognitive and procedural advantages of experiential learning in science education, offering important perspectives on how practical activities can enhance student comprehension. Nonetheless, the authors might have overstated their findings by linking the emergence of scientific attitudes such as open-mindedness and objectivity directly to hands-on activities. These characteristics are intricate and are usually developed through intentional teaching methods that encompass critical reflection, organized dialogue and clear demonstration by educators. In the absence of these elements, practical work may turn into a routine activity instead of being transformative and the presumed connection between performing and internalizing scientific thought stays fragile.

Likewise, the work of Panaredo (2017) and Mwamba et al. (2019) presents an engaging perspective on student-centered learning and the teacher's role as a facilitator, consistent with modern educational theories that highlight learner independence. However, the researchers appear to have an excessively positive perspective on students' preparedness to manage their own learning. Numerous learners, particularly those in initial developmental phases or in resource-limited environments, need greater organized assistance to cultivate the metacognitive abilities essential for efficient self-guidance. Lacking this support, the move away from direct teaching might unintentionally increase achievement disparities and lead to confusion or disengagement in students who thrive on explicit direction and organized routines.

A major limitation in both sets of results is the insufficient focus on contextual limitations, such as resource availability, teacher training and student readiness, which greatly affect the execution of optimal teaching frameworks. Pascoe et al. suggest progressively complex practical tasks under the assumption that adequate materials and time are available, conditions that are not always met in every school. Likewise, Panaredo and Mwamba et al.'s support for facilitation instead of instruction assumes a degree of classroom independence and backing that might not be attainable in numerous educational frameworks. A more refined approach would take into account the differences in classroom settings and suggest flexible strategies that connect teaching principles with real-world applications.

Marszalek et al. (2019) emphasize the importance of incorporating the nature of science into educational practices, enhancing both emotional and intellectual aspects of learning. The focus on emotional involvement and scientific perspectives aligns closely with comprehensive educational objectives. Nonetheless, their characterization of science process skills as generalized "cognitive and physical abilities" may be too vague regarding assessment and integration into the curriculum. The connection between these abilities and social progress is persuasive, but it presupposes a straightforward path from learning to effect without considering systemic obstacles. In general, although the researchers outline ambitious objectives, their results would improve with additional practical attention to implementation and fairness in science education.

Several approaches are employed to instruct practical work in physics. Research has been conducted by various researchers on the same topic. The majority of scholars have associated each methodology with its advantages in learning rather than focusing on accuracy and precision

in composing the practical report. Writing reports is among the final steps that influence success in physics education. For instance, as stated by Akpoghol et al. (2016), one teaching method that includes physics instruction is project-based learning, which highlights student understanding through real-world applications and provides students with more practical engagement compared to the conventional classroom. They contended that project-based instruction is most effective for advanced learners who are capable of working independently. The discovery involves factual information regarding the project-based instruction. Project work necessitates devices, some of which lead to the inaccuracies found in the project reports. These factors resulted in low scores in the project work, as they failed to consider how the findings should be accurately and precisely presented in the project report.

Stylos et al., (2023) recognized the subsequent effective teaching strategy as demonstration and observed that it depends on presenting new and related information to students in an approachable manner. The teacher's demonstration specifically restricts learning experiences, making it largely a teacher-centered activity. Physics students need to engage in numerous learning experiences to cultivate the necessary competencies in every concept. Chi (2018) recognized practical activities as a teaching method, noting that they aid students in gaining a solid grasp of the physics behind experimental measurements while also acquiring skills with various instruments.

Chi added that they will recall the material more effectively, experience a sense of achievement upon completing the task and can more easily apply that experience to other learning contexts. To ensure that learners experience a sense of achievement upon completing the task and can more readily apply that experience to different learning contexts, a high level of accuracy and precision in documenting the findings is essential. As pointed out by Sahdan and Abidin (2017),

the lecture method is among the approaches that certain educators employ to teach practical physics. They discovered that the lecture method includes explaining the content to students, wherein the teacher elucidates the material using basic tools, gestures, variances in voice, facial expressions and alterations in position within the classroom. They pinpointed straightforward tools for use, indicating that accuracy and precision must be ensured, especially when drafting practical reports. This approach does not address the individual differences of learners and is largely focused on the teacher's activities. It does not expose learners to practical activities, unlike what EPW will do. This research will be conducted to assess the variance in accuracy levels in composing practical reports between students using an electronics practical workbench and those using traditional methods.

Inferring, measuring, communicating, classifying and predicting abilities are among the fundamental scientific process skills that significantly contribute to the report writing process. Numerous researchers have conducted investigations on the link between hands-on work and the enhancement of science process skills. The majority of their results have focused on inferring, measuring, communicating, classifying and accurately predicting what appears on the devices; however, certain devices have been found to possess mechanical errors along with other issues. These, along with human mistakes, lead to imprecise data in the practical report. Veronika et al. (2017) state that hands-on activities in physics enhance students' familiarity with tools, instruments and equipment, asserting that these experiences influence learners' manipulative skills.

According to the research by Pascoe et al. (2018), students may become accustomed to tools, instruments and equipment alongside the mechanical errors they encounter. They also adapt to the feedback received from these devices and the hands-on skills developed from the erroneous

data could influence the learners as well. This is the reason the study suggests utilizing EPW in teaching and learning during practical work, as it will reduce both human and mechanical mistakes.

Conducting experiments, interpreting equipment measurements, handling experimental data and composing laboratory reports are among the practical abilities. Mihindo et al. (2017) asserted that students must engage in experimental and investigative tasks to enhance their practical abilities. With these practical skills, it is anticipated that learners will know how to use and be acquainted with standard laboratory equipment considered appropriate for their levels. The instruments found in certain physics laboratories have no errors, while others feature corroded moving parts, which can lead to inaccuracies in reading equipment scales, handling experimental data and composing laboratory reports. Consequently, these skills may not be cultivated effectively. This research will thus investigate the varying impacts of EPW as a technique for performing practical work on the acquisition of fundamental science process skills in contrast to traditional practical approaches.

According to Liu et al. (2023), physics is seen as a subject that is conceptually challenging and suitable only for students who are exceptionally talented and gifted. Pascoe et al. (2018) observed that the status of physics in Kenyan secondary schools indicates that the subject is regarded merely as an incidental or supplementary course. These factors relate to students' perceptions of physics and the approaches used to teach it. The interest of learners is crucial for their academic success. When students engage in hands-on tasks with malfunctioning equipment, their self-esteem regarding practical activities diminishes, while these tools should ideally introduce them to self-directed learning techniques that enhance their sense of competence and confidence in managing science-related tasks, as suggested by Fernandez-Rio et al. (2017). They

observed that attitude influences learning in physics and it is widely recognized that a negative attitude towards a subject hinders learning, which is indeed accurate.

Utilizing EPW in the teaching and practical learning process allows students to appreciate the hands-on activities since the time spent on preparing for practical work can be reduced, dangers related to high power supply in laboratories can be bypassed and they can achieve accurate and precise feedback (Mudana, 2023). This could alter the student's perspective on physics; hence, this research will assess the impact of an electronics practical workbench on students' attitude shifts towards physics in comparison to traditional practical techniques.

2.6.3. Knowledge gap on Attitude change towards physics

According to the literature, there is insufficient evidence regarding the long-term effects of experiential and digital learning tools like the Electronics Practical Workbench (EPW). Although many studies emphasize the benefits of experiential learning and tools like EPW for improving engagement and understanding in physics, a notable knowledge gap exists in determining the long-term retention of information and its applicability to other scientific areas. Numerous studies indicate heightened student engagement and temporary performance gains, yet they fall short of rigorous, long-term research that verifies whether these impacts endure beyond the immediate teaching environment. Furthermore, there is scant dialogue regarding whether EPW can promote a richer conceptual grasp or merely superficial involvement, particularly in educational contexts with limited resources typical of Kenya and analogous areas.

The exploration of sociocultural and institutional barriers in implementing EPW was insufficient. This is due to the fact that a significant portion of the literature focuses on enhancing pedagogical methods or integrating contemporary tools such as EPW while frequently neglecting

the wider sociocultural and institutional factors affecting students' perceptions of physics. Problems like ingrained societal stereotypes, parental beliefs, gender biases and disparities in schools (e.g., technology access in rural versus urban areas) are recognized but not adequately tackled. A research gap exists that assesses how these external factors could impede or promote the success of digital or experiential interventions and whether EPW strategies can be fairly applied in different school environments with varying resources.

A deficiency in focus on teacher preparedness and professional growth for EPW execution was uncovered. Aside from the notion that EPW serves as a remedy for obsolete and inefficient conventional methods, scant focus is given to the readiness of educators to embrace and successfully incorporate this technology into their teaching. The effectiveness of any educational tool greatly relies on teacher skill, but existing literature provides little understanding of how teachers are educated, their perceptions of digital tools such as EPW and the instructional support frameworks needed for successful implementation. A distinct gap exists in comprehending the professional development requirements of teachers in Kenyan secondary schools concerning digital literacy and student-centered, inquiry-driven teaching methods.

2.7. Summary of the Chapter

Hands-on learning plays a vital role in improving students' accuracy and precision in measurement during physics practical work. Through direct interaction with instruments and materials, learners develop a deeper understanding of measurement principles, error minimization, and data reliability. When students actively engage in experiments, they learn to handle apparatus systematically, take careful readings and verify results, thereby enhancing the

accuracy of their observations. According to Kumar (2018), such experiential approaches promote mastery of technical competence by allowing learners to make mistakes, reflect and correct them in real time. Consequently, accuracy in measurement becomes not only a skill but also a habit of scientific discipline, helping learners develop consistency and confidence in their experimental results, qualities that are essential for academic success and scientific inquiry.

Engaging in practical, hands-on learning significantly enhances students' acquisition of science process skills, particularly in observation, measurement, and communication. Observation skills are strengthened as learners directly explore phenomena and record detailed changes, fostering attention to scientific detail. Measurement skills are refined through repeated exposure to quantitative analysis, precision handling, and the use of appropriate instruments. Communication skills are improved when students discuss experimental findings, interpret data and present reports coherently. As Chen et al. (2024) emphasize, hands-on learning nurtures independent reasoning, enabling students to translate practical observations into meaningful scientific explanations. Moreover, the collaborative nature of laboratory work encourages peer communication, critical dialogue and scientific argumentation, all crucial for developing a well-rounded scientific mindset.

Practical activities in physics are fundamental for building students' practical skills, including setting up experimental apparatus, manipulating instruments safely and effectively, and writing comprehensive laboratory reports. When students physically engage in assembling circuits, aligning optical paths, or measuring forces, they gain tactile and procedural experience that cannot be replicated through theory alone. These experiences improve coordination, accuracy, and experimental design skills while fostering an understanding of the relationship between

theory and practice. Writing practical reports consolidates learning by encouraging students to organize data logically, analyze findings and draw conclusions consistent with empirical evidence. Kumar (2018) notes that such practical engagement not only boosts skill proficiency but also instills a sense of ownership and accountability in learning outcomes, bridging the gap between knowing and doing in physics education.

Practical and hands-on learning has a profound influence on students' attitudes toward physics by making the subject more engaging, relevant, and enjoyable. Many students perceive physics as abstract and difficult; however, experiential learning transforms it into an interactive exploration of real-world phenomena. Chen et al. (2024) highlight that hands-on activities increase motivation, reduce science anxiety and promote positive emotions associated with learning. When students experience success in experiments and witness the tangible application of concepts, their confidence and interest in physics grow, leading to more positive attitudes and greater persistence in the subject. Such positive engagement not only enhances performance but also encourages higher enrollment in physics courses, addressing the global and national concerns about declining student participation in STEM fields. Hands-on learning, therefore, serves as a catalyst for attitudinal change, transforming physics from a perceived challenge into an enjoyable and inspiring discipline.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter covers the research design, the research location, the target population, the sample size and sampling procedure, the research instruments and their piloting, data collection and data analysis procedures that were used in this study.

3.2. Research Paradigm

This is a set of beliefs, assumptions and principles that guide how a researcher views the world and approaches the process of inquiry. It defines what is considered valid knowledge, how that knowledge can be obtained and how reality is understood within a study. It provides the philosophical foundation for research, influencing the choice of methods, data collection techniques and interpretation of results (Paudel, 2024).

The study adopted the positivist paradigm; this is because it emphasizes objectivity, measurement and the use of empirical data to establish causal relationships between variables. This study aims were to compare academic achievement, accuracy of measurements, acquisition of science process skills, practical skills and attitudinal changes among students taught using the Electronics Practical Workbench and those taught through conventional methods. Such objectives align closely with the positivist worldview, which relies on quantifiable observation, controlled experimentation and statistical analysis to generate verifiable findings.

The adoption of a quasi-experimental design involving pre-test and post-test measures for non-equivalent groups further supports this paradigm, as it enables systematic comparison of the effects of the independent variable (teaching method) on the dependent variables (students'

performance and attitudes). Therefore, the positivist paradigm provided a coherent and rigorous framework for testing hypotheses and drawing objective conclusions about the impact of technology-enhanced instruction on physics practical learning outcomes.

3.3. Research Design

The study adopted a quasi-experimental design using both a pre-test and a post-test. The study included two non-equivalent groups, consisting of an experimental group and a control group that were taught practical work using different teaching methods. The experimental group was taught practical work using an electronics practical workbench, whereas the control group learned practical work through conventional practical teaching methods. The researcher opted for this design as it allowed for comparison of confounding variables by controlling them in the analysis or by selecting groups that are as comparable as possible, as indicated (Zhang, Pan & Zeng, 2023). Figure 3.1 shows the research design adopted in this study

Table 3.1: Pre-test, Post-test non-equivalent Quasi-Experimental Design

O₁ X O₃

O₂ C O₄

Key

Pre-tests: O₁ and O₂

Post- test: O₃ and O₄

X: Treatment with Electronics Practical Workbench

C: Control with conventional practical teaching method

3.4. Research Location

This study was conducted in Nairobi County, Kenya. Nairobi County, the capital city of Kenya, is located in the southern part of central region of the country, bordered by Kiambu County to the north, west and south, Machakos County to the northeast and Kajiado to the southeast. It lies 140 kilometers south of the Equator. Currently, Nairobi has approximately 81 public secondary schools. It is the largest city in Kenya, with an estimated population exceeding 4 million residents. It is the county that has the greatest proportion of secondary schools offering computer programs as one of the subjects, equipped with operational computer laboratories and additional digital learning resources. These makes it one of the top suitable research areas for this study. Owing to the large population in Nairobi, many schools have a significant number of students. This creates difficulties in finding space for growth; as a result, the classrooms and laboratories are very crowded with learners during lessons. This necessitates a contemporary approach and creative applications of the existing resources efficiently.

3.5. Target Population

The study population included 67 public secondary school and 1,639 form three physics students selected from. The schools must have been among those with average performance that offer physics as either a mandatory or optional science subject to form three students. The schools should also possess fully equipped and functional computer laboratories with electricity backup systems for power outages, the target population is illustrated in Table 3.1

Table 3.2: Target population

Sub-Counties	Number of Schools	Form 3 Physics Students of
Dagoretti North	4	108
Dagoretti South	6	126
Embakasi Central	4	96
Embakasi East	3	71
Embakasi North	4	68
Embakasi South	5	103
Embakasi West	4	95
Kamkunji	3	89
Kasarani	5	135
Kibra	3	57
Langata	2	42
Makadara	3	88
Mathare	4	60
Roysambu	7	175
Ruaraka	2	65
Starehe	4	144
Westlands	4	112
	67	1639

3.6. Sampling Procedure

The schools were selected from the list of schools provided by the County Director of Education (CDE) office. Nairobi County is segmented into 17 sub-counties and therefore, the administrative boundaries of each sub-county created a stratum. The sub-counties consist of Dagoretti North and South, Embakasi Central, East, West, North and South, Kamkunji, Kasarani, Kibra and Lang'ata. Additional sub-counties include Makadara, Mathare, Roysambu, Ruaraka, Starehe and Westlands. Both sub counties and schools were subsequently chosen using proportionate stratified random sampling for each stratum. This was determined by the number of secondary schools within each stratum. This method was adopted because it offers enhanced

accuracy of the sample size in comparison to simple random sampling by enhancing good representation across the sub counties and Entire County. It also offers a sample with considerable representation across the population under investigation (Cowden et. al., 2025).

Only a single stream took part in this study to form either experimental or control group for schools containing multiple streams with physics students. This action was taken to reduce diffusion of students from one stream to another as a risk reduction technique to internal validity, as students from the experimental or control group might interact, potentially affecting the results.

3.7. Sample Size

Out of a total of 67 secondary schools, 21 schools were samples and participated in the study. Every school had a single group, either an experimental group or a control group. The number of sampled form three students was 452. These comprised of at least 30% of every target group. Table 3.2 presents the sampling frame and the sample for the study.

Table 3.3: Sample Frame and Sample Size.

Sub-Counties	Sample Size of Schools	Sample Size of Physics Students		
		Gender		Sub-Total
		Male	Female	
Dagoretti North	3	47	44	91
Embakasi Central	3	41	40	81
Embakasi South	5	44	43	87
Kibra	3	25	23	48
Mathare	4	26	25	51
Westlands	3	48	46	94
TOTAL	21	231	221	452

3.8. Research Instruments

The study administered two Physics Practical Achievement Examinations (PPAE 1 and PPAE 2) on selected physics topics, with one administered at the start of the study and the other at its end; additionally, the study administered the Attitude Developed towards Physics Questionnaires (ADPQ I and ADPQ II), Science Skills Learnt Checklist (SSLC) and Focus Group Discussions (FGD) for students.

3.8.1. Physics Practical Achievement Examination (PPAE)

There were two of such examinations, with one given at the start of the study as a pre-test and the other administered at the end of the study as a post-test. Both tests were standard and were given to both experimental and control groups. The examinations were conducted and evaluated in a standardized way. This tool was used to collect data on accuracy in measurements, reading and recording values for objective 1, part of objective 2 involving observation skills, reading and recording (communication skills) and part of objective 3 involving practical skills such as setting up experiments and manipulation. The students participated in the identical test under the same conditions and timeframe. The pre-test assisted in determining initial performance (entry behavior) for both groups. The lowest score was 1 mark, the pass mark was 20 marks and the highest score was 40 marks. Both pre-test and post-test included the practical tasks from the selected form three physics topics including cells and simple circuits, current electricity and electronics as outlined in the Kenyan 8-4-4 curriculum.

3.8.2. Science Process Skills Learnt Checklist (APSLC)

The Science Process Skills Learned Checklist was utilized at the end of each topic for both experimental and control groups. Every science process skill received a score of 2 points. A score between 6 and 8 was considered above average, while scores of 4 to 5 were classified as

average and scores from 1 to 3 indicated below average. This was done to assess the science process skills and practical skills acquired by the students. The SPPSLC was used to collect data for both objective 2 and 3 involving both science process skills. The science process skills that were evaluated included observation, measurement and communication, with an emphasis on the levels of accuracy. Observation entailed using senses to collect data during hands-on activities; measurement included utilizing both standard and non-standard metrics to describe dimensions of an outcome.

3.8.3. Practical Skills Learnt Checklist (PSLC)

The practical skills checklist was administered at the end of each topic for both the experimental and control groups. each practical skill was scored out of 2 points, with total scores of 6 to 8 classified as above average, 4 to 5 as average, and 1 to 3 as below average. the checklist was used to assess students' practical practical skills, setting up experiments, manipulating experimental apparatus, and writing laboratory reports with accuracy and clarity.

3.8.3. Attitude Developed Towards Physics Practical Questionnaire (ADTPPQ)

This tool is a paper and pencil rating instrument that includes items representing respondents' attitudes towards physics practical work, utilizing a 5-point Likert scale with specific response statements that received grades (Refer to Appendix III). On the Likert scale, scores ranging from 4 to 5 were considered positive, while scores between 1 and 2 were viewed as negative. A score of 3 indicated indecisiveness. These responses contributed to evaluating learners' attitudes regarding this subject (Rokeman, 2024). The questionnaire was used to collect data for objective 4 which was to determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods. This

questionnaire was adapted from the Hasan Seker Questionnaire (Seker Ilhan, (2015) regarding students' attitudes towards school and altered to suit the evaluation of students' attitudes developed towards physics practical work. The questionnaire consisted of two parts, A and B. Part A contained 16 items related to physics practical lessons, while part B included 16 items focused on physics practical report writing tasks. The questionnaire was administered twice, at the beginning and at the end of the study.

3.8.4. Focus group discussion

A focus group discussion is a qualitative method for collecting data in which a researcher involves a small group of participants in a dynamic conversation to obtain their perspectives, thoughts and experiences regarding a particular subject. This research involved focus group discussions with Form 3 physics students to assess detailed understanding of accuracy level in measurement, reading and recording information during practical work. The tool was used gather information on their feelings about acquisition of science process skills, practical skills and attitude towards physics as a result of method of instruction used during the practical work. Throughout the sessions, the researcher guided open-ended dialogues, attentively listened to participants, and documented their opinions, rendering focus group discussions a highly effective approach for gathering in-depth qualitative data (Sahdan et al., 2017).

3.9. Piloting

Piloting involves carrying out an initial study before the primary research to evaluate the feasibility, validity and reliability of the research tools, methods and overall framework (Alfiyah et. al., 2025). The aim of piloting is to detect and address possible issues like unclear questions, vague instructions, logistical difficulties or problems with data gathering instruments. It aids the

researcher in fine-tuning their methods, ensuring that tools effectively gather the desired data and improving the integrity and effectiveness of the primary research. A pilot study acts as a test that reduces mistakes, conserves time and resources and enhances the overall quality and reliability of the final research results (Flake et. al., 2022).

Once the instruments were developed, they underwent a pilot test in advance before the main study. This was carried out to develop the study protocol and evaluate the feasibility of the created protocols. The efficacy of the sampling methods and sampling frame was determined during the pilot study. A pilot study was carried out to detect logistical issues in implementing the proposed research design. Evaluation of the suggested data analysis methods was also conducted at this point. These took place in four schools having 87 students within the county, where form three physics students were involved. These schools were not involved in the main study.

3.9.1. Validity of Research Instruments

Validity refers to the degree to which a method or instrument accurately assesses what it is meant to assess (Alfiyah, Zuhriyah & Chalishah, 2025). The items in all the instruments were evaluated for both face and content validity. The capability of each research tool to incorporate all necessary aspects and material to optimize scores in physics practical work was also evaluated for content validity. The internal validity of the research tools was evaluated to minimize other variables that might have affected the results. Content validity was conducted to assess the relevance of concepts covered in the tool to both independent and dependent variables. The external validity of the research tools was evaluated to determine the relevance of the findings to

different situations, groups or events. Assisted by supervisors, other experts and seasoned physics educators, these tasks were accomplished by making sure that all research objectives were explicitly defined and operationalized, while evaluating the consistency of the results with the research goals. To evaluate the internal consistency of the tool, validity tests were performed utilizing Cronbach's alpha and split-half reliability. A Cronbach's alpha value exceeding 0.70 was considered an acceptable level of internal consistency among the tools, indicating that the tools are assessing the same underlying construct. Likewise, a split-half reliability coefficient exceeding 0.70 was deemed to indicate the reliability of the tools. Although these reliability measures mainly indicate internal consistency instead of validity directly, they offer evidence backing construct validity; measuring theoretical concepts such as motivation and academic achievements by showing that the instrument reliably represents the construct it seeks to assess.

The identification and resolution of grammatical issues, as well as the comparison of acquired study findings with current literature, were also conducted. These actions were taken to evaluate the appropriateness and significance of the content in the research instruments concerning the objectives of the study. An expert created a rating scale and tally sheets for questionnaires. A performance checklist was used in the academic achievement tests.

3.9.2. Reliability of Research Instruments

Reliability refers to the degree to which the results achieved can be replicated when the research is conducted again under similar conditions, resulting from consistency in the methodology applied (Flake et. al., 2022). In this part, the precision of the research tools was evaluated. For Physics Practical Achievement Examinations (PPAE), the reliability of test-retest correlation was assessed between pre-test and post-test scores. This was achieved by plotting the data in a

scatterplot and calculating Pearson's r . A test-retest correlation of +.70 or higher was deemed to signify good reliability, as stated by Bao et al. (2019). The split-half technique was utilized to evaluate the reliability of the Attitude Developed towards Physics Practical Questionnaire (ADTPPQ). The questionnaires were numbered consecutively before being divided into two equal groups based on odd and even serial numbers. The scores for each group of items were calculated and the similarities and differences between the two sets of scores were analyzed. An inter-rater reliability test was performed to evaluate the degree to which observers or research assistants were consistent in their evaluations, ratings or judgments regarding responses from Science Process Skills Learnt Observation Checklists (SPSLOC) and practical skills. In this instance, various assessments from the observers or data collectors were contrasted with one another. This was conducted using various interview schedules and SPSLOCs.

3.10. Data Collection Procedure

The researcher acquired an introductory letter from the Directorate of Graduate Studies at Masinde Muliro University of Science and Technology. Subsequently a research permit was acquired from the National Commission for Science, Technology and Innovation (NACOSTI) and authority to conduct the research from the Ministry of Education, Nairobi County.

The schools were subsequently visited to become acquainted with the surroundings and permissions from the school principals were obtained. An introductory letter explaining the study was issued to the school principals. The research assistants (teachers of physics) received training on the nature of the study and requirement before study begun. All the form three physics students in a given class in each school took part as a collective group. All participants from three physics students sat for a pre-test on the chosen topics (cells and simple circuits,

current electricity and electronics) to gather data on overall initial performance and attitudes towards physics practical work. The study then begun by evaluating the proposed hypothesis by teaching the experimental group using an electronics practical workbench, while the control group were taught similar content by use of traditional practical teaching methods. The checklist included the following scientific process skills: observation, measurement and communication.

Table 3.4 shows the research instruments used for data collection per objective.

Table 3.4: Research instruments used for data collection per objective

Objectives	Research instrument used
1. To determine the difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method	Physics Practical Achievement Examination (PPAE)
2. To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills among students taught using workbench and those taught conventionally	Science Process Skills Learnt Checklist (APSLC)
3. To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally	Practical Skills Learnt Checklist (PSLC)
4. To determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods	Attitude Developed Towards Physics Practical Questionnaire (ADTPPQ)

A cumulative result from the three topics was collected and their averages computed to form post-test results ready for analysis. Data was gathered and examined using the suitable method described in section 3.10. Both quantitative and qualitative data was gathered from the research tools.

3.11. Data Analysis

The first objective was to determine the difference in accuracy levels when taking measurements between students performing practical work using an electronics practical workbench and those using conventional methods to do the same. Data for objective one was gathered by PPAE 1 and 2 then analysed by linear regression analysis statistical test. The second and the third objectives were to assess the impact of an electronics practical workbench as a technique for performing practical tasks on the acquisition of basic science process skills and practical skills in relation to traditional practical approaches. The data was gathered by SPSLOC and analysed by Mann-Whitney U statistical test. The fourth objective was to assess the effect of the electronics practical workbench on students' attitude shifts regarding physics in contrast to traditional practical methods. Information for objective four was gathered by ADTPPQ and analysed by linear regression analysis statistical test.

The data collected was organized and categorized into different groups, encoded and organized into tables for analysis based on the study's objectives. Based on the nature of data distribution and data type collected during the study parametric test; linear regression analysis test was used to analyse both ordinal and continuous data obtained from pre-test results, posts test results and questionnaires. Man-Whitney U Test was adopted because the two groups were independent, it was fit to examine nominal against continuous data obtained from skills learnt checklist and practical scores.

Qualitative data from focus group discussions and various sections of PPAE 1 and 2 were compiled, coded, organised and presented in a cohesive way through recurring themes.

Table 3.4: Data Analysis Framework.

	Objectives	Data Analysis Technique
1	To determine the difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method.	Linear Regression
2	To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills among students taught using workbench and those taught conventionally.	Man-Whitney U Test
3	To examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally.	Man-Whitney U Test
4	To determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods.	Linear Regression

3.12. Ethical Considerations

Prior to data collection, the research proposal was officially approved by the Directorate of Graduate Studies and the Senate at Masinde Muliro University of Science and Technology, followed by acquiring a research permit from the Kenya National Commission for Science, Technology and Innovation (NACOSTI) as per national regulations. Approval and permissions were also obtained from the County Director of Education for Nairobi County and Sub - County Education Directors in every sub-county, and the respective school principals, guaranteeing involvement from both the institutions. Every questionnaire tool was accompanied with a signed

introductory letter that introduced the researcher, outlined the study's objective and encouraged voluntary participation.

In accordance with ethical standards, the researcher obtained informed consent from every participant; individuals received detailed information regarding the objectives, methods, expected benefits and their rights, including the option to decline or withdraw without repercussions. This is consistent with findings from Kenyan studies indicating that the comprehension of consent procedures by participants is a crucial protective measure in research conducted in schools (Small et. al., 2024). The research ensured strict anonymity and confidentiality: no personally identifiable information was gathered beyond what was necessary, and all data were managed securely and privately. The data collected was used exclusively for research objectives, and only consolidated results were shared, without revealing any personal identities or individual answers.

CHAPTER FOUR

DATA PRESENTATION, INTERPRETATION AND DISCUSSION

4.1. Introduction

This chapter outlines the main results obtained from the information gathered throughout this study. The study assessed the impact of using an electronics practical workbench compared to conventional practical teaching methods in physics education by evaluating differences in measurement accuracy in practical reports, the acquisition of basic science process and practical skills in addition to changes in students' attitudes toward physics. Both quantitative and qualitative data was used in the data analysis. The analysis focuses on tackling the research objectives and questions specified in previous sections, utilizing either qualitative and or quantitative approaches as appropriate. The results are arranged thematically to ensure a coherent and logical progression, allowing for a comprehensive analysis of each main theme or variable. Where appropriate, tables, charts and figures are included to visually depict the data, providing a more profound insight into the patterns and connections revealed.

The chapter opens with a summary of the participants' demographic information, offering context for understanding the later findings. The interpretations then move on to the key themes that surfaced from the data, emphasizing important trends, repeated findings and any surprising feedback. The results are shown without discussions or commentary in this chapter, as the discussion is in Chapter Five of this document. This format guarantees an unbiased presentation of findings, establishing a strong basis for the subsequent interpretations and conclusions.

4.2. Demographic Information

Demographic information is essential to research outcomes as they offer context regarding the population under investigation. In this study factors like age, gender, education and working experiences assisted the researcher in comprehending the identity of their participants and how these attributes might affect the outcomes. Lacking this information could have led to challenge in making conclusion if the results were relevant to particular groups or if they could be biased because of an over or under-representation of specific demographics. Demographic information enabled the detection of trends, inequalities and relationships among subgroups within a population. Identifying these patterns may guide focused interventions, policy decisions and additional research suited to the requirements of those groups. It further increased the analytical in-depth by allowing the researcher to examine the relationship between demographic factors and the variables being studied. Incorporating demographic details boosted the trustworthiness and clarity of this study.

To comprehend the demographic trend of the study, socio-economic details regarding various categories of participants, including gender, age, work experience and educational level, were collected from those involved in this research. Additional information gathered includes school categories along with the number of form three physics students and availability of computers and functioning computer laboratories in sampled schools. The presence of physics labs furnished with essential electronics equipment for the research was also taken into consideration.

4.2.1. Gender of Students

Hsu et. al., (2021) defines gender as the sociocultural differences that arise from being male or female. He states that gender socially defines the traits of males and females as they grow into

men and women. The gender of students might impact the results of the study aims by influencing the ways in which male and female students interact with the electronics practical workbench compared to traditional teaching and learning techniques. According to Morpew, (2021) variations in previous experience or confidence regarding electronics and physics tasks might result in differences in measurement accuracy in practical reports, with one gender possibly achieving greater precision based on the learning method. Moreover, the attainment of fundamental scientific processes and practical abilities may be influenced by gender-specific learning preferences or support, resulting in differences in the effectiveness of skill development across various groups. Finally, perspectives on physics may vary by gender, with one group potentially demonstrating a greater increase in interest or confidence when engaging with hands-on, technology-enhanced resources like the electronics workbench versus conventional teaching methods. This study consequently recognized the gender of physics students in connection to the use of EPW, a computer-based workbench, for performing practical physics tasks. Figure 4.2.1 shows the gender proportion of the students.

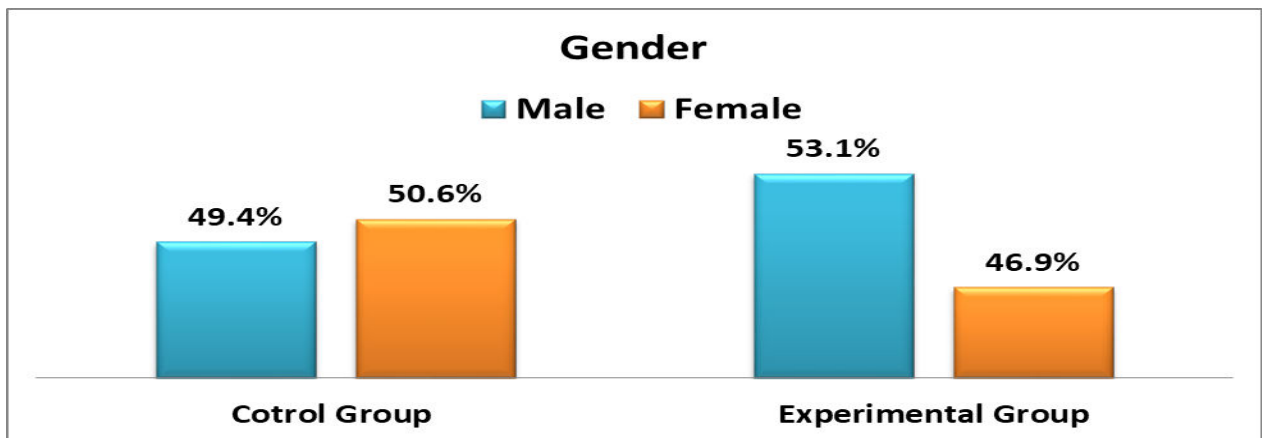


Fig. 4.2.1: Percentage Gender Representation of Students

This study was conducted in secondary schools that included pure boys', girls' and mixed schools. According to figure 4.2.1, there were 119 (49.4%) male students and 122 (50.6%) female students from the control group who participated in this study. Aside from that, there were 112 (53.1%) male and 99 (46.9%) female students, from the experimental group who took part in the study.

Electronics Practical Workbench (EPW) and traditional practical techniques might interact uniquely with the gender of physics students because sociocultural influences and previous experiences can affect how male and female students participate in these methods. Differences in confidence, familiarity with technology or learning styles linked to gender may influence measurement precision, development of scientific process skills and hands-on abilities, resulting in one gender possibly excelling based on the employed method (Gambari et. al., 2017). The perspectives on physics and engagement in practical activities may differ by gender, with students potentially reacting more favorably to interactive, technology-driven experiences such as EPW rather than conventional hands-on experiments. This study thus took into account the students' gender when examining how each hands-on method affected learning results in physics.

4.2.2. Age of Students

Yates, Starkey, Egerton and Flueggen, (2021), describes age as the total years a person has lived. The age of a learner influences how computers are utilized in their education. This is because they used a range of computing devices, from smartphones to desktop PCs. In research Msambwa et. al., (2024), examining systematic review of the factors affecting girls' participation in science, technology, engineering and mathematics subjects, it was found that boys were more inclined to utilize computers for projects compared to girls. Subsequently, Oladejo et al. (2023)

discovered that the overall computer usage for project work among boys and girls is nearly identical. The use of computers is highly favored by young people, as noted by Farillon et. al., (2022). In their research regarding games to control gaming behavior: An observation based on teenager families, Hu and Fan, (2024) observed that more than 58% of students aged 17 and below utilize home computers for gaming, while approximately 40% of those aged 11 to 17 use them to finish their schoolwork. Drawing from these views on the connection between students' ages and their enthusiasm for using computing devices in their studies, this research recognized age as an important factor to consider in the use of EPW in physics practical tasks.

The age of students might impact the study results by influencing their comfort with and ability to adapt to technology, their cognitive development stage and their previous experience with hands-on activities. Younger learners might discover the electronics practical workbench to be more attractive and user-friendly, which could result in enhanced perspectives on physics and greater advancements in essential science processes and hands-on capabilities. In contrast, older students may demonstrate improved measurement accuracy in practical reports because of their enhanced analytical abilities and previous experience, irrespective of the teaching approach. Therefore, age may serve as a moderating variable in the effectiveness with which students gain from the electronics workbench versus traditional methods. Figure 4.2.2 illustrates the percentage distribution of the ages of students who took part in this study

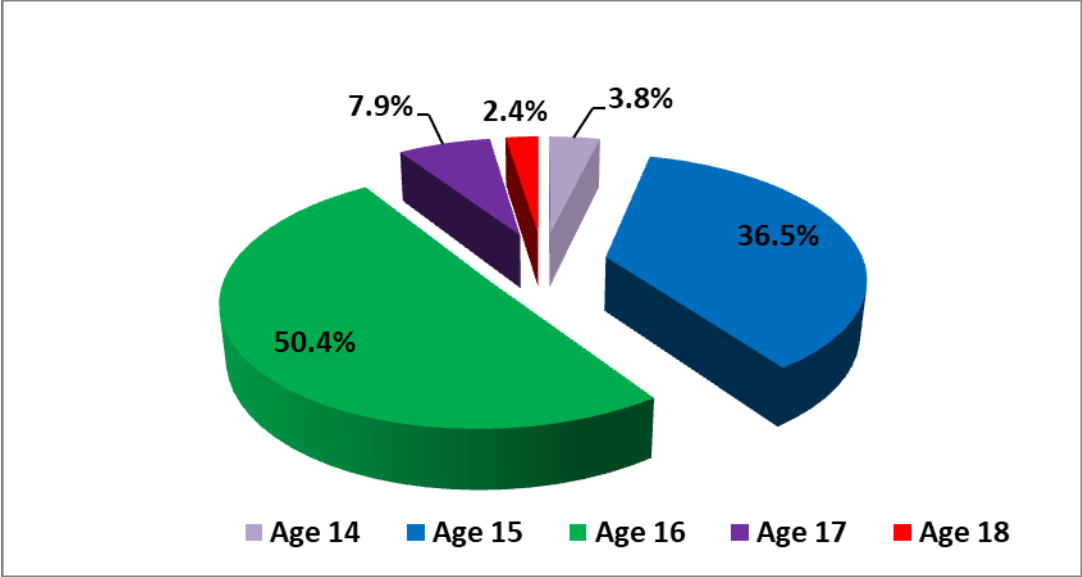


Fig. 4.2.2: Percentage representation of age of the students

According to figure 4.2.2, the ages of the form three students were identified to be between 14 and 18 years. Among those, there were 17 (3.8%) students aged 14, 165 (36.5%) students aged 15, 228 (50.4%) students aged 16, 31 (7.9%) students aged 17 and 11 (2.4%) students aged 18. The ages of the students in the control group were identified and shown as illustrated in figure 4.2.3.

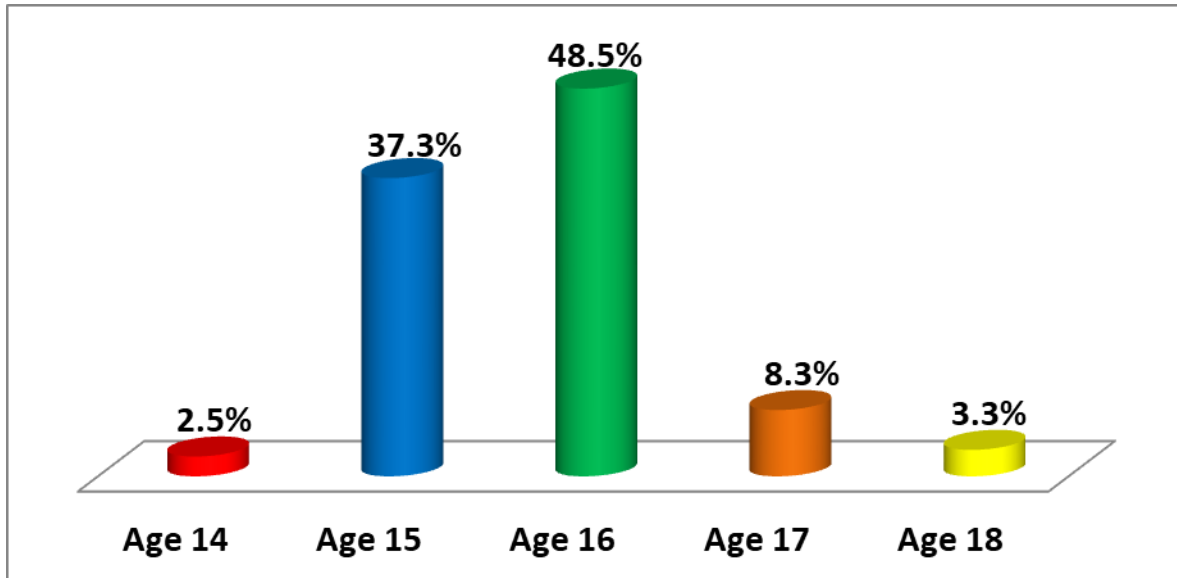


Fig. 4.2.3: Age of students in control group

According to table 4.2.3, the study found out that 6 (2.5%) students were 14 years old, 90 (37.3%) students were 15 years old, 117 (48.5%) students were 16 years old, 20 (8.3%) students were 17 years old and 8 (3.3%) students were 18 years old. Likewise, the age of students in the experimental group was assessed and displayed in figure 4.2.3

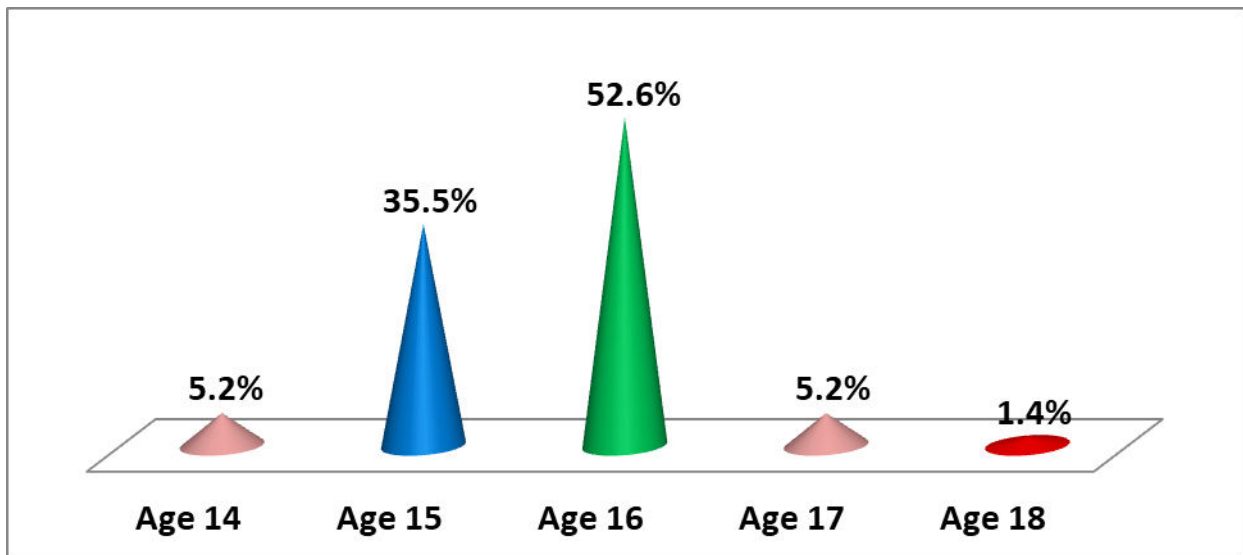


Fig. 4.2.4: Age of students in experimental group

The results shown in figure 4.2.4 indicated that the experimental group included 11 (5.2%) students aged 14, 75 (35.5%) students aged 15, 111 (52.6%) students aged 16, 11 (5.2%) students aged 17 and 3 (1.4%) students aged 18.

The age of physics students may impact the use of the Electronics Practical Workbench (EPW) and traditional practical techniques, as age influences their familiarity with technology, cognitive growth, and previous hands-on experience. Younger students might consider EPW more appealing and simpler to use, potentially boosting their enthusiasm for physics and aiding in the development of scientific and practical abilities. In contrast, older students may attain higher measurement precision and show enhanced analytical skills in practical reports, irrespective of their use of EPW or traditional approaches (Mrisho et. al., 2023). This study therefore regarded age as a variable influencing how students engage with and gain from various methods of physics practical work.

4.3. Accuracy Level of Measurements in the Practical Report

4.3.1. Introduction

This study evaluated the accuracy in measuring and recording voltages, electric currents, calculations, the application of suitable units and the conversions of those units. The use of suitable physics terminology in writing the practical report was evaluated as well. This was carried out during the first and second physics practical achievement examinations (PPEA 1 and PPAE 2). The practical mean scores of the school were examined and documented in table 4.3.1.

Table 4.3.1: General school practical mean scores before and after treatment [Experimental Group; N=211, Control Group; N=241].

Practical Mean Scores	Number of Schools			
	Experimental Group		Control Group	
	PPAE 1	PPAE 2	PPAE 1	PPAE 2
	N	N	N	N
1 1.0 - 4.9	0	0	0	0
2 5.0 - 9.9	1	0	1	1
3 10.0 - 14.9	1	0	1	1
4 15.0 - 19.9	3	1	2	1
5 20.0 - 24.9	1	2	1	2
6 25.0 - 29.9	0	3	0	0

Table 4.3.1 indicates the practical mean scores for the sampled schools before and after treatment per group. The study indicated that more schools achieved lower practical means scores at PPAE 1 than at PPAE 2. This was demonstrated in both experimental and control groups, as no school achieved a mean score within the intervals of 25.0 to 29.9 marks. The study revealed that at least one school achieved an average score within the lowest range of 5.0 to 9.9 marks in both the experimental and control groups at PPAE 1.

At PPAE 2, among the schools that hosted the experimental group, half of the schools (50.0%) attained a mean score within the highest range of 25.0 and 29.9 followed 2 (33.3%) of the schools achieved practical mean scores between 20.0 and 24.9 marks, while 1 (16.7%) of the schools achieved practical mean scores in the range of 15.0 to 19.9 marks. There was a slight positive improvement in schools with control groups at PPAE 2 in comparison to their mean scores at PPAE 1.

4.3.2. Measurement of potential difference

In the study, students carried out measurements of potential difference (p.d.) across components in a circuit using voltmeters. The outcomes achieved were recorded in table 4.3.2.

Table 4.3.2: Frequencies and percentages of students on accuracy in measurements of potential difference using 1 dry cell before and after treatment [Experimental Group; N=211, Control Group; N=241].

Measured Quantity	Range of Possible Values	Experimental Group				Control Group			
		PPAE 1		PPAE 2		PPAE 1		PPAE 2	
		N	%	N	%	N	%	N	%
Potential Difference (pd) in Volts	1.16-1.25	5	2.4	3	1.4	10	4.1	16	6.6
	1.26-1.35	21	10	4	1.9	26	10.8	29	12
	1.36-1.45	125	59.2	184	87.2	121	50.2	104	43.2
	1.46-1.55	58	27.5	19	9	65	27	75	31.1
	1.56-1.65	2	0.9	1	0.5	19	7.9	17	7.1

Based on table 4.3.2, the students subsequently took measurements of potential difference (pd) from the voltmeter. Relatively, there were some variations in the number of students obtaining voltmeter readings across different ranges in PPAE 1 and PPAE 2. The study confirmed this when the number of students in the experimental group making readings from every voltmeter range decreased, except for the range of 1.36 – 1.45V, which contains the true voltmeter reading. In this voltmeter reading range, the number of students in the experimental group achieving potential difference readings increased by 28.0%, which was greater than the rise in the number of students in the control group obtaining the voltmeter reading in the same range.

As the number of students in the experimental group able to read values within most voltmeter ranges, a comparable pattern was noted in the control group where students could obtain the p.d readings within the ranges of 1.26 – 1.35, 1.36 – 1.45V and 1.46 – 1.55V, with a rise of 1.1.6%, drops of and 4.1% respectively, taking into account that the number of students in control group who managed to get the accurate p.d reading within the voltmeter range of 1.36 – 1.45V fell by 7.0% compared to students in the experimental group students who could reading within the same rage which increased by 28.0%.

The students additionally conducted measurements for electromotive force (emf) using the voltmeter. Data obtained was documented as classified in table 4.3.3.

Table 4.3.3: Frequencies and percentages of students on accuracy in measurements of potential difference using multiple dry cells in series before and after treatment [Experimental Group; N=211, Control Group; N=241].

Quantity	Groups	Achievement Exam.	2 Cells				3 Cells			4 Cells		
			2.75-2.84	2.85-2.94	2.95-3.04	4.19-4.28	4.29-4.38	4.39-4.48	5.45-5.64	5.65-6.84	6.85-7.04	
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

According to table 4.3.3., the actual values of p.d. for 2, 3 and 4 dry cells set up in series fell within the reading ranges of 2.85-2.94V, 4.29-4.38V and 5.65-6.84V. 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 2.85-2.94V, 4.29-4.38V and 5.65-6.84V respectively. Regardless of the number of dry cells used in the circuit, the student number decreased by less than 8.6% from PPAE 1 to PPAE 2 across the remaining reading ranges. In the control group, the study observed a rise in the number of students obtaining the p.d. reading values in the ranges of 2.75-2.84V, 2.85-2.94V, 4.19-4.28V, 4.29-4.38V and 5.45-5.64V. The noted rises were 0.9%, 2.5%, 1.7%, 0.4% and 2.9% respectively. Conversely, the student number dropped 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 2.95-3.04V for 2 dry cells, 4.39-4.48V for 3 dry cells and 6.85-7.04V for 4 dry cells.

As the actual p.d. values were contained within the ranges of 2.85-2.94V, 4.29-4.38V and 5.65-6.84V, where the deviations were greater among the control group students, the study 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 away from the true values, while the number of students in that group getting readings within nearer to the true value was simultaneously increasing. The treatment allowed a greater number of students in the experimental group to make readings nearer to the true value than those in the control group. The study established that the electronics practical workbench affects measurement accuracy in physics experiments. Students then gauged pd for the 2 and 3 dry cells set in parallel with different connections. Data obtained was documented as classified in table 4.3.4.

Table 4.3.4: Frequencies and percentages of students on accuracy in measurements of Potential difference (pd) for multiple cells in parallel [Experimental Group; N=211, Control Group; N=241].

			2 cells			3 cells			
			0.01-0.90	1.00-1.90	2.00-2.90	0.01-0.90	1.00-1.90	2.00-2.90	
Potential Difference (pd); V	Experimental	PPAE 1	N	65	66	80	75	108	28
			%	30.8	31.3	37.9	35.5	51.2	13.3
		PPAE 2	N	15	180	16	13	187	10
		%	7.1	85.3	7.6	6.2	89.3	4.5	
	Control	PPAE 1	N	72	85	84	83	131	27
			%	29.9	35.3	34.8	34.4	54.4	11.2
PPAE 2		N	76	105	60	88	125	28	
	%	31.5	44	24.5	36.5	51.9	11.6		

Based on table 4.3.4, the actual pd values for both 2 and 3 dry cells linked in parallel fell within the reading range of 1.00-1.50V. The research observed from table 4.3.8 that the number of students in the experimental group who achieved the readings between 1.00 – 1.90V increased from PPAE 1 to PPAE 2 by 54% and 38.1% for 2 and 3 dry cells respectively. On the other hand, the number of students in the experimental group decreased by 23.7% and 30.3% for the readings in the ranges of 1.00 – 1.90V and 2.00 – 2.90V, respectively, when two dry cells were linked in parallel.

The number of students in the control group was noted to increase from PPAE 2 in comparison to the amount at PPAE 1. This observation occurred across all pd reading ranges except for the 2.00 – 2.90V range, where a 10.0% decrease was recorded when two dry cells were connected in parallel. In certain reading ranges, the number of students in the control group increased when 3 dry cells were joined in parallel. The ranges were 1.00 - 1.09V and 2.00 - 2.90V, with observed increases of 2.1% and 0.4%, respectively. Along with the rise, the study observed an increase of 1.6% and 8.7% from PPAE 1 to PPAE 2 among students in the control group who were able to

read values within the ranges of 0.01 – 0.09V and 1.00 – 1.90V when two dry cells were linked in parallel.

Since the actual pd value for either two or three dry cells connected in parallel was 1.5V. This value was contained within the interval of 1.00 – 1.90V, where most students in the experimental group were able to achieve their readings at PPAE 2 compared to their peers in the control group. A smaller number of students in the experimental group than in the control group managed to achieve readings that were significantly more deviated from the true values. This validated a beneficial impact of EPW on accuracy in measuring both current and pd for parallel-connected dry cells.

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 4.3.5.

Table 4.3.5: Descriptive statistics on practical mean score and average values of potential difference for multiple cells arranged in series [Experimental Group; N=211, Control Group; N=241].

	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 4.3.5, 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 true values.

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 for 1 dry cell, respectively. Nonetheless, following treatment, the mean pd value

for 1 dry cell was greater for the students in the experimental group compared to those in the control group, with a difference of 0.04V. The study 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 study also highlighted a significant decrease in standard deviation by $\alpha = 2.06$ within the students in the experimental group, leading to more precise readings at PPAE 2, bringing obtained values closer to true values. This was opposed to the increase in standard deviation among students in the control group at PPAE 2 whose decrease was dismal by $\alpha = 0.27$ indicating that majority of readings within the group were still away from the correct values

A similar trend was noted for the pd readings when two cells were used 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 study 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, deviating from the true value by a small value of 0.01 units.

The study then evaluated the relationship between accuracy in reading potential difference valuea and the average scores of practical reports. The discovery was documented as shown in table 4.3.6.

Table 4.3.6: Correlation between accuracy of potential difference values and practical mean scores [Experimental Group; N=211, Control Group; N=241].

		Group	PPAE 1 Practical Report Scores		PPAE 2 Practical Report Scores	
	Potential Difference (pd) reading		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 4.3.6, 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 statistically significant finding at PPAE 2 concerning the accuracy of pd readings with practical report scores [P-value = .0001] within the experimental group of students as reflected in table 4.3.5 at [\bar{x} = 27.99, SD =6.38 p = 0.001]. This is due to the P-value (.0001) being lower than the significance level (.05). Consequently, the intervention affected practical report scores by the accuracy of reading p.d. values. These results were opposite to those observed in the control group of students at [\bar{x} = 15.49, SD =3.32 p = 0.393] during PPAE 2. During PPAE 1 and 2, both

experimental and control groups attained more or less practical mean scores at [$\bar{x} = 15.37$, $SD = 8.44$ $p = 0.341$] and [$\bar{x} = 15.33$, $SD = 3.59$, $p = 0.426$] respectively for the experiment involving 2 dry cells. 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 study among the control group.

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 study 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.

4.3.3. Measurement of Electromotive Force (EMF)

The students conducted measurements for electromotive force (emf) using the voltmeter and 1 dry cell. Data from obtained was documented as classified in table 4.3.

Table 4.3.7: Frequencies and percentages of students on accuracy in measurements of Electromotive Force (EMF) using 1 dry cell before and after treatment [Experimental Group; N=211, Control Group; N=241].

Measured Quantity	Range of Possible Values	Experimental Group				Control Group			
		PPAE 1		PPAE 2		PPAE 1		PPAE 2	
		N	%	N	%	N	%	N	%
Electromotive Force (EMF) (V)	1.15-1.25	12	5.7	0	0	16	6.6	18	7.5
	1.26-1.35	30	14.2	3	1.4	43	17.8	28	11.6
	1.36-1.45	51	24.2	20	9.5	59	24.5	75	31.1
	1.46-1.55	98	46.4	186	88.2	86	35.7	81	33.6
	1.56-1.65	20	9.5	2	0.9	37	15.4	39	16.2

In comparing the readings in PPAE 1 and PPAE 2, table 4.3.7 shows that there was a notable decrease in the number of students reading emf values across all ranges except for the range of 1.46-1.55V, where the count increased by 28.0% among the students in the experimental group. A comparable analysis was conducted for the students in the control group during PPAE 1 and PPAE 2. The study observed a rise in the number of students able to read emf values in the ranges of 1.16 – 1.25V, 1.26 – 1.35V, 1.36-1.45V and 1.56-1.65V, with increases of 2.5%, 1.2% and 4.1% respectively among students in the control group. These ranges contained reading values with much deviations away from the true values. In addition, the number students who could read emf values in the range of 1.46-1.55V decreased by 7.0% among students from PPAE 1 to PPAE 2 owing that actual emf value was contained within the reading range of 1.46-1.55V. Students subsequently conducted the experiment again, increasing the number of dry cells to 4, adding them one at a time. The students then conducted measurements for electromotive force (emf) using the voltmeter and multiple dry cells. Data obtained was documented as classified in table 4.3.8.

Table 4.3.8: Frequencies and percentages of students on accuracy in measurements of Electromotive Force (EMF) using multiple dry cells in series before and after treatment [Experimental Group; N=211, Control Group; N=241].

	Group	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	
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

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. According to table 4.3.8, the study 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 number 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 number 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 study demonstrated that EPW affects the accuracy of reading voltage values from the voltmeter. This was validated as additional students from experimental group obtained measurements with slight variations from actual values for various dry cells connected in series during the practical tasks performed in this study.

4.3.4. Measurement of Current

The students also carried out ammeter readings while performing the physics practical activities. The data obtained was documented as classified in table 4.3.9.

Table 4.3.9: Frequencies and percentages of students on accuracy in measurements of Current (I) using 1 dry cell before and after treatment [Experimental Group; N=211, Control Group; N=241].

Measured Quantity	Range of Possible Values	Experimental Group				Control Group			
		PPAE 1		PPAE 2		PPAE 1		PPAE 2	
		N	%	N	%	N	%	N	%
Current (I) in Amperes	0.45-0.49	4	1.9	0	0	8	3.3	21	8.7
	0.50-0.54	18	8.5	3	1.4	31	12.9	26	10.8
	0.55-0.59	108	51.2	195	92.4	94	39	96	39.8
	0.60 -0.64	70	33.2	11	5.2	93	38.6	84	34.9
	0.65-0.69	11	5.2	2	0.9	15	6.2	14	5.8

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 4.3.9, 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 number 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% apart from the reading ranges that housed the true values. In the control group, the number 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 which was a low comparative increase compared to those observed among the experimental group students. It was also observed that the number of students decreased by not less than 1.3% across other present reading intervals. The students also carried out ammeter readings while performing the physics practical activities. The data obtained was documented as classified in table 4.3.10.

Table 4.3.10: Frequencies and percentages of students on accuracy in measurements of Current (I) using multiple dry cell before and after treatment [Experimental Group; N=211, Control Group; N=241].

				2 cells		3 cells		4 cells			
		Exam.	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	33.2	52.7	14.1	35.7	49.8	14.5	

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 4.3.10, 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 number 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% apart from the reading ranges that housed the true values. In the control group, the number 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 which was a low comparative increase compared to those observed among the experimental group students. It was also observed that the number of students decreased by not less than 1.3% across other present reading intervals. The students the linked the dry cells in parallel, obtained the readings from the ammeter. The data obtained was documented as classified in table 4.3.11.

Table 4.3.11: Frequencies and percentages of students on accuracy in measurements of Current (I) using multiple dry cells in parallel before and after treatment [Experimental Group; N=211, Control Group; N=241].

Quantity	Group(s)	Exam.	2 Cells				3 Cells		
			0.19-0.69	0.70-1.20	1.21-1.71	1.29-1.79	1.80-2.30	2.31-2.81	
Current I (A)	Experimental	PPAE 1	N	75	108	28	76	98	37
			%	35.5	51.2	13.3	36.1	46.4	17.5
		PPAE 2	N	20	181	10	18	187	6
			%	9.5	85.3	5.2	8.5	88.6	2.8
	Control	PPAE 1	N	86	128	27	85	121	35
			%	35.7	53.1	11.2	35.3	50.2	14.5
		PPAE 2	N	83	130	28	86	123	32
			%	34.5	53.9	11.6	35.7	51	13.3

Based on table 4.3.11, the current readings for 2 dry cells connected in parallel were within the ranges 0.19-0.69A, 0.07-1.20 A and 1.21-1.71A, whereas the readings for 3 dry cells set up in parallel were 1.29-1.79A, 1.80-2.30 A and 2.31-2.81A. With a resistance present in the circuit, the actual ammeter readings for 2 and 3 dry cells connected in parallel fell within the ranges of 0.70-1.20A and 1.80-2.30A, respectively. According to the data in table 4.3.11, there was a notable rise in the number of students in the experimental group who were able to obtain ammeter readings within the ranges of 0.70-1.20A and 1.80-2.30A for 2 and 3 dry cells, respectively connected in parallel. This rise was observed following a comparative assessment of PPAE 1 and PPAE 2.

At PPAE 2, the number of students in the experimental group obtaining ammeter readings between 0.70-1.20A for two dry cells connected in parallel rose by 34.1%. Conversely, the number of students in the experimental group able to read ammeter values between 1.80-2.30A rose by 42.2%. The two reading intervals (0.70-1.20A and 1.80-2.30A) contain the actual values of ammeter readings for both sets of 2 and 3 dry cells linked in parallel. The number of students taking the ammeter readings in the experimental group decreased by at least 8.1% across the other reading ranges.

In the control group, the number of students obtaining ammeter readings at PPAE 1 rose at PPAE 2 by 0.8% in both reading ranges of 0.70-1.20A and 1.80-2.30A, followed by an increase of 0.4% in both ranges of 1.21-1.71A and 1.29-1.79A. Conversely, the study observed a decrease in the number of students by 1.3% and 1.2% in the reading ranges of 0.19-0.69A and 2.31-2.81A, respectively, from PPAE 1 to PPAE 2.

Based on the comparative feedback between PPAE 1 and PPAE 2, the study found out that a greater number of students in the experimental group compared to the control group were able to get readings within the ammeter ranges that contained the actual values. A smaller number of students in the experimental group achieved readings within the ammeter reading ranges with larger variations from the true values at PPAE 2 than with the feedback at PPAE 1. This was validated when the number of students in the experimental group obtaining ammeter readings that significantly deviated from the true values at PPAE 2 decreased by at least 8.1%. Aside from that, the number of students in the control group obtaining the ammeter readings within the ranges that exhibited greater deviations from the true values at PPAE 2 diminished, at the same time, number of students in both reading ranges of 1.21-1.71A and 1.29-1.79A rose by 0.4% for the 2 and 3 dry cells, respectively, set up in parallel.

This consequently showed an impact of utilizing electronics practical workstations in conducting physics practical tasks. This is due to the findings after treatment indicating that the number of students in the experimental group decreased when measuring values with larger deviations from the true value, while it increased when measuring values with smaller deviations from the true value. Conversely, the number of students in the control group rose when receiving readings within certain ranges with greater discrepancies from actual values. This thus suggested an effect of utilizing an electronics practical workbench in performing physics experiments compared to traditional practical teaching and learning methods.

A simple linear regression was conducted to examine whether accuracy in reading values predicts physics practical scores. A regression model summary table was generated from

regression analysis that validated the correlation coefficient (R) and the model's strength (R^2), as displayed in table 4.3.12.

Table 4.3.12: Regression model summary for current reading accuracy values for cells in series versus practical scores [Experimental Group; N=211, Control Group; N=241].

	Group	PPAE 1 2 Cells in series	PPAE 2 3 Cells in Series
R (Correlation value)	Experimental	0.092	0.221
	Control	0.034	0.017
R^2 (Power of the Model)	Experimental	0.009	0.444
	Control	0.002	0.035

a. Predictors: (Constant) Current 2 Dry Cells in Series

b. Dependent Variable: Practical Report Scores

As indicated in table 4.3.12, the model revealed proportion of variance [$R^2 = .009$ and $.002$] in practical score explained by accuracy in readings. This means that accuracy in readings values could explain up to 0.9% and 0.2% of the practical report scores obtained by students in the experimental and control groups, respectively, before treatment. After treatment, the model revealed proportion of variance [$R^2 = .444$ and $.035$]. This means that the accuracy in reading values could explain 44.4% of the practical report scores obtained by students in the experimental group, while the existing reading values could account for up to 3.5% of the practical report scores of students in the control group. This suggested that EPW significantly influenced practical work, since the precision of the ammeter readings after treatment showed a stronger ability to explain the rise in practical report scores in the experimental group compared to the control group.

A coefficient output was generated from linear regression analysis to ascertain the nature of the relationship between a predictor variable (current value reading accuracy) and the response variable (practical report scores). This sought to further illustrate the notable disparity between the accuracy of reading the values and the results from the practical report. The information in table 4.3.13 presents the coefficient value, t-value and P-value.

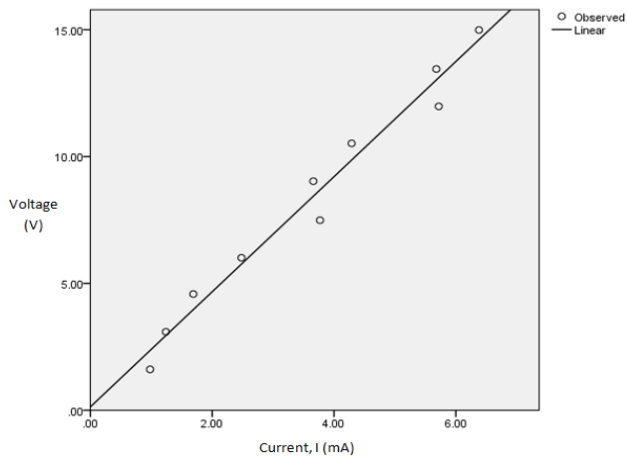
Table 4.3.13: Linea regression coefficient output between accuracy of ammeter readings and practical scores for 2 cells in series [Experimental Group; N=211, Control Group; N=241].

		Unstandardized Coefficients (B)		t-value		Sig.	
		PPAE 1	PPAE 2	PPAE 1	PPAE 2	PPAE 1	PPAE 2
Group(s)		2 Cells in Series	2 Cells in Series	2 Cells in Series	2 Cells in Series	2 Cells in Series	2 Cells in Series
Current Reading	Experimental	0.723	6.561	1.289	3.07	0.187	0.001
	Control	-0.029	0.148	0.018	0.225	0.672	0.848

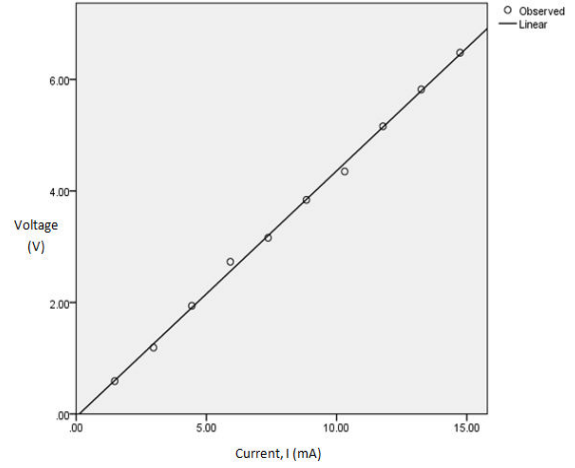
a. Dependent Variable: Practical Report Scores

According to table 4.3.13, a linear regression analysis was performed to assess if the accuracy in reading current values was a significant predictor of physics practical scores. The findings showed that the model was statistically significant for the experimental group during PPAE 2 at [B = 6.561, t (210) = 3.07, p < .05], demonstrating that for every added unit of accuracy or reading, the practical score rose by roughly 6.56 points. This was contrary to the feedback received during PPAE 1 where both the experimental and control groups revealed no significant results at [B = 0.723, t (210) = 1.289, p > .05] and [B = -0.029, t (210) = 0.018, p > .05] respectively. The model showed no statistical significance in the control group, at [B = -0.029, t (210) = 0.018, p > .05] during PPAE 2.

While the students conducted the practical activities, they obtained ten readings from the ammeter and voltmeter to demonstrate the connection between potential difference (V) and current (I). Given that Resistance (R) = $\frac{\text{Voltage}(V)}{\text{Current}(I)}$ and that voltage is directly proportional to current and the researcher was extremely focused on the accuracy of the curve. The average scores achieved by students in the experimental and control groups were calculated separately, entered into SPSS and the graphs presented in figures 4.3.6 and 4.3.7 were created.

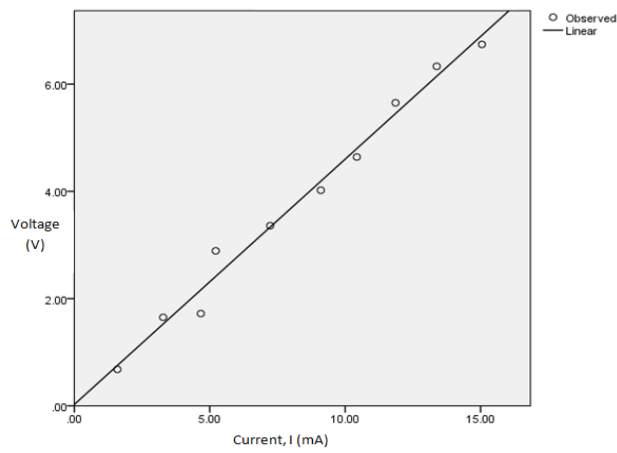


(a)

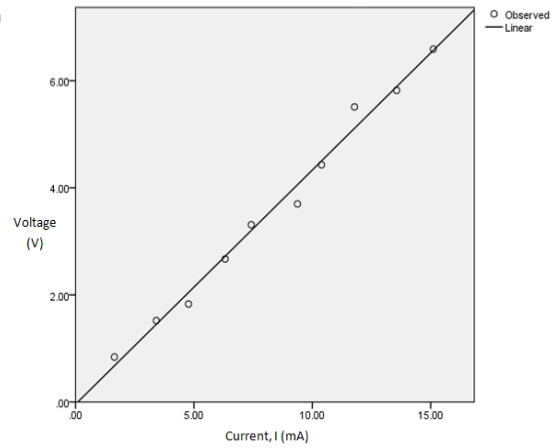


(b)

Fig. 4.3.6 (a) and (b): Voltage-current curve on measurement accuracy in experimental group (a) at PP1 and (b) at PP2



(a)



(b)

Fig. 4.3.7 (a) and (b): Voltage Current curve on measurement accuracy by students in Control group (a) at PP1 and (b) at PP2

Figures 4.3.6 (a) and (b) illustrate that students in both the experimental and control groups scored higher than the line of best fit at PPAE 1. A comparable trend was still noted in the graphs plotted by students in the control group at PPAE 2, while the graphs plotted by the students in the experimental group at PPAE 2 had a greater number of points along the line of best fit. This indicated that following the instruction of practical tasks to students in the experimental group via the electronics practical workbench, their accuracy level enhanced, as illustrated in figure 4.3.6 (b) obtained at PPAE 2, where a greater number of plotting points fell along the line of best fit. In contrast, the graph in figure 4.3.7 (b) from the control group at PPAE 2 showed that more points were outside the line of best fit.

To determine if EPW affects the accuracy of current readings and if the accuracy levels influence the practical report scores, a linear regression analysis was performed on the current reading values and the practical report scores. The results of the regression analysis are shown as a descriptive report, highlighting the correlation between the current readings and the practical report scores, as well as how much the current reading values influence the practical report scores. Two tests were given to students in both groups; the initial test occurred prior to treatment (called PPAE 1) and the subsequent test took place after treatment (called PPAE 2). The findings of the descriptive analysis were documented in table 4.3.14.

Table 4.3.14: Descriptive analysis output from linear regression between accuracy in ammeter values for 2 cells in parallel and practical scores [Experimental Group; N=211, Control Group; N=241] .

	Group	N	Mean		Std. Deviation	
			PPAE 1	PPAE 2	PPAE 1	PPAE 2
Practical Report Scores	Experimental	211	15.37	27.99	3.42	6.25
	Control	241	15.33	15.49	3.59	3.58
Mean Current Reading	Experimental	211	0.7488	1.059	0.36	0.2121
	Control	241	0.7059	0.7369	0.288	0.3738

As indicated in table 4.3.14 students from both groups achieved similar mean scores for practical reports with the experimental group scoring 15.37 and the control group scoring 15.33. Following the treatment, students in the experimental group and those in the control group achieved gains of 12.62 and 0.06 mean scores, respectively, in comparison to their mean scores prior to treatment in the practical report. Based on mean of the current readings, both experimental and control groups got means with high deviations from the true value (1.0 A). These were [$\bar{x} = 0.7488$, SD =0.36 p = 0.099] and [$\bar{x} = 0.7059$, SD =0.288, p = 0.339] during PPAE 1. During PPAE 2, there was much move closer to the true value within the experimental group at [$\bar{x} = 1.059$, SD =0.2121 p = 0.001] compared to the control group at [$\bar{x} = 0.7369$, SD =0.3738, p = 0.407]. This serves as proof that EPW impacted the scores of the practical report. The regression descriptive analysis report in table 4.3.9 indicated that the current reading values of students in the experimental group were more accurate following treatment than the accuracy levels of students in the control group and their accuracy prior to treatment. This occurred because the standard deviation decreased by .148 units closer to the true value of 1.0A for the students in the experimental group, while for those in the control group, it increased far away from the true value of 1.0A by .0858 units.

A correlation analysis was the done before and after treatment to assess the strength of the relationship between the accuracy of current reading values and the practical report scores. The feedback was displayed in table 4.3.15.

Table 4.3.15: Correlation output between accuracy in current values from 2 cells in parallel and practical scores [Experimental Group; N=211, Control Group; N=241].

		Group	PPAE 1 Practical Report Scores	PPAE 2 Practical Report Scores
Pearson Correlation	Current readings	Experimental	0.089	0.418
		Control	-0.027	0.015
Sig. (1-tailed)	Current Readings	Experimental	0.099	0.001
		Control	0.339	0.407

According to the results presented in table 4.3.10, the correlations between the current reading values and the practical report scores were lower among students in both groups prior to treatment, particularly for the control group (-.027), when compared to the correlation values observed after treatment. Following treatment, the correlation values for students in the experimental and control groups increased by .33 units and .042 units, respectively, compared to the correlation values measured prior to treatment. This indicated that adopting EPW in physics lab activities affects the scores of practical reports. This was validated by the correlation results, which indicated a notable finding among students in the experimental group post-treatment. The P-Value was determined to be .001, which is lower than the significant threshold of .05. Prior to treatment, this was not the same for students in either the experimental or control groups, with P-Values of .099 and .339, both exceeding the significance level of .05. Simultaneously, the P-

value obtained at post-treatment for students in the control group was .407, exceeding the critical level of .05.

To identify the extent of practical report scores that can be accounted for by precise readings of current values, a summary model table was generated from regression analysis that validated the correlation coefficient (R) and the model's strength (R^2), as displayed in table 4.3.16.

Table 4.3.16: Regression model summary for accuracy of current values for 2 cells in parallel versus practical scores [Experimental Group; N=211, Control Group; N=241].

	Group	PPAE 1 2 Cells in Parallel	PPAE 2 2 Cells in Parallel
R (Correlation value)	Experimental	0.089	0.218
	Control	-0.027	0.015
R^2 (Power of the Model)	Experimental	0.008	0.476
	Control	0.001	0.031

a. Predictors: (Constant) Current 2 and 3 Dry Cells in Series

b. Dependent Variable: Practical Report Scores

As shown in table 4.3.16, the model revealed proportion of variance [$R^2 = .008$ and $.001$] in practical score explained by accuracy in readings for both experimental and control groups at PPAE 1. This means that accuracy in the current readings could account for as much as 0.8% and 0.1% of the practical report scores recorded by students in the experimental and control groups, respectively, prior to treatment. At post-treatment, the model revealed proportion of variance [$R^2 = .476$ and $.031$] indicating that accuracy in reading could account for 47.6% of the practical report scores achieved by students in the experimental group, whereas accuracy in current reading values could explain as much as 3.1% of the practical report scores from students in the control group. This indicated that EPW had a significant impact on practical work, as post-treatment, the accuracy of the ammeter readings demonstrated a greater capacity to account for

the increase in practical report scores in the experimental group relative to those in the control group.

To determine the nature of the relationship between a predictor variable (current value reading accuracy) and the response variable (scores on practical reports), a coefficient output was produced through linear regression analysis. This aimed to further demonstrate the significant difference between the accuracy of reading the current values and the scores from the practical report. The data in table 4.3.17 shows the coefficient value, t-value and P-value.

Table 4.3.17: Linea regression coefficient output between accuracy of ammeter values for 2 cells in parallel and practical scores [Experimental Group; N=211, Control Group; N=241].

		Unstandardized Coefficients (B)		t-value		Sig.	
		PPAE 1	PPAE 2	PPAE 1	PPAE 2	PPAE 1	PPAE 2
		2 Cells in Parallel	2 Cells in Parallel	2 Cells in Parallel	2 Cells in Parallel	2 Cells in Parallel	2 Cells in Parallel
Current Reading	Experimental	0.846	6.416	1.294	3.22	0.197	0.001
	Control	-0.035	0.145	-0.027	0.234	0.678	0.815

a. Dependent Variable: Practical Report Scores

As shown in table 4.3.17, The findings showed that the model was statistically significant for the experimental group during PPAE 2 at [B = 6.416, t (210) = 3.22, p < .05], demonstrating that for every added unit of accuracy on reading, the practical score rose by roughly 6.42 points. This was contrary to the feedback received during PPAE 1 where both the experimental and control groups revealed no significant results at [B = 0.846, t (210) = 1.294, p > .05] and [B = 0.035, t (210) = -0.027, p > .05] respectively. The model showed no statistical significance in the control group, at [B = 0.145, t (210) = 0.234, p > .05] during PPAE 2. The null hypothesis was thus dismissed based on the comparison of coefficient values, t-values and P-values derived from linear regression analysis results conducted both prior to and following treatment.

4.3.5. Accuracy in report writing

In circuit-related physics practical activities, accuracy in report writing pertains to the accuracy with which students document and showcase their experimental findings, measurements and computations. It requires accurately recording values like current, potential difference and electromotive force making sure that the units are properly applied. Precise documentation enables reliable comparisons with theoretical forecasts and shows a correct comprehension of the experiment process, manipulation and output. The study assessed level of accuracy by looking at taking care of errors that appeared in data, identifying sources of errors, using the provided equations to carry out calculations and explain how the errors may have affected the experiment and the results. Data obtained was recorded on table 4.3.18.

Table 4.3.18: Frequencies and percentages of students on accuracy in report writing and practical scores; [Experimental Group; N=211, Control Group; N=241].

Indicators	Group	Exams	SA		A		NS		D		SD	
			N	%	N	%	N	%	N	%	N	%
1. I could easily take care of errors that appeared in data I obtained	Experimental	PPAE 1	10	4.7	86	40.8	36	17.1	51	24.2	28	13.2
		PPAE 2	33	15.6	139	65.9	18	8.5	12	5.7	9	4.3
	Control	PPAE 1	11	4.5	21	8.7	55	22.9	89	36.9	65	27
		PPAE 2	13	5.4	21	8.7	60	24.9	84	34.9	63	26.1
2. Identifying sources of errors in the physics practical work was very simple for me.	Experimental	PPAE 1	30	14.2	43	20.4	28	13.3	75	35.5	35	16.6
		PPAE 2	62	29.4	111	52.6	15	7.1	14	6.6	9	4.3
	Control	PPAE 1	19	7.9	28	11.6	63	26.2	90	37.3	41	17
		PPAE 2	25	10.4	26	10.8	67	27.8	77	31.9	46	19.1
3. I could easily use the provided equations to carry out calculations in that physics practical work	Experimental	PPAE 1	20	9.5	34	16.1	71	33.6	54	25.6	32	15.2
		PPAE 2	55	26.1	63	29.8	45	21.3	28	13.3	20	9.5
	Control	PPAE 1	23	9.5	33	13.8	40	16.6	76	31.5	69	28.6
		PPAE 2	22	9.1	35	14.5	42	17.4	78	32.4	64	26.6
4. It was very easy to explain how the errors may have affected the experiment and the results	Experimental	PPAE 1	24	11.4	41	19.4	58	27.5	64	30.3	24	11.4
		PPAE 2	63	26.1	83	34.4	28	11.6	24	10	13	5.4
	Control	PPAE 1	9	3.7	22	9.1	49	20.3	92	38.2	69	26.6
		PPAE 2	14	5.8	24	9.9	59	24.5	86	35.7	58	24.1

Table 4.3.18 shows that students in the experimental group were able to effectively address errors present in the data they collected. This was confirmed by 33 (15.6%) and 139 (65.9%) of the students who agreed strongly and agreed, respectively. The research observed that the percentage rise from PPAE 1 and PPAE 2 was 10.9% and 25.1% of students who found it easy to manage relevant errors in the data they collected among those who strongly agreed and agreed, respectively. This was in contrast to 12 (5.7%) and 9 (4.3%) of the students who disagreed and strongly disagreed, respectively, while 18 (8.5%) were uncertain. Aside from that, the study showed a reduction in the number of students who struggled to manage the relevant errors found in the data they collected. The declines were 18.5% for students who disagreed and 8.9% for those who strongly disagreed. In the control group, 11 (4.5%) of the students strongly believed they could easily manage errors in the data they collected, reflecting a 5.4% increase in PPAE 2 from 4.5% at PPAE 1. An additional 21 students (8.7%) at PPAE 2 shared that viewpoint, which remained unchanged compared to the student number at PPAE 1. Conversely, 84 (34.9%) of the students at PPAE 2 expressed disagreement with the notion that it was simple for them to manage the errors in the data they collected.

This case was comparable but more severe, with 63 (26.1%) of the students in the control group expressing strong disagreement in the same assessment regarding their ability to manage errors in the data they collected. The study indicated that the number of students in the control group who failed to address appropriate errors fell by a lesser degree in contrast to those in the experimental group, demonstrating the effect of the treatment given to students in the experimental group, specifically the implementation of EPW during practical work. As a result, addressing errors in the data collected during physics practical work was more manageable for a

greater number of students in the experimental group compared to those in the control group at PPAE 2.

More students from the experimental group found it easier to identify sources of errors in the physics practical work compared to those in the control group after the treatment. This was disclosed following the instruction of practical tasks to both student groups and the experimental group using two distinct teaching techniques. To back that up, the study highlighted that 62 (29.4%) and 111 (52.6%) students from the experimental group acknowledged their capability to recognize sources of mistakes in the physics practical task by strongly agreeing and agreeing respectively. The two percentages showed that 29.4% and 52.6% of the students in the experimental group strongly agreed and agreed, respectively, that identifying sources of errors in that physics practical work was very easy for them at PPAE 2.

In comparison to their peers in the control group, where 25 (10.4%) and 26 (10.8%) strongly agreed and agreed, respectively, that identifying sources of errors in that physics practical was easy, there was a minor rise of 2.5% in the number of students who strongly agreed and a 0.8% decline among those who agreed. Conversely, for the students who disagreed and those who strongly opposed the idea, recognizing sources of errors in that physics practical task was not perceived as very easy. A confirmation was shown when 14 (6.6%) students in the experimental group compared to 77 (31.9%) of the control group disagreed with the notion that it was easy to pinpoint sources of errors in that physics practical work at PPAE 2. Moreover, 9 (4.3%) students in the experimental group and 46 (19.1%) from the control group expressed strong disagreement, with a higher proportion of 14.8% of students in the control group indicating greater difficulty in identifying errors in that physics practical work at PPAE 2. While these were being disclosed, 15

(7.1%) students from the experimental groups and 67 (27.8%) students from the control group were uncertain about the ease of identifying sources of errors in that physics practical work. The growth in the number of students from the experimental group, surpassing those from the control group who could recognize sources of errors at PPAE 2, indicated the impact of EPW on teaching and learning physics practical work.

Some students found it easy to use the given equations for necessary calculations in that physics practical work, while others found it challenging. A total of 55 (26.1%) and 22 (9.1%) students from the experimental and control groups, respectively, strongly agreed that they could effortlessly utilize the given equations to perform essential calculations in the physics practical activity at PPAE 2. This assertion was subsequently backed by 63 (29.8%) students in the experimental group and 35 (14.5%) students in the control group, who concurred that they could easily utilize the given equations to perform essential calculations in that physics practical during the same exam. In comparison, while the number of students in the experimental group who utilized the given equations for essential calculations in that physics practical work at PPAE 2 was rising significantly, the number of students in the control group who felt they could use the offered equations for those calculations diminished. This indicated that EPW affected students' capability to apply the given equations for performing required calculations. At the same time, 45 (21.3%) students in the experimental group were uncertain about the ease of using the given equations for performing required calculations in that physics practical task. A comparable situation occurred with 42 (17.4%) of the students from the control group. Other students either completely disagreed or merely disagreed with the idea that they could effortlessly utilize the given equations to perform required calculations in that physics practical activity.

In PPAE 2, there were 28 (13.3%) and 20 (9.5%) of the students in the experimental group who concurred and strongly concurred, respectively, indicating a decrease in the number of students in this group by 12.3% and 5.7%, respectively, from PPAE 1 to PPAE 2. In the control group, 78 (32.4%) and 64 (26.6%) of the students expressed agreement and strong disagreement, respectively, at PPAE 2, reflecting a 0.9% increase and a 2.0% decrease in the number of students from that group who found it somewhat difficult and very difficult, respectively, to easily use the given equations for performing necessary calculations in the physics practical work. The more significant reduction in the number of students from the experimental group compared to their control group counterparts, who were able to easily utilize the provided equations for essential calculations in the physics practical at PPAE 2, indicated that EPW had an impact on using the provided equations for calculations in practical work.

Sixty-three (26.1%) and eighty-three (34.4%) students in the experimental group found it easy to express how the errors might have affected the experiment and results, with those strongly agreeing and agreeing respectively at PPAE 2, showing percentage rises of 14.7% and 15.0% from PPAE 1. The support for this was observed in 14 (5.8%) and 24 (9.9%) of the control group students in a similar order at PPAE 2, showing a rise of 2.1% and 0.8% respectively from PPAE 1.

In contrast, 24 (10.0%) and 13 (5.4%) of the students in the experimental group disagreed and strongly disagreed with the view that it was very simple to clarify how the errors might have influenced the experiment and results. This showed a reduction in both cases of 20.3% and 6.0% respectively at PPAE 2 compared to PPAE 1 among the students in the experimental group. Discrepancies were also noted with 86 (35.7%) and 58 (24.1%) of the students in the control group who disagreed and strongly disagreed, respectively, with the belief that it was quite simple

to clarify how the mistakes might have influenced the experiment and its results. In this instance, the research observed a minor decrease in the number of students by 2.5% from PPAE 1 in both groups of students who disagreed and strongly disagreed that it would be easy for them at PPAE 2 to articulate how the errors could have impacted the experiment and its results. During this event, 28 (13.3%) students in the experimental group were uncertain, while 59 (24.5%) students in the control group were also unsure.

This study observed that the simplicity of clarifying how the errors potentially impacted the experiment and results was more favored by the students in the experimental group than those in the control group at PPAE 2. This was due to a greater increase in the number of students from the experimental group compared to the control group who were able to articulate how the errors may have influenced the experiment and its outcome at PPAE 2 and vice versa for those who couldn't. As a result, the suggested that EPW impacted students' ability to articulate how the errors could have influenced the experiment and its results.

The trend in the experimental group showed that the number of students who agreed that it was easy to manage appropriate errors in the data they gathered increased, while those who disagreed decreased from PPAE 1 to PPAE 2, indicating that EPW influenced academic success when implemented in teaching and learning physics practical work. Moreover, the study observed that at PPAE 2, more students in the experimental group than in the control group were able to manage errors, recognize sources of errors, utilize given equations to resolve numerical issues and articulate how errors might have influenced the results of the experiment while composing their practical reports.

The mean rating averages for each respondent were calculated and examined using linear regression statistical tests in relation to practical report scores from PPAE 1 and PPAE 2 reports which was acquired was documented as displayed in table 4.3.19.

Table 4.3.19: Descriptive analyses mean rating on accuracy in report writing and practical scores [Experimental Group; N=211, Control Group; N=241].

	Group	N	Mean		Std. Deviation	
			PPAE 1	PPAE 2	PPAE 1	PPAE 2
Practical Report Scores	Experimental	211	15.37	27.9905	3.419	6.38
	Control	241	15.33	15.487	3.585	3.361
Mean Rating	Experimental	211	1.7536	3.1555	0.8205	0.686
	Control	241	1.95	2.081	0.864	1.009

According to table 4.3.19 and 4.3.20, average mean scores from students in both groups were approximately identical prior to treatment, showing a difference of .04 marks. Following treatment, students in both groups demonstrated an increase in their average practical report scores by 12.62 marks and 0.157 marks in the experimental and control groups, respectively. At the same time experimental group attained higher mean rating during PPAE 2 at [$\bar{x} = 3.255$, SD =0.686 p = 0.0311] compared to the control group at [$\bar{x} = 2.081$, SD =1.009 p = 0.412] This demonstrated an impact of employing EPW in practical tasks on the scores of practical reports when compared to traditional practical conduction techniques.

The linear regression analysis produced correlation results to determine the strength and direction of the linear relationship between the average rating from the Likert scale on accuracy in practical report writing and the scores of practical reports. The correlation results are presented in table 4.3.20.

Table 4.3.20: Correlation output between mean ratings on accuracy in report writing and practical scores [Experimental Group; N=211, Control Group; N=241].

		Group	PPAE 1 Practical Report Scores	PPAE 2 Practical Report Scores
Pearson Correlation	Mean Rating	Experimental	0.041	0.34
		Control	-0.042	0.014
Sig. (1-tailed)	Mean rating	Experimental	0.278	0.0311
		Control	0.26	0.412

As shown in table 4.3.20, the correlation among students in both groups was less before treatment than the correlation value recorded after treatment. The students in the experimental group achieved correlation values of .041 and .34 prior to and following treatment respectively. Conversely, the control group students achieved correlation values of -.042 and .014 prior to and following treatment. A summary model table was created from regression analysis to illustrate the extent to which the amount of practical report scores can be attributed to accuracy in writing reports, confirming the correlation value (R) and model strength (R²), as displayed in table 4.3.21.

Table 4.3.21: Regression analysis summary model on mean rating of accuracy level in report writing and practical scores [Experimental Group; N=211, Control Group; N=241].

Indicators	Group	PPAE 1	PPAE 2
R (Correlation value)	Experimental	.041a	0.34
	Control	.042a	0.054
R ² (Power of the Model)	Experimental	0.002	0.11
	Control	0.002	0.0001

a. Predictors: (Constant), Mean Rating

b. Dependent Variable: Practical Report Scores

In table 4.3.16, the model revealed proportion of variance [$R^2 = .002$ and $.002$] in practical score explained by accuracy in readings for both experimental and control groups at PPAE 1. This was

different at PPAE 2 when the proportion variance (practical scores) explained by accuracy in report writing were [$R^2 = .11$ and $.0001$]. The accuracy in writing practical report could explain 0.2% of the achieved practical report scores in both groups before treatment. After treatment the percentages changed in that accuracy in report writing could explain 11.0% of the achieved practical scores among students in experimental group and 0.01% of the attained practical report scores among students in control group. This showed that using EPW in practical work has an effect on accuracy of practical report writing which translates to better scores in the reports themselves.

The direction of the relationship between accuracy in writing practical reports; having mean ratings from a questionnaire likert scale and the practical report scores was determined by linear regression. Existence of significance difference between the accuracy in practical report writing and the practical report scores was also established through linear regression. A coefficient output table was generated and presented in terms of coefficient value, t-value and P-value as shown in table 4.3.22.

Table 4.3.22: Regression coefficient output on accuracy level in report writing and practical scores [Experimental Group; N=211, Control Group; N=241].

		Unstandardized Coefficients (B)		t-value		Sig.	
	Group	PPAE 1	PPAE 2	PPAE 1	PPAE 2	PPAE 1	PPAE 2
Mean Rating	Experimental	0.268	4.57	0.589	0.868	0.556	0.023
	Control	-0.173	0.048	-0.042	0.014	0.0521	0.824

a. Dependent Variable: Practical Report Scores
Based on table 4.3.22, at the beginning, the findings indicated that the model was not statistically significant for both experimental and control groups during PPAE 1 at [$B = 0.286$, $t(210) = 0.589$, $p > .05$] and [$B = -0.173$, $t(210) = -0.042$, $p > .05$] respectively. The findings therefore

showed that as the accuracy of report writing in terms of mean rating units increases, the practical report scores were also increasing by .268 units among the students in experimental group. This was contrary with findings obtained at the same time among the students in control group, where increase in the accuracy of report writing in terms of mean rating units seemed to reduce the practical report scores by .173 units.

After treatment, the findings showed that the model was statistically significant for the experimental group during PPAE 2 at $[B = 4.57, t(210) = 0.868, p < .05]$, the accuracy in report writing in terms of mean rating units among students in experimental group could raise the practical report scores by 4.57 units compared to increase by .048 units among the students in control group at $[B = 0.048, t(210) = 0.014, p > .05]$. This was a confirmation that application of EPW has an influence on the accuracy of report writing which can translate to better practical scores. The study further assessed the t-values from linear regression analysis before and after treatment. The t-values obtained further gave stronger evidence against the null hypothesis among the students in experimental group than the students in the control group after treatment. This is because t-value was higher among students in the experimental group (.868) than that among the students in the control group (.014) after treatment. This was contrary to the t-values obtained before treatment in both groups where t-values were much lower especially among students in the control group where the t-value was -.042. The evidence against the null hypothesis was later proved by P-values obtained in the coefficient table 4.3.13 which was below significant level of .05 after treatment among students in experimental group. This was contrary to the P-values obtained before treatment among students in both groups and even among the students in the control group after treatment where the P-values were above significant level of .05. The null hypothesis was therefore rejected based on comparison between the coefficient

values, t-values and P-values obtained from linear regression analysis results both before and after treatment.

When asked to mention some of the challenges physics student encounter while carrying out calculations involved in the physics practical work. Some teachers who were handling the experimental group pointed out that some computer operations were challenges to the students while carrying out practical work at the initial stages. These included finding a scientific calculator in the computer and using it and generating practical graphs after feeding in values variables among others as could be quoted as follows.

ST-EXP-PPAE 2 ‘.....In the initial stages, some of the students took time to perfectly learn how to use the Electronics Practical Workbench (EPW) which involved computer applications. So knowing how to use computer is one thing and applying EPW it is another thing. Some software like calculators, generating graphical output was not easy, but as time goes, they were able to do it effectively and consistently.....’

TE-EXP-PPAE 2 ‘....viewing the practical process in the computer screen was a challenge to some students. Some of them could complain of screen brightness which was minimized by adjusting the screen.....’

ST-EXP-PPAE 2 ‘.....In my school students faced the challenge of frequent blackout interruption, even though there was a standby generator, there were interruptions in the Kenya power electricity interchange with the standby generators....., but they managed to carry out all the practical and they performed well....’

When responding to a question during FGD on how they could take care of errors that appears in measured their data, some students noted that they were not able to detect the errors themselves as was quoted below;

ST – CON- PAE 1 “....what do you mean by taking care of the error, I did not know the errors, .. so how could I begin to control what I don’t know....’

ST-EXP-PAE 1: “I did not know that I was making errors until the teacher came and connected for me the dry cells well, so the teacher helped me to control the error which I was making.....”

ST-CON-PAE 2. “ mwalimu I don’t understand what you mean by controlling errors, the error I saw was..... was when my bulb went off while I was doing the experiment, so I could not observe its brightness increasing or reducing...”

ST-EXP-PAE 1 “...you mean.... Making mistakes during practical or what do you mean, teacher!... for me I could call the lab technician to help me connect my circuit, ... because it refused to work when I did it for the first time...”

Apart from them, some students could do the same practical more than once, others could call the teacher or the laboratory technician to first help them confirm their set ups before they begin getting readings. Other students mentioned testing the values obtained using relevant equations as were quoted below;

ST-CON-PAE 1 “...me I could repeat the experiment twice and confirm whether I could get the same values I obtained in the first one.”

ST-EXP-PAE 2 “I used the computer to do my experiment, but I did not see any error because the values I got were almost similar to the ones I could have gotten when I used Ohm’s law equations to get current or voltage..”

The findings in this study concur with those of Banik and Biswas (2017) noted that taking repeated measurements is one of the ways to control errors in measurements. They added that it is good to take measurements at least twice to enable you know whether the instruments used are accurate or not by comparing obtained set of measuring values. Chi (2018) recommended use of large samples to ensure that errors are minimized or completely eliminated while Guy and Lownes (2015) hinted that some of the ways of controlling the errors should be making sure that students are well trained on procedures involved.

The findings from descriptive statistics showed that the experimental group outperformed the control group notably after the treatment. Although both groups possessed nearly the same mean scores and readings prior to the treatment, the experimental group exhibited significant

enhancements afterward, realizing a considerably higher mean practical report score (27.99 compared to 15.49) and showing improved accuracy and precision in potential difference (pd) readings. Their post-treatment outcomes were consistently nearer to the true values, exhibiting smaller deviations and lower standard deviations compared to the control group, whose enhancements were minimal in certain instances, characterized by greater variability. These results indicate that the intervention, specifically the implementation of the workbench significantly improved the performance of the experimental group.

The accuracy level in measurement refers to how close the measured value is closer to the standard true value (Veronika et al., 2017). To achieve accuracy, a small reading is done to reduce potential errors. When using a measuring device, accuracy can be evaluated by examining the accuracy point of the instrument, which is identifiable at a specific location on its scale. It can also be calculated as a percentage of the scale range, which entails an increase or decrease in a measured value by a specific percentage. As stated by Chklovski et. al., (2023), accuracy refers to how close the measured value is to the true standard value, whereas error represents the variance between the approximation and the true standard value. Consequently, error assists in assessing accuracy in measurements. Chklovski et. al., (2023) observed that the accuracy of measurement can be affected by an inadequate understanding of the object being measured, influenced by varying elasticity levels under different environmental conditions.

Farillon et. al., (2022) pointed out that the accuracy of measurements can be influenced by the failure to consider all potential factors impacting the object during measurement. For instance, when assessing free fall acceleration, the influence of air resistance can be disregarded. It is the resolution of a measuring device that causes limitations on smaller differences, potentially

affecting measurement accuracy as stated by Farillon et. al., (2022). Before carrying out any measurements, the calibration of a measuring device should be verified, if there are uncertainties, the user of the instrument should compare the calibrations with those of other similar or related instruments. A zero offset must be done prior to taking any measurements with the selected apparatus or instrument. In the absence of this, the outcome will typically exhibit consistent errors. The student conducting the measurement should acquire several measurements across a specified suggested range to uncover variations that could remain unnoticed. Parallax, as a mistake that happens when there is a gap between the measuring scales and the indicator used for taking measurements, can affect the accuracy of the results. Instrument drift such as deviated pointer away from zero mark, which can happen over time primarily in electronic measuring devices, may lead to considerable inaccuracies in the long term. Human mistakes due to negligence, incorrect measurement, reading methods and any form of bias in the measurements can lead to inaccurate values.

A linear regression analysis showed that the experimental group had higher mean practical report scores after treatment compared to the control group, along with decreased standard deviations from pre-treatment to post-treatment. At the onset of the study, the average scores of the practical report were fairly similar for students in both the experimental and control groups. This conclusion aligns with the research of Bao and Koenig (2019), who identified ICT integration in hands-on tasks as a method for enhancing students' academic performance. They encouraged instructors of science-related subjects to involve students more in utilizing digital media for conducting experiments, field trips and projects. This is due to the fact that accuracy is improved via this type of media.

A correlation output also showed more favorable results in all readings post-treatment among students in the experimental group compared to those in the control group. Prior to treatment, the situation was different, as students in the control group noted a negative correlation in one of their readings, while those in the experimental group recorded consistently poor positive values across all their readings. The research also validated statistically significant outcomes for all readings post-treatment among the students in the experimental group, which was not observed prior to treatment. On the other hand, the research established that there were no significant results in any assessments for students in the control group, both prior to and following the treatment. Consequently, there was compelling evidence that an electronics practical workbench affects the accuracy of measurements during physics lab work. Consequently, the initial hypothesis asserting that there is no difference in the accuracy of writing up practical reports between students using an electronics practical workbench and those employing the conventional method was dismissed.

Minimizing sources of errors in scientific practical work is crucial. Data must be highly accurate and precise, indicating how near the measured values are to the true values. For a clear interpretation of data, the accuracy and precision of the collected information are crucial (Ampiah, 2014). To achieve this, the research highlighted that organizing a physics practical necessitates, among other things, checking the calibration of a measuring device prior to its use, by comparing its calibration with that of another similar or related device. In the event of a zero error, adjust the zero reading before operating the device or instrument. As stated by Chesitit (2015), these are several time-consuming factors during a practical exam if not addressed beforehand by the student, teacher or laboratory technician. Conversely, EPW was discovered to face minimal challenges regarding the preparedness of the equipment for use in practical tasks.

The research revealed that key factors contributing to errors included substandard working conditions of the existing equipment and the inability to take precise measurements. This aligned with the discovery of Dare and Roehrig (2016), who identified parallax (the distance error between the measuring scales and the observer or indicator) as a source of error in practical work. He additionally connected negligent scale reading to the observer as another source of mistake.

Cook and Artino (2016) stated that to incorporate a graph in practical tasks, a student must recognize the variables, establish the range of the variables, decide the graph scale, number and label each axis and plot the points on the graph. Upon plotting the points, the students must create the graph and include an informative title. Gambari et. al., (2017) elaborated that many graphs in physics feature a line of best fit. They subsequently clarified that, in order to create a line of best fit, the student ought to disregard outliers, the line must represent the data trend with most points aligning along it, and it should remain equidistant from the points above and below. Homer et. al., (2014) advised students against trying to make the line intersect particular data points or the origin. The primary purpose of this line of best fit is to illustrate the trend among all the identified points. Jax et. al., (2019) highlighted that the primary purpose of establishing a line of best fit is to reduce the impact of errors, specifically random and systematic errors. They believe that the line of best fit enhances the accuracy and reliability of the experiment in the practical work. They additionally connected the application of the slope of the line of best fit to identify unknowns that may be recognized in the experiment.

The research results led to the rejection of the null hypothesis, which asserted that there is no difference in the accuracy of writing up practical reports between students using an electronics practical workbench and those using the traditional method. This choice was backed by various

pieces of evidence; participants in the experimental group consistently obtained measurements that were nearer to actual values after treatment, exhibited statistically significant enhancements in practical report scores and displayed less variability in results compared to the control group. Before the treatment, both groups showed comparable performance, but only the experimental group demonstrated significant improvements afterward. Moreover, correlation and regression analyses validated improved accuracy and reliability in the experimental group's post-treatment results. These findings offer strong proof that incorporating the electronics practical workbench considerably enhances students' precision in performing and documenting physics lab measurements.

The researcher noted difference in the accuracy of physics practical tasks between students utilizing the Electronics Practical Workbench (EPW) and those instructed through traditional practical approaches. Both groups started with low scores in the initial assessment (PPAE 1), but the experimental group utilizing EPW demonstrated significant progress by PPAE 2, with 75% of the schools achieving improved practical mean scores. The accuracy in assessing current, voltage and electromotive force saw a notable enhancement among EPW users, with 92.4% obtaining accurate current measurements, contrasted with merely 39.8% in the control cohort. Regression analyses reinforced these results, demonstrating significant positive associations between measurement accuracy and practical scores in the experimental group ($r = .63$, $p = .0001$; $R^2 = 0.444$), whereas the control group exhibited minimal improvement. In general, using the EPW significantly improved students' accuracy, analytical abilities and report-writing standards, showing that technology-assists practical teaching and can result into better accuracy in conducting practical tasks and improved conceptual grasp in physics compared to conventional approaches.

4.4. Basic science process skills

Science process skills are a set of transferable appropriate abilities that can be reflected in the behavior of the scientist who has acquired them. They comprise of using senses to make observations, making educated guess about a phenomenon based on the previous generated data, using both standard and non-standard estimates to take measurement. They also consist of application appropriate words and graph work to pass information in science, grouping objects based on their characteristics and predicting the future outcomes based on evident patterns. Science contributes to skills that enable learners to hypothesize, manipulate physical world and ability to reason out from the obtained information. The scientific skills are described by critical creative thinking. When students are adequately exposed to learning experiences, they acquire appropriate science skills. This study sought to examine the effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills compared to conventional practical teaching methods. Observation, measuring and communication skills are some of the science process skills that were assessed during practical work in this study.

4.4.1. Observation

This involves using of senses to gather information about practical processes. In this study, senses of sight were applied to observe the labels for potential terminal of the apparatus, colors of the insulators for the connecting wires and identify the difference in brightness of the bulb in the circuit. Such observation was made based on the number of dry and arrangement of the dry cells.

In addition, observation was applied to make accurate readings and recordings as indicated in section 4.3; tables 4.3.10 to 4.3.12. This is the observation of materials, choosing and using them appropriately. In this case at PPAE 1, each student was provided with dry cells, cell holders, a voltmeter, an ammeter, connecting wires with crocodile clips and switch. The students carried out practical work where they were to design and set up electric circuits. In the process, they were to observe each item based on the electric potential terminals; positive (+) pole and negative (-) pole. For connecting wires and crocodile clips, red color was identified to be for + pole connections while black color was identified for - pole connections. Using a checklist, the researcher identified students who could carry out identification and classification processes effectively. The feedback was recorded as shown in table 4.4.1.

Table 4.4.1: Frequency and percentage of students who acquired observation skills on electric potential of practical materials [Experimental Group; N=211, Control Group; N=241].

Pre-Test and Post Test	Practical Materials	Experimental Group				Control Group			
		Yes		No		Yes		No	
		N	%	N	%	N	%	N	%
PPAE 1	1. dry cells	102	48.3	109	51.7	142	58.9	99	41.1
	2. cell holders,	76	36.0	135	64.0	102	42.3	139	57.7
	3. a voltmeter	59	28.0	152	72.0	52	21.6	189	78.4
	4. an ammeter	71	33.6	140	66.4	75	31.1	166	68.9
	5. connecting wires	43	20.4	168	79.6	54	22.4	187	77.6
	6. crocodile clips	53	25.1	158	74.9	60	24.9	181	75.1
	7. a switch	37	17.5	174	82.5	32	13.3	209	86.7
PPAE 2	1. dry cells	161	76.3	50	23.7	107	44.4	134	55.6
	2. cell holders	-	-	-	-	120	49.8	121	50.2
	3. a voltmeter	159	75.4	52	24.6	63	26.1	178	73.9
	4. an ammeter	175	82.9	36	17.1	80	33.2	161	66.8
	5. connecting wires	143	67.8	68	32.2	58	24.1	183	75.9
	6. crocodile clips	-	-	-	-	64	26.6	177	73.4
	7. a switch	160	75.8	51	24.2	39	16.2	202	83.8

According to table 4.4.1, at PPAE 102 (48.3%) students of experimental group could identify dry cells with their potentials while 109 (51.7%) of them could not do so. There were 76 (36.0%), 59 (28.0%) and 71 (33.6%) students who could identify cell holders, a voltmeter and an ammeter in that order by their electric potential terminals during the same test. On the contrary observation 135 (64.0%), 152 (72.0% and 140 (66.4%) of the students from experimental group could not correctly identify the terminals of cell holders, a voltmeter and an ammeter respectively. Another material that could be identified through observing their electric poles was a switch. This could be done by 37 (17.5%) of students from experimental group but could not correctly be done by 174 (82.5%) of the students from the same group. Making observation to know the connecting wires and crocodile clips based on their insulation colors in relation to how they are used in different electric circuit potentials could be done by 43 (20.4%) and 53 (25.1%) in that order.

The study also noted that at PPAE 1, 168 (79.6%) and 158 (74.9%) students from experimental group could not classify connecting wires and crocodile clips based on their insulation colors that represent which electric potential they should be used in.

The PPAE 1 test was also administered to the control group students. In this group, identification of electric potential terminals of dry cells, cell holders, a voltmeter and an ammeter were possible to 142 (58.9%), 102 (42.3%), 52 (21.6%) and 75 (31.1%) students respectively. This was not the case with 99 (41.1%), 139 (57.7%), 189 (78.4%) and 166 (68.9%) students who could not identify electric potential terminal of dry cells, cell holders, a voltmeter and an ammeter respectively. Some students in this group could identify connecting wires and crocodile clips by observing their insulation colors and relate them to which electric terminal they best represent. These were 54 (22.4%) and 60 (24.9%) students in that order. As this was happening, 187 (77.6%) and 181 (75.1%) fellow students could not classify the connecting wires and crocodile clips based on their insulation colors. In addition, 32 (13.3%) students from control group could identify the electric potential terminals of a switch while 209 (86.7%) could not do so.

During PPAE 2, the students from experimental group carried out practical work using EPW where they were to identify electrical potential (terminals) of the cells, a voltmeter, an ammeter and a switch. They were also to brand the connecting cables with the right insulation colors representing the electric polarity where they should be used given that cell holders and crocodile clip were not applicable in this case. The study noted from table 4.4.1 that 161 (76.3%), 159 (75.4%) 175 (82.9%) and 143 (67.8%) students in this group could identify electric pole terminals of cells, a voltmeter, an ammeter and brand connecting wires in that order. There were

50 (23.7%), 52 (24.6%), 36 (17.1%) and 68 (32.2%) students from experimental group who could not identify electric terminals of the cells, a voltmeter, an ammeter and brand connecting wires in that order. As they were using a switch, the researcher noted that 160 (75.8%) students from experimental group could identify its electric poles while 51 (24.2) of the students could not.

Students in the control group continued to use dry cells, cell holders, a voltmeter, an ammeter, connecting wires, crocodile clips and a switch to carry out practical work at PPAE 2. The study noted that 107 (44.4%), 120 (49.8%), 63 (26.1%) and 80 (33.2%) students in this group could identify electric pole terminals of the dry cells, cell holders, a voltmeter and an ammeter respectively. While they were doing this, groups of 134 (55.6%), 121 (50.2%), 178 (73.9%) and 161 (66.8%) students could not identify electric pole terminals of dry cells, cell holders, a voltmeter and an ammeter in that order. Observing and identifying connecting cables and crocodile clips into their respective insulation colors in relation to which electric circuit terminal they are used in, was possible to 64 (26.6%) and 39 (16.2%) of the students in control group. Such identification could not be done by 177 (73.4%) and 202 (83.8%) students from the same group for connecting wires and crocodile clips in that order.

The study also assessed the influence of the ability of the students to identify basic apparatus for carrying out practical work. This assessment was conducted for all students during pre-test and posttest examinations. Mann Whitney test was used to assess the influence students' ability to identify the apparatus on their practical report scores. Table 4.4.2 represents the Mann Whitney test results.

Table 4.4.2: Mann Whitney-U test results on observation skills on practical equipment verses practical scores [Experimental Group; N=211, Control Group; N=241].

Exam	Mann–Whitney U = 0.000 Practical Materials	Experimental Group				Control Group			
		Yes	No	z- value	Sig. (2-sided test)	Yes	No	z-value	Sig. (2-sided test)
		Mean rank	Mean rank			Mean Rank	Mean Rank		
PPAE 1	1. I could identify dry cells	103.61	108.55	.058	0.37	122.79	118.44	0.048	0.53
	2. I could identify connecting wires	102.58	106.88	.052	0.55	118.92	122.03	0.046	0.57
	3. I could identify an ammeter	105.55	106.23	.048	0.6	119.14	121.84	0.043	0.58
	4. I could identify a voltmeter	103.64	112.07	.032	0.62	108.55	120.72	-0.29	0.63
	5. I could identify cell holders	105.25	107.34	-0.56	0.68	118.58	124.29	-0.32	0.74
	6. I could identify a switch	105.05	110.47	-0.67	0.81	119.89	126.77	-0.53	0.78
	7. I could identify crocodile clips	104.74	109.75	-8.99	0.95	119.53	125.07	-6.59	0.83
PPAE 2	1. I could identify dry cells	124.37	100.3	5.547	0.002	117.49	125.47	0.074	0.38
	2. I could identify cell holders	***	***	***	***	120.45	121.55	-0.31	0.90
	3. I could identify a voltmeter	137.38	95.74	9.73	0.008	109.98	123.58	-0.67	0.72
	4. I could identify an ammeter	160.35	94.82	12.03	0.0001	119.19	122.06	0.095	0.44
	5. I could identify connecting wires	127.5	95.78	6.16	0.002	183.58	128.65	0.113	0.34
	6. I could identify crocodile clips	***	***	***	***	119.71	120.83	0.165	0.25
	7. I could identify a switch	130.76	98.11	7.23	0.0011	105.64	123.35	0.193	0.18

Based on table 4.4.2, students' ability to identify practical apparatus did not show statistically significant influence on practical report scores among students in both experimental and control groups at PPAE 1. This is because obtained p-values were above the significant level [$p > .05$]. Among the students in both groups, the study noted that mean rank values for those who could identify the apparatus had lower mean rating than those who could not do so at PPAE 1. This meant that irrespective of having the ability to identify the apparatus, the practical report scores still could not improve much. Even though more students could not identify the items at PPAE 1, both experimental and control groups could easily identify dry cells at [$z = .058$ and $p = .37$] and [$z = .048$ and $p = .53$] in that order. This was followed by identifying connecting wires at [$z = .052$ and $p = .55$] and [$z = .046$ and $p = .57$] for experimental and control groups respectively. Identifying crocodile clip at [$z = -8.99$ and $p = .95$] and [$z = -6.59$ and $p = .83$] and a switch at [$z = -0.67$ and $p = .81$] and [$z = -0.53$ and $p = .78$] was a bit challenge to both experimental and control groups.

Unlike in PPAE 2, majority of the students in experimental groups improved in their practical report scores compared to their counterparts in control group at PPAE 2. The study confirmed this after noting that mean rank values among students in experimental group were higher than the values obtained from students in control group. At the same time, among students in experimental group, the study established statistically significant results between the students' ability to identify the practical apparatus and their practical report scores at PPAE 2. This was confirmed by p-values obtained which were below the significant level [$p < .05$] in all the apparatus identified. The most significant result was noted between students' ability to identify an ammeter, followed by a switch, voltmeter, a dry cell, connecting wires and a voltmeter with z-value and p-values of [$z = 12.03$, $p = 0.0001$], [$z = 7.23$, $p = 0.0011$], [$z = 5.547$, $p = 0.002$], [$z =$

6.16, $p = 0.002$] and [$z = 9.73$, $p = 0.008$] respectively. This was contrary to the findings obtained among control group.

An experiment was conducted and students given opportunity to make observation on the brightness of electric bulb and make a conclusion on whether the brightness of the bulb changes with addition or reduction of dry cell(s) in a series or parallel circuit connection. Data for observation skills development on brightness of bulbs was collected and recorded in table 4.4.3.

Table 4.4.3: Frequencies and percentages of students for acquisition of observation skills on bulb brightness [Experimental Group; N=211, Control Group; N=241].

			Experimental				Control			
			Yes	%	No	%	Yes	%	No	%
2 Dry Cells in Series	Bulb Brightens	PPAE 1	45	21.3	38	18.0	108	44.8	133	55.2
		PPAE 2	91	43.1	37	17.5	92	38.2	149	61.8
	Bulb Brightens remains the same	PPAE 1	30	14.2	53	25.1	128	53.1	113	46.9
		PPAE 2	16	7.3	112	53.1	134	55.6	107	44.4
	Bulb Brightness Decreases	PPAE 1	21	10.0	62	29.4	99	41.1	142	58.9
		PPAE 2	18	8.5	110	52.1	116	48.1	125	51.9
2 Dry Cells in Parallel	Bulb Brightens	PPAE 1	19	9.0	64	30.3	117	48.5	124	51.5
		PPAE 2	8	3.8	120	56.9	126	52.3	115	47.7
	Bulb Brightens remains the same	PPAE 1	44	20.9	39	18.5	103	42.7	138	57.3
		PPAE 2	109	51.7	55	26.1	114	47.3	127	52.7
	Bulb Brightness Decreases	PPAE 1	38	18.0	45	21.3	101	41.9	140	58.1
		PPAE 2								

Based on table 4.4.3 (b), students in experimental group and control group who could observed that additional of a dry cell in a series' circuit makes the bulb brighter during PPAE 1 were 45 (21.3%) and 108 (44.8%) respectively. The number increased by 21.8% among the students in experimental group at PPAE 2. This was higher than the increment of 6.6% observed among student in control group. In this experiment, more than half of the students; 128 (53.1%) in control group got it wrong at PPAE 1 by observed that additional dry cells in series makes brightness of the bulb remain the same. The number even increased during PPAE 2 by 2.5%. This means that the method of practical instructions they were exposed to may have not added value in terms of developing observation skills. This was contrary to the number of students in experimental group which dropped from 30 (14.2%) to 16 (7.6%) resulting to a drop of 6.9% indicating that treatment may have improved their acquisition of observation skills. A bigger number of students, 125 (51.9%) in control group compared to that of students in experimental group, 18 (8.5%) also made a wrong observation during PPAE 2, that brightness of a bulb decreases when a dry cell is added in series in a circuit. For dry cells in parallel, more students in control group, (47.3%) than those in experimental group (51.7%) confirmed the right conclusion of brightness of the bulb remaining the same irrespective of the addition of dry cell(s).

The research employed a Mann-Whitney U test to assess the inference abilities of students regarding the brightness of a bulb when two batteries are linked in a series circuit. Table 4.4.4 displays the results of the Mann-Whitney U test.

Table 4.4.4: Mann-Whitney U test outcome of acquisition of observation skills on brightness of bulb and practical scores [Experimental Group; N=211, Control Group; N=241].

			Mean Rank		Mann-Whitney U		Wilcoxon W		Asymptotic Sig. (2-sided test)	
			EXP.	CONT.	EXP.	CONT.	EXP.	CONT.	EXP.	CONT.
2 Dry Cells in Series	Bulb Brightens	PPAE 1	112.14	101.19	6,012.00	5,189.00	21,956.00	14,893.00	0.348	0.941
		PPAE 2	128.56	122.36	6,616.00	6,244.00	23,106.00	21,876.00	0.0091	0.361
	Bulb Brightens remains the same	PPAE 1	105.11	115.06	3,445.27	6,406.00	25,543.50	19,494.00	0.169	0.679
		PPAE 2	116.68	111.66	3,742.49	6,400.00	25,693.50	19,678.00	0.176	0.761
	Bulb Brightness Decreases	PPAE 1	106.66	117.65	3,830.50	6,509.00	25,780.50	19,589.00	0.171	0.744
		PPAE 2	112.72	104.57	3,681.33	6,419.00	25,585.50	19,888.00	0.158	0.779

The capacity of students to foresee the brightness of the bulb when two batteries are linked in series was evaluated. At PPAE1, observations for students in both groups did not yield any significant results in relation to practical report scores. This is the reason why the p-values from the experimental and control groups were .348 and .941, respectively, both of which are below the significance threshold of .05. This was distinct among the students in the experimental group at PPAE 2, where student observations produced statistically significant results concerning practical report scores [$p=.0091$; $< .05$; mean rank 128.56]. The outcomes did not match the answers related to forecasting if the bulb will maintain or diminish its brightness. In both scenarios, no forecast demonstrated noteworthy outcomes regarding practical report scores, as all their p-values exceeded the significance threshold (.05).

During the practical work, students were asked to arrange bulbs and dry cells in series and parallel. In each case, they were to make observations and make inference and conclusion about the brightness of the bulbs used in the circuit as the numbers of cells was being increased one at a time then give correct reason(s) for the same. According to some students, after carrying out the tasks by arranging dry cells in series, the common observation was that when the cells are arranged in series and one bulb is used in the circuit, then the brightness of the bulb rises with increase in the number of cells. They however had mixed reactions on the scientific reasons why the brightness changed with increase in number of dry cells. This was confirmed from some of the statements noted in the answer sheet. Some of the statements are as follows

ST-EXP-PPAE 1 ‘...when one bulb is used, its brightness increases as you add one dry cell connected in series..., I don’t know the reason.....’.

ST-EXP-PPAE 1 ‘...bulb became bright when I added one dry cell..., when I added the third one the bulb was more brighter,.....but the bulb went off when I

added the fourth dry cell..., I think the reason was because the dry cells produced more power....’.

ST-CON-PPAE 1 ‘...the bulb was deem when I used one dry cell but when I added one dry cell, it was more bright and continued as I added more dry cell,...I feel the bulb was now consuming more energy from the dry cells, that is why.....’

ST-CON-PPAE 1 ‘....bulb became bright when I added more dry cells....’ This is because wen we begun it was just one dry cell but the moment we added other dry cells, they were now more,...and this made the bulb to be more bright....’

During practical work, for bulbs in series with potential difference remaining constant, the students noted that when bulbs are arranged in series, their brightness decreases as you add more bulb in the circuit. When a circuit is broken by disconnecting one of the bulbs which were in series, all other bulbs go off. Most of the students could not support what they observed scientifically. To confirm this, the following statements were drawn from sampled students’ responses.

ST-CON-PPAE 1 ‘...it took me a lot of time to connect the circuit,..... this is because most of the time after connecting everything, I could not observe the bulb lighting.....’but after the teacher had helped me to connect it, I could see brightness of the bulbs reducing as I add another bulb.....I think they divide power among themselves.....’.

ST-EXP -PPAE 1 ‘...brightness of the bulbs reduced every time I added a bulb, but again when I removed any of the bulb from the circuit, all other bulbs went off immediately...’.

When the cells were connected in parallel, students observed no change in brightness of the bulb irrespective of additional cell in the circuit but most of them could not scientifically justify such an observation. Some of the statements made by the students are as follows;

ST-CON-PPAE 1 ‘..... brightness of the bulb did not change even after including up to the fourth dry cell.....and I don’t know why...’

ST-EXP-PPAE 1 ‘...it seems my bulb had a problem, that is why its brightness remained the same even after I had added the second, the third and even the fourth dry cell...’

When the bulbs were arranged in parallel, their brightness decreases as you add more bulbs in the parallel circuit. The accurate reasons were not given by the students.

ST-EXP-PPAE 2 ‘...me I realized that the brightness of the bulb remained the same, I tried and removed one bulb, the rest remained with same brightness.....’

4.4.2. Measurement

This is the ability to understand measurable attributes, carry out comparison of the measurement points and scale order. It is the ability to have the knowledge of how to carry out measurements of physical attributes for a given object, using the right measurement tools and the appropriate measurement techniques. To assess the measurement skills, students were provided with authentic and real-life practical work experience giving each of them an opportunity to practice, interact and use innovative skills to carry out varied measurements. Use of right scientific and mathematical language, and SI units were considered both for experimental and control group students at PPAE 1 and PPAE 2. Comparisons were then done between the groups and tests. Among other basic science process skills, measurement skills were assessed through questionnaires and checklist. Questionnaires were administered to students to assess the acquired basic science process skills. They were to respond to the questionnaires by filling in the blank or ticking where appropriate as described by the likert scales. The feedback from the questionnaire was recorded as in table 4.4.5.

Table 4.4.5: Frequencies and percentages of students on acquisition of measurement skills verses their practical scores [Experimental Group; N=211, Control Group; N=241].

S/No.	Statement	Group	Exam	SA		A		U		D		SD	
				N	%	N	%	N	%	N	%	N	%
1	It was very easy to carry out all required measurements in the practical	Experimental	PPAE 1	11	5.2	16	7.6	30	14.2	102	48.4	52	24.6
			PPAE 2	68	32.2	84	39.8	11	5.2	35	16.6	13	6.2
		Control	PPAE 1	8	3.3	15	6.2	30	12.4	149	61.9	39	16.2
			PPAE 2	9	3.7	19	7.9	36	14.9	132	54.8	45	18.7
2	I could give my reading values to the best accuracy	Experimental	PPAE 1	20	9.4	41	19.4	13	6.2	110	52.2	27	12.8
			PPAE 2	43	20.4	81	38.4	9	4.2	40	19	38	18.0
		Control	PPAE 1	2	0.9	25	10.4	42	17.4	146	60.6	26	10.7
			PPAE 2	3	1.3	27	11.2	49	20.3	141	58.5	21	8.7
3	It was very easy to provide all practical measurement results with best estimates.	Experimental	PPAE 1	19	9	45	21.3	20	9.5	89	42.2	38	18
			PPAE 2	30	14.2	95	45	13	6.2	47	22.3	26	12.3
		Control	PPAE 1	1	0.4	29	12	61	25.3	115	47.8	35	14.5
			PPAE 2	2	0.8	35	14.5	54	22.4	109	45.2	41	17
4	It was very easy for me to interpret the results	Experimental	PPAE 1	32	15.2	54	25.6	21	10	61	28.9	43	20.3
			PPAE 2	48	22.7	70	33.2	15	7.1	46	21.8	32	15.2
		Control	PPAE 1	4	1.6	25	10.4	23	9.5	138	57.3	51	21.2
			PPAE 2	6	2.5	29	12	27	11.2	122	50.6	57	23.7
5	I could easily explain the comparison of the results I got and what I was expecting.	Experimental	PPAE 1	7	3.3	46	21.8	40	19	72	34.1	46	21.8
			PPAE 2	18	8.5	52	24.6	38	18	60	28.5	43	20.4
		Control	PPAE 1	9	3.7	29	12	33	13.8	136	56.4	34	14.1
			PPAE 2	5	2.1	23	9.5	34	14.1	141	58.5	38	15.8

According to table 4.4.5, 68 (32.2%) students in the experimental group strongly agreed that carrying out all the required measurements in the practical was easy. There was a group of 84 (39.8%) students who agreed that carrying out all the required measurements in the practical was easy to them. In the contrary 35 (16.6%) students found it uneasy to carry out all the required measurements in the practical, so they disagreed with the statement provided in the questionnaire. Apart from those who disagreed, 13 (6.2%) of the students strongly disagreed with the statements and could not carry out all required measurements in the practical at ease. As this was happening, 11 (5.2%) students remained undecided. For the control group, 9 (3.7%) students found it easy to carry out all required measurements in the practical teasing them to strongly agree with statement 1 as was in the questionnaire. This was also supported by 19 (7.9%) of the students but was not the same case with 132 (54.8%) and 45 (18.7%) of the students who disagreed and strongly disagreed with the same statement. They found it a challenge to carry out all required measurements in the practical. There were 36 (14.9%) students who had not made up their mind whether they found it easy to carry out all required measurements in the practical or not. Giving readings to the best accuracy was possible to 43 (20.4%) of the experimental group who strongly agreed that they could do so. To confirm this 81 (38.4%) more students of the same group agreed that they could give their reading values to the best accuracy. While they confirmed the ability to give reading values to the best reading, some students noted that this was not possible for them.

These were 40 (19.0%) and 38 (18.0%) students who disagreed and strongly disagreed with the fact that other fellow students could give their reading values to the best accuracy. Apart from these students, there were 9 (4.2%) students who had not made up their mind by then. There were 30 (12.4%) students in the control group also confirmed their ability to give reading values to the best accuracy while 162 (67.2%) students disagreed with the fact that some students could give their reading values to the best accuracy. There were 49 (20.4%) students who were undecided whether they found it easy to give their reading values to the best accuracy.

Providing all practical measurements with best estimates was a skill that could be demonstrated at ease by 125 (58.3%) students in the experimental group and 37 (15.4%) students of the control group. There were those students who did not find it easy to provide all practical measurement results with best estimates. These were 73 (34.6%) students from experimental group and 150 (62.2%) students from control group. As the students were expressing their experience for the ability to provide all practical measurement results with best estimates, some 13 (6.2%) and 54 (22.4%) students from experimental and control groups respectively, had not made up their minds over the statement.

Interpretation of the results was an easy task for 118 (55.9%) students from experimental group and 35 (14.5%) students of the control group. This was a contrary for 78 (36.9%) students in the experimental group and 179 (74.3%) students in the control group. As they were making decision after the practical work, 15 (7.1%) students in the experimental group and 27 (11.2%) students from control group remained undecided.

Explaining the comparison of the results got and what was expected was something easy to 70 (33.2%) students in the experimental group and 28 (11.6%) students in the control group. In the contrary, 103 (48.8%) students of the experimental group and 179 (74.3%) students of the

control group could not explain the comparison of the results they got and what was expected, but 38 (18.0%) students of the experimental group and 34 (14.1%) students in the control group remained undecided.

An observation checklist was used to collect data on science process skills acquired by students in a practical work. This was administered during PPAE 1 and PPAE 2 to students in both experimental and control groups after which comparisons were done to determine percentage difference of students who acquired the basic science process skills both at PPAE 1 and PPAE 2. These involved abilities of the student to carry out all required measurements in the practical work and providing all practical measurement results with best estimates, the feedback obtained was recorded in table 4.4.3 as indicators 1 and 2.

Within these skills, accuracy of reading values, identification of error sources in physics practical work, interpretations of data in the results, providing discussion of the results and relating results back to the aim of the experiment. Other attributes were providing an explanation of why the experiment produced the obtained results, providing information about how their results are compared to their expectations from text books and providing brief conclusion on the conducted practical work, the feedback obtained was recorded in table 4.4.6 as indicators 3 to 9.

Table 4.4.6: Descriptive analyses on acquisition of measurement skills verses their practical scores [Experimental Group; N=211, Control Group; N=241].

	Group	N	Mean		Std. Deviation	
			PPAE 1	PPAE 2	PPAE 1	PPAE 2
Practical Report Scores	Experimental	211	15.37	27.99	3.42	6.24
	Control	241	15.33	15.49	3.66	3.472
Mean Rating	Experimental	211	1.612	2.258	0.522	0.679
	Control	241	1.69	2.517	0.743	1.018

Table 4.4.6 indicates that the average mean scores of students in the two groups were quite alike before treatment at PPAE 1, revealing a discrepancy of .04 marks. After treatment, students in both groups experienced an increase in their average scores for practical reports, with the experimental group rising by 12.62 marks and the control group increasing by 0.16 marks, respectively. This revealed the effect of using EPW in practical tasks on the scores of the practical report compared to conventional practical execution methods.

The linear regression analysis generated correlation findings to establish the strength and direction of the linear association between the average ratings obtained from the Likert scale on accuracy in practical report writing and the scores of the practical reports. The outcome of the correlation is shown in table 4.4.7.

Table 4.4.7: Correlation output between acquisition of measurement skills and their practical scores [Experimental Group; N=211, Control Group; N=241].

		Group	PPAE 1 Practical Report Scores	PPAE 2 Practical Report Scores
Pearson Correlation	Mean Rating	Experimental	0.039	0.31
		Control	-0.041	0.016
Sig. (1-tailed)	Mean rating	Experimental	0.296	0.0307
		Control	0.24	0.423

As shown in table 4.4.7, the correlation between the practical teaching approach and acquisition of science process skills among students in both groups was weaker prior to treatment than the correlation value measured post-treatment. The students in the experimental group achieved correlation values of .039 and .31 prior to and following treatment, respectively. Conversely, the students in the control group achieved correlation values of -.041 and .016 prior to and following the treatment in that order. This indicated an increase in correlation values for students in both

groups, particularly for those in the experimental group, which saw a rise of .271 units, in contrast to the control group's .057 units.

In order to illustrate the extent to which the scores of practical reports could be accounted for by the development of science process skills, a summary model table was created from regression analysis, validating the correlation value (R) and the model's power (R²), as depicted in table 4.4.8.

Table 4.4.8: Regression analysis summary model on students' acquisition measurement skills and their practical scores [Experimental Group; N=211, Control Group; N=241].

Indicators	Group	PPAE 1	PPAE 2
R (Correlation value)	Experimental	.044a	0.31
	Control	.038a	0.049
R ² (Power of the Model)	Experimental	0.005	0.13
	Control	0.003	0.004

a. Predictors: (Constant), Mean Rating

b. Dependent Variable: Practical Report Scores

The study noted that for every unit increase in in mean rating before treatment, there was an increase of .044 units and .038 units of practical report scores among students in experimental and control group respectively. After treatment, increase in a unit of mean rating meant increase on .31 units and .049 units of practical report scores among students in experimental and control groups in that order. The acquisition of science process skills could explain 0.05% of the achieved practical report scores in both groups before treatment. After treatment the percentages changed in that acquisition of science process skills could explain 13.0% of the achieved practical scores among students in experimental group and 0.03% of the attained practical report scores among students in control group which latter improved by 0.04% at PPAE 2. This showed

that using EPW in practical work has an effect on acquisition of science process skills which translates to better scores in the reports themselves.

The direction of the relationship between acquisition of science process skills; having mean ratings from a questionnaire likert scale and the practical report scores was determined by linear regression. Existence of significance difference between acquisition of science process skills and the practical report scores was also established through linear regression. A coefficient output table was generated and presented in terms of coefficient value, t-value and P-value as shown in table 4.4.9.

Table 4.4.9: A coefficient output on students’ acquisition of measurement skills and their practical scores [Experimental Group; N=211, Control Group; N=241]

		Unstandardized Coefficients (B)		t-value		Sig.	
		PPAE 1	PPAE 2	PPAE 1	PPAE 2	PPAE 1	PPAE 2
Mean Rating	Experimental	0.276	4.68	0.597	0.882	0.533	0.046
	Control	-0.151	0.045	-0.046	0.012	0.0543	0.829

a. Dependent Variable: Practical Report Scores

According to table 4.4.9, at the study's outset, as the mean rating units for acquiring science process skills rise, the practical report scores for students in the experimental group also increased by .276 units. This was in contrary to the results found simultaneously in the control group students, where an increase in the acquisition of science process skills, measured in mean rating units, appeared to lower the practical report scores by .151 units.

Following treatment, the gain in science process skills measured in mean rating units for students in the experimental group could enhance the practical report scores by 4.68 units, whereas the

increase in the control group was only 0.45 units. This confirmed that the use of EPW affects the development of science process skills, leading to improved practical report scores. The research additionally evaluated the t-values obtained from linear regression analysis prior to and following treatment. The t-values obtained provided more substantial evidence against the null hypothesis for the students in the experimental group compared to those in the control group after the treatment. This is due to the t-value being greater for students in the experimental group (.882) compared to that of students in the control group (.012) post-treatment. This contrasted with the t-values recorded prior to treatment in both groups, which were significantly lower, particularly for students in the control group, where the t-value stood at -.046. The null hypothesis was subsequently supported by the P-values in the coefficient table for students in the experimental group, which fell below the significant level of .05 following the treatment. This opposed the P-values found prior to treatment for students in both groups and even for those in the control group post-treatment, where the P-values exceeded the significant level of .05. Consequently, the null hypothesis was dismissed due to the comparison of coefficient values, t-values and P-values derived from the results of linear regression analysis conducted both prior to and following treatment. The data obtained was recorded on table 4.4.10.

Table 4.4.10: Frequencies and percentages on students' acquisition measurement skills and their practical scores [Experimental Group; N=211, Control Group; N=241]

Indicator	Yes						No							
	M	%	F	%	Total	%	M	%	F	%	Total	%		
1. Was able to carry out all required measurements in the practical	Experimental	PPAE 1	79	37.4	65	30.8	144	68.2	44	20.9	23	10.9	67	31.8
		PPAE 2	102	48.3	74	35.1	176	83.4	21	9.9	14	6.6	35	16.6
	Control	PPAE 1	32	13.3	23	9.5	55	22.8	119	49.4	67	27.8	186	77.2
		PPAE 2	29	12	15	6.2	44	18.2	123	51	74	30.7	197	81.7
2. Has provided all practical measurement results with best estimates.	Experimental	PPAE 1	77	36.5	31	14.7	108	51.2	77	36.5	26	12.3	103	48.8
		PPAE 2	122	57.8	37	17.5	159	75.4	37	17.5	15	7.1	52	24.6
	Control	PPAE 1	34	14.1	19	7.9	43	17.8	121	50.2	67	27.8	188	78.1
		PPAE 2	39	16.2	20	8.3	59	24.5	109	45.2	73	30.3	182	75.5
3. Could identify sources of errors in physics practical work.	Experimental	PPAE 1	31	14.7	15	7.1	46	21.8	96	45.5	69	32.7	165	78.2
		PPAE 2	76	36.5	42	19.4	118	55.9	58	27.5	35	16.6	93	44.1
	Control	PPAE 1	11	4.6	7	2.9	18	7.5	145	60.2	78	32.3	223	92.5
		PPAE 2	10	4.2	4	1.6	14	5.8	140	58.1	87	36.1	227	94.2
4. Has included interpretations of data in the results	Experimental	PPAE 1	47	22.3	23	10.9	70	33.2	89	42.2	52	24.6	141	66.8
		PPAE 2	89	42.2	44	20.9	133	63	49	23.2	29	13.7	78	36.9
	Control	PPAE 1	27	11.2	11	4.5	38	15.8	103	42.8	100	41.5	203	84.2
		PPAE 2	23	9.5	14	5.8	37	15.4	109	45.2	95	39.4	204	84.6
5. Has provided discussion of the results	Experimental	PPAE 1	33	15.6	13	6.2	46	21.8	91	43.1	74	35.1	165	78.2
		PPAE 2	78	36.9	38	18	116	54.9	56	26.5	39	18.5	95	45
	Control	PPAE 1	26	10.8	14	5.8	40	17.4	141	58.5	60	24.9	201	83.4
		PPAE 2	26	10.8	16	6.6	42	17.4	132	54.8	67	27.8	199	82.6
6. Has related results back to the aim of the experiment	Experimental	PPAE 1	24	11.3	19	9	43	20.4	113	53.6	55	26.1	168	79.6
		PPAE 2	64	30.3	37	17.5	101	47.9	74	35.1	36	17.1	110	52.1

Indicator	Yes								No				Total	%
	M		%		F		%		M		%			
	M	%	F	%	Total	%	M	%	F	%				
7.Has provided an explanation of why the experiment produced the obtained results	Control	PPAE 1	21	8.7	15	6.2	36	14.9	147	61	58	24.1	205	85.1
		PPAE 2	18	7.5	12	5	30	12.4	155	64.3	56	23.2	211	87.6
	Experimental	PPAE 1	11	5.2	17	8.1	28	13.3	110	52.1	73	34.6	183	86.7
		PPAE 2	60	28.4	36	17.1	96	45.5	81	38.4	34	16.1	115	54.5
	Control	PPAE 1	8	3.3	13	5.4	21	8.7	159	66	61	25.3	220	91.3
		PPAE 2	10	4.1	8	3.3	18	7.5	168	69.7	55	22.8	223	92.5
8.Have included information about how their results compared to their expectations from text books.	Experimental	PPAE 1	19	9	9	4.3	28	13.3	133	63	50	23.7	183	86.7
		PPAE 2	55	26.1	29	13.7	84	39.8	82	38.9	45	21.3	127	60.2
	Control	PPAE 1	20	8.3	10	4.1	30	12.4	167	69.3	44	18.3	211	87.6
		PPAE 2	16	6.6	11	4.6	27	11.2	165	68.5	49	20.3	214	88.9
	Experimental	PPAE 1	39	18.5	19	9	58	27.5	98	46.4	55	26.1	153	72.5
		PPAE 2	97	45.9	46	21.8	143	67.8	43	20.4	25	11.9	68	32.2
Control	PPAE 1	40	16.6	29	12	69	28.6	111	46.1	61	25.3	172	71.4	
	PPAE 2	46	19.1	32	13.3	78	32.4	107	44.4	56	23.2	163	67.6	

As shown in table 4.4.10, 176 (83.4%) learners from the experimental group and 44 (18.2%) students from the control group successfully performed all necessary measurements in the practical at PPAE 2. Among the 176 students in the experimental group, 102 (48.3%) were males and 74 (35.1%) were females. In the control group of 44 students, there were 29 (12.0%) males and 15 (6.2%) females. Conversely, 35 (16.6%) students from the experimental group and 197 (81.7%) from the control group could not complete all necessary measurements in the practical. In the experimental group of students, there were 21 (9.9%) males and 14 (6.6%) females, while the control group included 123 (51.0%) male students and 74 (30.7%) female students.

A total of 159 (75.4%) students from the experimental group were able to measure all the supplied practical results with the best estimates, including 122 (57.8%) male students and 37 (17.5%) female students. Aside from that, 51 (21.2%) of the students in the control group were able to measure all of the given practical results with the best estimates. Among the 51 students, 31 (12.8%) were male and 20 (8.3%) were female. Conversely, there were 52 (24.6%) students from the experimental group who were unable to estimate all of the given practical results accurately. Among these, 37 (17.5%) were male students and 15 (7.1%) were female students. Additionally, the control group comprised 190 students (78.8%), with 119 (49.4%) being male and 71 (29.5%) being female.

Out of the experimental group, 118 (55.9%) students were able to identify sources of errors in physics practical work, comprising 77 (36.5%) boys and 41 (19.4%) girls. This excluded 93 (44.1%) students from the experimental group who were unable to recognize the sources of errors in physics practical tasks. Among the 93 students, 58 (27.5%) were male and 35 (16.6%) were female. In contrast, the control group had 14 (5.8%) students capable of recognizing sources of errors in physics practical activities. Out of the 14 students, there were 10 (4.2%) boys

and 4 (1.7%) girls. Among the students in the control group, 227 (94.2%) could not pinpoint sources of errors in physics practical work, comprising 140 (58.1%) boys and 87 (36.1%) girls.

The interpretations of data in the results were included by 133 (63.0%) of the students in the experimental group, consisting of 89 (42.2%) boys and 44 (20.9%) girls. Among the experimental group students, 78 (36.9%) did not include data interpretations in their results. This comprised 49 (23.3%) boys and 29 (13.7%) girls. In the control group, 37 students (15.4%) were able to incorporate interpretations of data into the results. Boys accounted for 13 (9.5%) students, whereas girls made up 14 (5.8%) students among those who could incorporate data interpretations in the findings. In contrast, 204 (84.6%) students were unable to incorporate data interpretations in their results; among them were 109 (45.2%) boys and 95 (39.4%) girls.

Discussion of the results was provided by 116 (54.9%) students in the experimental group. Of this total of students, 78 (36.9%) were male and 16 (6.6%) were female. The other 95 (45.0%) students were unable to analyze the results in their practical reports. Included in the group were 56 (26.5%) boys and 39 (18.5%) girls. In the control group, 42 (17.4%) students were able to discuss the findings in the practical report; this included 26 (10.8%) boys and 16 (6.6%) girls. In contrast, 199 (82.6%) students, including 132 (54.8%) boys and 67 (27.8%) girls, failed to discuss the results in their practical reports.

Connecting the results to the experiment's objective is a task that 101 (47.9%) students in the experimental group managed to perform with ease; this included 64 (30.3%) boys and 37 (17.5%) girls. In another experimental group, 110 students (52.1%) were unable to connect the results to the experiment's aim, comprising 71 boys (35.1%) and 36 girls (17.1%). The control group included students who were able to connect the results to the experiment's objective. There were 30 (12.4%) students made up of 18 (7.5%) boys and 12 (5.0%) girls. Aside from those,

there were 211 (87.6%) students in the control group unable to connect the results to the experiment's aim, including 155 (64.3%) boys and 56 (23.2%) girls.

The practical reports could contain explanations for the results of the experiment from 96 (45.5%) students, which included 60 (28.4%) boys and 36 (17.1%) girls from the experimental group. Aside from that, there were no clarifications regarding why the experiment yielded the results seen in the practical reports of 115 (54.4%) students, which included 81 (38.4%) boys and 34 (16.1%) girls. In the control group, 18 (7.5%) students offered explanations for the results of the experiment; this included 10 (4.1%) boys and 8 (3.3%) girls. Out of the students who failed to explain why the experiment led to the results found in the control group, there were 223 (92.5%), including 168 (69.7%) boys and 55 (22.8%) girls.

Details on how the achieved results aligned with textbook expectations were included in the practical reports of 84 (39.8%) students, consisting of 55 (26.1%) boys and 29 (13.7%) girls. This information was absent in the practical reports submitted by 127 (60.2%) students in the experimental group. This group consisted of 82 (38.9%) boys and 45 (21.3%) girls. Certain students in the control group might also incorporate details on how their outcomes could be contrasted with their expectations from textbooks. There were 27 students (11.2%), consisting of 16 boys (6.6%) and 11 girls (4.6%). On the other hand, 214 (88.9%) participants provided details on how their results aligned with their textbook expectations. This consisted of 165 (68.5%) boys and 49 (20.3%) girls.

A brief conclusion was provided by 143 (67.8%) of the students in the experimental group. There were 97 (45.9%) males and 46 (21.8%) females. In comparison, 68 (32.2%) students from the control group failed to provide a brief conclusion, comprising 43 (20.4%) boys and 25 (11.8%) girls. In the control group, 78 students (32.4%) provided a short conclusion, including

46 boys (19.1%) and 32 girls (13.3%). In contrast, 163 (67.6%) students did not add a short conclusion; this group included 107 (44.4%) boys and 56 (23.2%) girls.

Checklist outcomes regarding the science process skills obtained by students through practical work and their practical report scores were utilized to perform a Mann-Whitney U statistical analysis. The research analyzed student feedback regarding their capacity to perform all necessary measurements in the practical, aiming to identify error sources in physics practical tasks both prior to and following the intervention. The research additionally evaluated the students' capability to deliver all practical measurement outcomes with optimal estimates, a discussion of the findings, a rationale for why the experiment yielded the achieved results and a concise conclusion. The research additionally evaluated students' capacity to connect findings to the experiment's objective, including data interpretations in the results and providing details on how their outcomes aligned with textbook expectations. The results regarding mean ranks, Mann-Whitney U, Wilcoxon W and significance values were gathered and documented as shown in table 4.4.11.

Table 4.4.11: Mann-Whitney U output on students' acquisition of measurement skills and their practical scores [Experimental Group; N=211, Control Group; N=241].

		Mean Rank		Mann-Whitney U		Wilcoxon W		Asymptotic Sig. (2-sided test)	
		EXP.	CONT.	EXP.	CONT.	EXP.	CONT.	EXP.	CONT.
Science process skills acquired	PPAE 1	103.21	115.56	5,025.50	7,210.00	14,109.50	14,836.00	0.83	0.93
	PPAE 2	159.43	123.33	5,105.50	7,108.00	5,774.50	14,562.00	0.0001	0.902

Table 4.4.9 shows that the science process skills acquired significantly influenced the practical report scores [$p=0.0001$; $<.05$; mean rank =159.43]. This was noted in students in the experimental group after the intervention. The findings differed for the experimental group at

PPAE 1 [$p=.83$; $>.05$; mean rank=103.21] compared to the control group at PPAE 1 [$p=.93$; $>.05$; mean rank=115.56]. After treatment, the students in the control group still demonstrated non-significant results concerning the acquired science process skills and practical report scores [$p=.902$; $>.05$; mean rank =123.33].

In a Focus Group Discussion (FGD) involving students, it was noted that they could effectively use nearly all the measuring tools during hands-on activities, particularly those in the experimental group. Both student groups, those who claimed they could use most of the measuring equipment and those who couldn't operate certain devices, offered explanations for their answers. Numerous reasons mentioned by individuals unable to use the supplied equipment effectively encompassed; the incapacity to obtain accurate readings because of faulty devices, inadequate connections of some wires and the existence of corroded terminals on cell holders. A few people mentioned they were unable to operate specific equipment due to wrong connections they may have created, especially when choosing the right terminals for circuit links. Certain individuals could not operate the device because of a fear of electric shock. The students were cited in the subsequent manner;

ST-CON-PAE 1: “..for me my ammeter first indicated negative, so the readings I could get were not the same which what others were getting until the teacher came and helped me adjust the scale..”

ST-CON-PAE 2.. i could not get any reading even after the teacher had told me to... to reverse the terminal of voltmeter which I had connected wrongly, ... but I realized that the cell holder had its plates rusted.....

ST-EXP-PAE 1: The connecting wires I was given..whe.!..., they had some joints which brought me many problems,... after connecting all of them, I had to keep on pressing the joints is when I could get the readings, imagine tu....

With justification, certain students stated that they were able to use most of the equipment available and some of them were cited as follows:

ST-CON-PAE2: “....some of the apparatus we have in school are very new,... in fact since from fours use them during KCSE, it was this time again when we were using them for this practical,.. so me I could use the and get somehow accurate values...”

ST-EXP-PAE2“...the apparatus were on the screen of the computer, it was just clicking and computer could inform you the name of the apparatus you have chosen,.. so it was very easy to use majority of them...”

It is evident that students who engaged in practical work with traditional methods encountered multiple difficulties regarding the apparatus itself and in using it correctly, among other issues. Conversely, students utilizing EPW to perform practical tasks faced few challenges. The results are consistent with those of Shafik et. al., (2023), who observed that certain equipment in the science labs is not used effectively by students because inadequate storage causes them to become dusty and rusty. Haridasan et. al., (2023), observed that certain science equipment is often mishandled, particularly during transitions between classrooms or workspaces, resulting in breakages and losses. Consequently, when other students attempt to utilize these tools for practical activities, they may encounter broken items or may not find them at all.

These findings align with Kumar (2018), who discovered that many students complete secondary school education without knowing most laboratory equipment by name or how to utilize them. Kumar connects her results to minimal learning experiences, particularly those involving hands-on activities. Marszalek et. al., (2019) however, observed that the majority of students admitted in their study that they encounter certain laboratory equipment during final exams, so they might not recognize them, particularly when they are expected to do so in junior classes or grades. Pascoe et al. (2018) also notes the absence of or insufficient practical tools and equipment in certain secondary schools, hindering students' ability to recognize the materials. They

subsequently suggest utilizing digital devices to familiarize students with such equipment and their usage for schools that may lack the necessary apparatus. This aligns with the practical use of EPW, which is computer-based.

A Mann Whitney test was performed to evaluate the impact of identifying materials on practical report scores. The research observed that recognizing the materials is one aspect, while utilizing them appropriately is a different aspect. This is why the results showed that certain students were able to recognize specific equipment at PPAE 1, particularly the identification of dry cells. Students in both groups were able to identify the dry cells, with most students in each group doing so; however, they still displayed lower mean ranks and showed statistically significant results at the beginning and end in certain instances. Nonetheless, the identifications of materials by students in the experimental group at PPAE 2 resulted in statistically significant findings related to practical report scores. Understanding and utilizing ammeters and voltmeters showed a more statistically significant outcome with practical report scores. A comparable pattern was noted in the development of measurement and inference abilities.

These results align with those of Sahdan and Abidin (2017), who advise that students must be well acquainted with lab equipment prior to conducting any practical tasks. They explained that a lack of proper understanding of the equipment prevents the student from knowing how to operate it and address any errors that might occur. As stated by Ben (2023), recognizing the items and utilizing them are distinct actions, thus merely knowing and identifying them might not lead to better practical report scores. They may not achieve very good practical scores until they use the apparatus correctly during practical work.

Classification is a fundamental scientific process skill that follows the exercise of identification. Recognizing electric poles for the given equipment or resources at PPAE 1 relied on the understanding of electric pole symbols acquired in form one within the topic of cells and simple circuits. Following PPAE 1 as a pre-test for students in both the experimental and control groups, the treatment was given to the experimental group, which involved practical work using EPW, while the control group persisted with traditional teaching methods for practical work. Upon comparing the similarities and differences, the researcher observed that the frequencies of students able to recognize the electric poles of the apparatus were fairly similar between the experimental and control groups at PPAE1. It was verified that a smaller number of students were able to recognize electric poles and terminals from each device in either group. The storyline shifted at PPAE2 in contrast to PPAE1, particularly for students in the experimental group. As a result, most of the students in the control group were still unable to recognize such poles. The research showed that the treatment involving teaching practical work with EPW given to students in the experimental group affected their acquisition of certain basic science process skills.

According to the results of this study, the null hypothesis, which suggested that there is no meaningful difference in the development of essential science process skills between learners instructed with the Electronics Practical Workbench (EPW) and those educated using conventional practical methods, is dismissed. The experimental group that was taught using the EPW showed notable statistical enhancements in identifying, categorizing and efficiently using scientific tools, as indicated by superior practical report scores at PPAE 2 in comparison to the control group. The Mann-Whitney test validated these distinctions, particularly in recognizing and accurately utilizing instruments like ammeters and voltmeters. These findings indicate that

the EPW intervention had a beneficial effect on students' acquisition of essential scientific process skills, thus offering solid proof against the null hypothesis.

The researcher found out that students who learned practical work using the Electronics Practical Workbench (EPW) demonstrated significantly greater acquisition of science process skills compared to those taught through conventional practical methods. Initially, both groups exhibited weak abilities in observation, measurement and interpretation at PPAE 1, but by PPAE 2, the experimental group showed remarkable improvement in observing and identifying circuit components, achieving up to 82.9% accuracy for ammeters and over 75% for voltmeters, switches and dry cells, while the control group remained below 50% in most categories. Statistical analyses indicated that the experimental group's improved identification after observation and measurement accuracy had a significant positive effect on practical report scores ($p < .05$), whereas the control group's progress was minimal and statistically insignificant. Feedback data reinforced these outcomes, with 68% of EPW users finding measurements and data interpretation easier compared to only 11.6% in the control group. Generally, the use of EPW greatly enhanced students' observation, measurement and communication skills, fostering deeper conceptual understanding and confidence in experimental work, unlike the traditional method, which led to only marginal skill development.

4.5. Practical Skills

Practical skills are abilities that can be exhibited through hands-on activities utilizing the required equipment, tools or technology. In this study, practical skills assessed included setting up experiments, manipulation and report writing involving graphing and performing necessary calculations. In the physics curriculum, the instructor and the lab technician are responsible for

organizing physics practical activities, while students are allowed to set up an experiment, handle the provided equipment, observe, gather data with suitable precision, recognize the variables and select the appropriate range and distribution of values and draw a well-informed conclusion. Students also show data, perform data analysis, create graphs, execute necessary calculations and compose the practical reports. This study thus evaluated students' skills in setting up experiments, manipulation and report writing involving gathering data, creating graphs, analyzing data, performing necessary calculations, presenting data correctly and drawing conclusions as outlined in their practical reports.

4.5.1. Setting up Experiment

Science experiments adhere to the principles of the scientific method, which guarantees that precise tests are performed to obtain trustworthy results that lead to valid conclusions. As stated by Hagiopol and Leru, (2024), every scientific experiment ought to adhere to fundamental scientific process principles for a quality investigation. In the scientific process, essential steps consist of observing, identifying problems, formulating and testing hypotheses, analyzing and presenting data and drawing conclusions. This ought to be succeeded by forecasts to evaluate the recorded outcomes in various scenarios. Subsequently, testing and error estimations should be conducted, followed by documenting the results using the appropriate presentation.

To correctly conduct the experiment, the students needed to observe the instructions given in the test papers. Understanding the issue that every question aims to address, anticipating potential outcomes, forecasting solutions for the problems, as well as testing and error estimation, could empower students to select the appropriate tools and conduct experiments during their physics practical activities. The appropriate experiment setup would dictate the type of results produced

in each experiment. In this study, students were guided through scientific methods as they conducted experiments. The experimental group learned to perform practical work using EPW, while the control group learned through traditional teaching methods. A science practical checklist was given during PPAE 1 and PPAE 2 and subsequently, the two outcomes were compared. A discussion in a focus group took place prior to and following the treatment. The feedback from the group was contrasted for the two tools used. Table 4.5.1 presents the responses gathered from the observation checklist regarding practical skills.

Table 4.5.1: Frequencies and percentages of students on setting up practical apparatus [Experimental Group; N=211, Control Group; N=241].

Criteria	Group	PPAE 1				PPAE 2			
		Yes		No		Yes		No	
		N	%	N	%	N	%	N	%
Was able to use all the available apparatus to carry out required measurements	Experimental	78	37.4	133	63	142	67.3	69	32.7
	Control	65	27	176	73	59	24.5	182	75.5
Was able to carry out all required measurements in the practical	Experimental	80	37.6	131	62.1	124	58.8	87	41.2
	Control	87	36.1	154	64	70	29	171	71
Could identify the right terminals (polarity) of the cells provided.	Experimental	102	48.3	109	51.7	118	55.9	93	44.1
	Control	117	48.5	124	51.5	129	53.5	112	46.5
Could correctly use connecting wires of the right colors for a given cell terminal.	Experimental	64	30.3	147	69.7	132	62.6	79	37.4
	Control	71	29.5	170	70.5	67	27.8	174	72.2
Could correctly connect switch in right cell terminal	Experimental	59	28	152	72	150	71.1	61	28.9
	Control	52	21.6	189	78.4	50	20.7	191	79.3
Could correctly connect provided cells in series.	Experimental	86	40.8	125	59.2	120	56.9	91	43.1
	Control	83	34.4	158	65.6	93	38.6	150	62.2
Could correctly connect provided cells in parallel.	Experimental	47	22.3	164	77.7	159	75.4	52	24.6
	Control	60	24.9	181	10.3	74	30.7	167	69.3
Could correctly connect ammeters in series.	Experimental	79	37.4	132	62.6	134	63.5	77	36.5
	Control	85	35.3	156	64.7	76	31.5	165	68.5
Could correctly connect voltmeters in parallel.	Experimental	84	39.8	127	60.2	109	51.7	102	48.3
	Control	73	30.3	168	69.7	51	21.2	190	78.8
Could identify the apparatus/equipment and other materials provided.	Experimental	120	56.9	91	43.1	99	46.9	112	53.1
	Control	109	45.2	132	54.8	89	36.9	122	50.6
Has indicated why each and every apparatus was used in the practical.	Experimental	88	41.7	123	58.3	110	52.1	101	47.9
	Control	76	31.5	165	68.5	62	25.7	179	74.3

As indicated in table 4.5.1, 78 (3.7.0%) of the experimental group and 65 (27.0%) of the control group were able to utilize all the necessary apparatus to perform the required measurements in PPAE 1 practical work. The number of students able to utilize all the available equipment for necessary measurements in PPAE 2 shifted to 142 (67.3%) in the experimental group and 69 (32.7%) in the control group. Completing all necessary measurements in the PPAE 1 practical task was achieved by 80 (37.6%) students in the experimental group and 87 (36.1%) students in the control group. This differed from the number of students capable of doing so in PPAE 2 practical work; there were 124 (58.8%) students from the experimental group and 70 (29.0%) from the control group.

Recognizing the correct terminals of the given cells is a task that 102 (48.5%) students in the experimental group and 117 (48.5%) students in the control group were able to manage. This was noted in PPAE 1, which varied from the number of students able to do so in PPAE 2. To verify this, 118 (55.9%) students from the experimental group and 129 (53.5%) students from the control group were able to recognize the correct terminals of the cells given in PPAE 2. In PPAE 1, 64 (30.3%) students from the experimental group and 71 (29.5%) students from the control group successfully used connecting wires of the appropriate colors for the correct cell terminal. This situation was different in PPAE 2, where 132 (62.6%) students were from the experimental group and 67 (27.8%) students were from the control group.

Properly linking the switch to the appropriate cell terminal in PPAE 1 is a hands-on task that was undertaken by 59 (28.0%) students in the experimental group and 52 (21.6%) students in the control group. This was different from the number of students who accurately linked the switch to the correct cell terminal in PPAE 2; there were 150 (71.1%) students and 50 (20.7%) students

from the experimental and control groups, respectively. Connecting the given cells in series was accurately performed by 86 (40.8%) students from the experimental group and 83 (34.4%) from the control group, which differed from PPAE 2, where 120 (56.9%) students in the experimental group and 93 (38.6%) in the control group successfully connected the provided cells in series. Accurately linking the given cells in parallel within PPAE 1 is a useful ability that 47 (22.3%) students from the experimental group and 60 (24.9%) students from the control group could demonstrate. This type of skill was noted in 159 (75.4%) students from the experimental group and 74 (30.7%) students from the control group during PPAE 2, showing different figures compared to those seen in PPAE 1.

Achieving the correct connection of ammeters in series for PPAE 1 was accomplished by 79 (37.4%) students from the experimental group and 85 (35.3%) students from the control group. In comparison to PPAE 2, the numbers shifted, with 134 (35.3%) students in the experimental group and 76 (31.5%) in the control group successfully connecting ammeters in series. Correctly connecting voltmeters in parallel in PPAE 1 is a task that 84 (39.8%) students in the experimental group and 73 (39.8%) students in the control group could perform. This was not the case in PPAE 2, where 109 (51.7%) students in the experimental group and 51 (21.2%) students in the control group successfully connected voltmeters in parallel. A total of 120 (56.9%) students from the experimental group and 109 (45.2%) students from the control group were able to identify the supplied apparatus/equipment and other materials during the execution of PPAE 1. In PPAE 2, 99 (46.9%) students from the experimental group and 89 (36.9%) from the control group were able to recognize the apparatus/equipment and other materials given. Eighty-eight (41.7%) students from the experimental group and seventy-six (31.5%) from the control group specified the reasons for using each apparatus in the practical. In PPAE 1, there were 110

(52.1%) students in the experimental group and 62 (25.7%) in the control group. In order to verify the effect of establishing practical apparatus on practical report scores, a Mann-Whitney U statistical test was performed and the results are documented in table 4.5.2.

Table 4.5.2: Mann-Whitney U test outcome on how setting up practical apparatus influences practical scores [Experimental Group; N=211, Control Group; N=241].

		Mean Rank		Mann-Whitney U		Wilcoxon W		Asymptotic Sig. (2-sided test)	
		EXP.	CONT.	EXP.	CONT.	EXP.	CONT.	EXP.	CONT.
Ability to set up practical apparatus	PPAE 1	116.43	119.74	7,217.00	5,367.50	14,828.00	21,128.50	0.927	0.578
	PPAE 2	127.65	108.88	6,723.00	4,861.50	23,099.00	21,687.50	0.007	0.339

The study found that students' skill in assembling practical equipment affects their scores on practical reports. This was validated by the results of the Mann-Whitney U test, which showed significant differences in establishing practical apparatus on practical report scores at PPAE 2 [p=.007; < .05; mean rank 127.65] for students in the experimental group. This was not true for the students in the experimental and control groups, as no statistically significant results were found at PPAE 1 [p=.927; > .05; mean rank 116.43] and [p=.0578; > .05; mean rank 119.74] for the experimental and control groups, respectively. Likewise, the research revealed non-significant outcomes for the students in the control group at PPAE 2 [p=.339; > .05; mean rank 108.88]. This indicated that the intervention (utilization of EPW in carrying out practical tasks) given to the students in the experimental group had a greater impact on their practical report scores than traditional methods of performing physics practical work.

4.5.2. Manipulative Skills

These are abilities that allow students to correctly utilize and manage scientific tools, lab materials and samples. Mudana, (2023), stated that manipulative skills are reliant on mastering the science process skills, which this study examined in terms of basic science process skills. In managing scientific laboratory equipment, materials and samples, the research used a checklist to assess the safety and behavior of students while performing practical tasks, precise documentation and summarizing and concluding their work.

Table 4.5.3: Frequencies and percentages of students acquisition of manipulative skills before and after treatments [Experimental Group; N=211, Control Group; N=241].

	Group	PPAE 1				PPAE 2			
		Yes		No		Yes		No	
		N	%	N	%	N	%	N	%
Used the equipment/apparatus only for its designed purposes	Experimental	60	28.4	151	71.6	176	83.4	35	16.6
	Control	77	32	164	68	81	33.6	164	68
Had laboratory coats	Experimental	0	0	211	100	0	0	211	100
	Control	0	0	241	100	0	0	241	100
Were wearing safety glasses	Experimental	56	26.5	155	73.5	82	38.9	129	61.1
	Control	64	26.6	177	73.4	95	39.4	146	60.6
Set equipment too close to the edge of the working bench	Experimental	0	0	211	100	0	0	211	100
	Control	98	40.7	143	59.3	101	41.9	140	58.1
Could only activate the circuits after inspection from the instructor	Experimental	115	54.5	96	45.5	189	89.6	22	10.4
	Control	101	41.9	140	58.1	104	43.2	137	56.8
Turned off all the electrical devices which were not in use at a particular time.	Experimental	121	57.3	90	42.7	144	68.2	67	31.8
	Control	130	53.9	111	46.1	128	53.1	113	46.9
Could leave the working station neat, clear and organized at the end of the practical work	Experimental	196	92.9	15	7.1	204	96.7	7	3.3
	Control	49	20.3	192	79.7	54	22.4	187	77.6
Could make summary and conclusions based on the evidence.	Experimental	29	13.7	182	86.3	123	58.3	88	41.7
	Control	41	17	200	83	45	18.7	196	81.3

The data shown in table 4.5.3 concerning PPAE 1 revealed that 60 (28.4%) of the students in the experimental group and 77 (32.0%) in the control group were able to use the equipment/apparatus solely for its intended functions. In PPAE 2, these figures shifted, with 176 (83.4%) of the experimental group and 81 (33.6%) of the control group students using the equipment/apparatus solely for its intended functions. All students lacked laboratory coats in PPAE 1 as well as PPAE 2. In the experimental group, there were 56 (26.5%) students and 64 (26.6%) students with safety glasses in PPAE 1, while in PPAE 2, there were 82 (38.9%) students in the experimental group and 95 (39.4%) students in the control group who could do so. Certain students were observed to position the experimental apparatus too near the edge of the workbench in both PPAE 1 and PPAE 2. These students were part of the experimental group exclusively, with 98 (40.7%) participating in PPAE 1 and 101 (41.9%) engaging in the same activity in PPAE 2. In the experimental group, 121 (57.3%) students could only activate the circuits following an instructor's inspection, while in the control group, 130 (53.9%) students did so at PPAE 1. In PPAE 2, the experimental group comprised 189 (89.6%) students, while the control group included 104 (43.2%) students. The research found that 121 (57.3%) students in the experimental group and 130 (53.9%) students from the control group successfully turned off all electrical devices that were not in use during PPAE 1. In PPAE 2, the situation was different, as 144 (68.2%) students from the experimental group and 128 (53.1%) students in the control group were aware and able to switch off all the electrical devices that were not being used at a given time.

Following the experiments conducted in PPAE 1, 196 students (92.9%) from the experimental group maintained their working stations tidy, clear and organized, while only 49 students

(20.3%) from the control group did the same. The figures altered in PPAE 2, showing that 204 (96.7%) students were in the experimental group, while 54 (22.4%) students were in the control group. Forming summaries and conclusions based on the evidence in PPAE 1 was achieved by 29 (13.7%) students in the experimental group and 41 (17.0%) students in the control group. In PPAE 2, there were 123 (58.3%) students in the experimental group and 45 (18.7%) in the control group.

In order to evaluate the impact of developed manipulative skills on practical report scores, the Mann-Whitney U statistical test was performed and the results were documented as displayed in table 4.5.4.

Table 4.5.4: Mann Whitney U test output on how acquisition of manipulative skills affects practical scores [Experimental Group; N=211, Control Group; N=241].

		Mean Rank		Mann-Whitney U		Wilcoxon W		Asymptotic Sig. (2-sided test)	
		EXP.	CONT.	EXP.	CONT.	EXP.	CONT.	EXP.	CONT.
Manipulative skills acquired by the students	PPAE 1	113.41	116.29	6,609.00	7,265.50	15,852.00	17,226.50	0.383	0.465
	PPAE 2	124.18	115.03	4,865.50	6,586.00	15,777.00	6,116.50	0.017	0.361

According to table 4.5.4, the research determined that the manipulative skills gained by students through the use of EPW in practical work impact their practical report scores. This was validated by the notable level reached within the experimental group of students [$p=.017$; $< .05$; mean rank 124.18] in contrast to the significant levels noted among students in both experimental [$p=.383$; $> .05$; mean rank 113.41] and control groups [$p=.465$; $> .05$; mean rank 116.29] prior to treatment, specifically at PPAE 1 and also at PPAE 2 but solely for the students in the control group [$p=.361$; $> .05$; mean rank 115.03]. This demonstrated that the scores on practical reports may be affected by the manipulative skills gained by students through their practical activities.

4.5.2. Data Analysis and Presentation

In this part, the research aimed to assess students' capability to identify resistance, including internal resistance, Ohm's law and to connect potential difference (V) with current (I) in both PPAE 1 and PPAE 2. The research additionally evaluated the drawn graphs regarding the area taken by the graph on the page both horizontally and vertically, the presence of units on both axes, labeling of the axes, precision of the plotted points, construction of the line of best fit and determination of the gradient/slope. Table 4.5.5 displays the responses received from the data analysis checklist.

Table 4.5.5: Frequencies and percentages of students on data analysis and presentation [Experimental Group; N=211, Control Group; N=241].

S/No.	Group	PPAE 1				PPAE 2				
		Yes		No		Yes		No		
		N	%	N	%	N	%	N	%	
1	Was able to determine resistance (R) in Ohm's Law	Experimental	46	21.8	165	78.2	141	66.8	70	33.2
	Control	61	25.3	180	74.7	73	30.3	168	69.7	
2	Was able to determine internal resistance (IR) of the cells used in the circuits	Experimental	29	13.7	182	86.3	66	31.3	145	68.7
	Control	20	8.3	221	91.7	32	13.3	209	86.7	
3	Was able to determine ohm's law	Experimental	103	48.8	108	51.2	157	74.4	54	25.6
	Control	95	39.4	146	60.6	100	41.5	141	58.5	
4	Was able to relate potential difference (V) to current (I)	Experimental	88	41.7	123	58.3	120	56.9	91	43.1
	Control	92	38.2	149	61.8	109	45.2	132	54.8	
5	Choosing the right scale to balance space occupied by the graph within the page both horizontally and vertically	Experimental	79	37.4	132	62.6	133	63	78	37
	Control	85	35.3	156	64.7	92	38.2	149	61.8	
6	Could provide units and label both axes	Experimental	75	35.5	136	64.5	170	80.6	41	19.4
	Control	69	28.6	172	71.4	70	29	171	71	
7	Could accurately plot the points	Experimental	67	31.8	144	68.2	124	58.8	87	41.2
	Control	71	29.5	170	70.5	78	32.4	163	67.6	
8	Could accurately draw line of the best fit	Experimental	60	28.4	151	71.6	132	62.6	79	37.4
	Control	68	28.2	173	71.8	72	29.9	169	70.1	
9	Could calculate the gradient/slope	Experimental	73	34.6	138	65.4	100	47.4	111	52.6
	Control	96	39.8	145	60.2	104	43.2	137	56.8	
10	Relate the gradient to the equation of a straight line	Experimental	54	25.6	157	74.4	113	53.6	98	46.4
	Control	50	20.7	191	79.3	62	25.7	179	74.3	

As per table 4.5.5, 46 (21.8%) students from the experimental group and 61 (25.3%) students from the control group were able to identify resistance (R) in Ohm's Law at PPAE 1. At PPAE 2, 141 (66.8%) students from the experimental group and 73 (30.3%) students from the control

group were able to identify resistance (R) in Ohm's Law. Assessment of the internal resistance (IR) of the cells utilized in the circuits was accomplished by 29 (13.7%) teachers from the experimental group and 20 (8.3%) students from the control group at PPAE 1. The individuals able to assess the internal resistance (IR) of the cells utilized in the circuits at PPAE 2 comprised 66 (31.3%) students from the experimental group and 32 (13.3%) students from the control group. In PPAE 1, Ohm's law was identified by 103 (48.8%) students from the experimental group and 95 (39.4%) students from the control group. The law might also be identified as PPAE 2 by 157 (74.4%) students from the experimental group and 100 (41.5%) students from the control group.

The connection between potential difference (V) and current (I) was observed by 88 (41.7%) students in the experimental group and 92 (38.2%) students in the control group at PPAE 1. In PPAE 2, the situation was different, as 120 (56.9%) students in the experimental group and 109 (45.2%) students in the control group were able to associate potential difference (V) with current (I). Selecting the appropriate scale to evenly distribute the space taken by the graph on the page both horizontally and vertically was achieved by 79 (37.4%) students in the experimental group and 85 (35.3%) students in the control group at PPAE 1. At PPAE 2, 133 (63.0%) students from the experimental group and 92 (38.2%) students from the control group were able to select the appropriate scale to balance the space taken up by the graph on the page both horizontally and vertically. Writing the units and labeling both axes was accomplished by 75 (35.5%) students in the experimental group and 69 (28.6%) students in the control group at PPAE 1, whereas at PPAE 2, 170 (80.6%) students in the experimental group and 70 (29.0%) students in the control group were able to write the units and label the two axes.

Points were accurately plotted by 67 (31.8%) of the students in the experimental group and 71 (29.5%) of the students in the control group in PPAE 1. Nevertheless, the number of students able to do so shifted at PPAE 2, as 124 (58.8%) students from the experimental group and 78 (32.4%) students from the control group were able to correctly plot the points for the graph task. The line of best fit was created by 60 (28.4%) students in the experimental group and by 68 (28.2%) students in the control group. This occurred in PPAE 1 at PPAE, where the students who were able to accurately represent the line of best fit for the experimental and control groups were 132 (62.6%) and 72 (29.9%), respectively. At PPAE 1, the gradient was calculated by 73 (34.6%) students from the experimental group and 96 (39.8%) from the control group, respectively. This was somewhat different in PPAE 2, where 100 (47.4%) and 104 (43.2%) students were able to calculate the gradient in the experimental and control groups, respectively. Connecting the gradient to the equation of a straight line in PPAE 1 was achievable by 54 (25.6%) students in the experimental group and 50 (20.7%) students in the control group. At PPAE 2, 113 (53.6%) participants from the experimental group and 62 (25.7%) participants from the control group were able to connect the gradient to the linear equation. To evaluate the impact of obtained data analysis and presentation skills on practical report scores, the Mann-Whitney U statistical test was performed and the results were documented as presented in table 4.5.6.

Table 4.5.6: Mann-Whitney U test output on how acquisition of data analysis and presentation skills influences practical scores [Experimental Group; N=211, Control Group; N=241].

		Mean Rank		Mann-Whitney U		Wilcoxon W		Asymptotic Sig. (2-sided test)	
		EXP.	CONT.	EXP.	CONT.	EXP.	CONT.	EXP.	CONT.
Acquired data	PPAE 1	109.76	109.78	7,275.00	7,097.00	17,427.50	14,769.00	0.612	0.902
analysis and presentation skills	PPAE 2	138.23	119.09	8,226.00	6,619.00	17,939.00	19,634.00	0.034	0.318

Table 4.5.6 showed a statistically significant finding between the analysis of acquired data and presentation abilities in relation to practical report scores. This was validated among students in the experimental group when a significant value post-treatment was determined to be under .05; [p=.034; < .05; mean rank 138.23]. On the other hand, the statistically significant values found among students from both the experimental group [p=.612; > .05; mean rank 109.76] and the control group [p=.902; < .05; mean rank 109.78] were determined to be below the significance threshold of .05. This indicated that EPW helped students develop data analysis and presentation skills, which later impacted their practical report scores.

The results align with those of Billard and Kragic, (2019) who observed that manipulative tasks involving computers are simpler and yield more precise outcomes compared to using traditional tools for the manipulation. Chi, (2018) connected potential difference (V) to current (I) by graphing the values to determine a gradient which represents R. Chi observed that employing digital media to plot the curve results in a precise line of best fit. And this makes it simpler to calculate the gradient.

The data and statistical analyses confirm that the EPW intervention had a substantial and positive impact on the experimental group. Gains were significant in nearly all practical areas,

particularly in hands-on skills, data handling, interpretation and report writing. The control group showed only modest or negligible improvements, validating the effectiveness of EPW over traditional instruction methods. Based on the comprehensive data presented, the experimental group consistently outperformed the control group across nearly all measured parameters in the physics practical assessments (PPAE 1 and PPAE 2). In conclusion, the experimental group clearly did well, benefiting significantly from EPW, while the control group did not perform as well, reflecting limited impact from conventional teaching methods. The Mann Whitney statistical test indicated that the capability to conduct experiments had a statistically significant outcome related to practical report scores for students in the experimental group at the conclusion of the study. At the start of the study, this was not true for students in either the experimental or control groups.

The results of the study align with those of Sani (2014), who discovered that utilizing computing devices for practical work provides students with easier access to technology for diverse experiments. Sani claimed that a workbench platform facilitates the learner's ability to identify necessary materials for practical tasks, as computers can assist in naming those materials. Teke, Dogan and Duran (2015), conversely, pointed out that utilizing a computer-based practical workbench simplifies the process of setting up an experiment and enhances the academic performance of students.

Students who exhibited mastery of manipulative skills were capable of utilizing the equipment solely for its intended functions, remembered to don protective gear in the lab and managed to keep equipment from being too near the edge of the workbench. Simultaneously, these students could engage the circuits even prior to the instructor's inspection, deactivate most electronic devices not in use at that moment, leave the workstation tidy, uncluttered and orderly after

completing the practical work and generate summaries and conclusions based on the findings. These abilities were recognized at the conclusion of the research and most of these students belonged to the experimental group. This indicates that the application of EPW treatment affected the learning of manipulative skills, ultimately resulting in an improvement in practical report scores. The Mann-Whitney U statistical test further verified this by the conclusion of the study, showing higher mean rank values for students in the experimental group compared to those in the control group. Simultaneously, the test revealed a statistically significant outcome regarding the relationship between the development of manipulative skills and practical report scores at the conclusion of the study among students in the experimental group. This demonstrated that the scores of practical reports can be affected by the manipulative skills students develop through hands-on work. Remarks from students in the FGD indicated that those in the experimental group were able to handle the apparatus and organize experiments to achieve their established goals or objectives.

A discovery by Mwamba et. al., (2019) connects with this study's finding regarding students' capability to conduct different practical experiments on the same computer-based platform, allowing them to obtain optimal solutions for specific problems. They observed that these activities can be performed with minimal risk of injury or damage. Learners will have the opportunity to evaluate various scenarios, analyze differences and similarities and identify the most efficient solution(s).

In data analysis and presentations, the research evaluated the depicted graphs regarding the area they cover on the page both horizontally and vertically, the presence of units on both axes, the labeling of the axes, the precision of the plotted points, the creation of the line of best fit and the computation of the gradient/slope. At PPAE 2, a greater number of students from the

experimental group compared to the control group were able to analyze the data available and present it correctly using graphical representations. Within the experimental group of students, the Mann Whitney test yielded a higher mean rank compared to the control group at PPAE 2. Simultaneously, there is a statistically significant correlation between the capacity to perform data analysis and representation and the scores on practical reports. This indicated that EPW helped students develop data analysis and presentation skills, which subsequently affected their practical report scores.

The results of the research lead to the rejection of the null hypothesis. The information clearly shows that utilizing the Electronics Practical Workbench (EPW) greatly improved students' acquisition of practical skills such as experimental design, manipulation skills and data analysis and presentation, when compared to conventional practical methods. The Mann-Whitney U test consistently showed statistically significant differences favoring the experimental group in various skill areas, especially in conducting experiments and accurately presenting results, thereby enhancing their practical report scores. These results show that the EPW treatment significantly influenced students' hands-on performance, thus offering adequate proof to dismiss the null hypothesis and affirm that EPW plays a vital role in fostering the essential practical skills necessary for physics education.

The researcher noted that students using the EPW demonstrated significantly greater acquisition of practical skills in physics compared to those using conventional methods, encompassing experiment setup, manipulative abilities and report writing. While both groups initially struggled at PPAE 1, the experimental group showed marked improvements by PPAE 2, with 67.3% correctly using equipment versus 32.7% for the control, 62.6% correctly applying color-coded

wires and 75.4% achieving proper setting of series and parallel cell connections. The experimental group students also excelled in identifying apparatus functions at 52.1% and 25.7% for control groups, maintaining organized workstations was at 96.7% and 22.4% for experimental and control groups respectively. Activating circuits responsibly was at 89.6% and 43.2% for experimental and control groups in that order. This is reflecting enhanced procedural understanding and safety awareness. Furthermore, the experimental group outperformed in practical calculations, understanding Ohm's Law, analyzing current-voltage relationships and presenting data graphically, with over 80% labeling graphs correctly and 53.6% accurately calculating gradients, compared to much lower control group performance. Statistical analysis confirmed that these manipulative and analytical skills significantly contributed to higher practical report scores at post-intervention, demonstrating that EPW not only improved hands-on abilities but also strengthened students' competence in measurement, observation, data analysis and scientific reporting, unlike traditional methods which produced minimal gains.

4.6. Influence of electronics practical workbench on students' attitudinal change towards physics

4.6.1. Introduction

Attitude change toward physics was assessed by administering attitude change questionnaires at the before and after treatment to both the experimental and control groups. The questionnaires included items measuring students' interest, enjoyment, confidence and perceived relevance of physics practical work tasks to real life. By comparing the pre-test and post-test responses, the researcher could determine whether students' attitudes positively improved after the intervention. The questionnaires assisted the researcher in gathering students' perspectives and thoughts regarding the significance of physics practical lessons delivered and the activities of writing

practical work reports. Table 5.6.1 (a) and (b) presents the responses gathered from the attitude formed towards the physics practical questionnaires. The questionnaires enabled the students to communicate their sentiments by marking whether they comprehended the concepts taught and if the physics practical lessons were engaging, significant and relevant. Students shared their opinions on the ease or difficulty of conducting physics practical activities during classes and how meaningful the lessons delivered through the electronics practical workbench were for them. The questionnaires were distributed two times; once at the start of PPAE 1 and again at the conclusion of PPAE 2. Every student received a serial number that later facilitated the comparison of their responses at the start and conclusion of the study.

Table 4.6.1(a): Frequencies and percentages of students on attitude developed towards physics [Experimental Group; N=211, Control Group; N=241].

SN	STATEMENT	Group		At the beginning of PPAE 1					At the end of PPAE 2				
				SA	A	U	D	SD	SA	A	U	D	SD
1.	The physics concepts taught in the lessons were well understandable	Experimental	N	30	43	30	76	32	56	81	8	40	26
			%	14.2	20.4	14.2	36	15.2	26.5	38.4	3.8	19	12.3
		Control	N	36	49	37	50	69	42	54	29	48	68
			%	14.9	20.3	15.4	20.7	28.7	17.4	22.4	12.1	19.9	28.2
2.	The physics practical lessons were dull	Experimental	N	66	61	27	36	21	35	39	11	56	70
			%	31.3	28.9	12.7	17.1	10	16.6	18.5	5.2	26.5	33.2
		Control	N	80	68	40	31	22	76	63	33	42	27
			%	33.2	28.2	16.6	12.9	9.1	31.5	26.1	13.8	17.4	11.2
3.	The physics practical skills were useful and are applicable in human life.	Experimental	N	57	59	24	40	31	93	71	9	24	14
			%	27	28	11.3	19	14.7	44.1	33.6	4.3	11.4	6.6
		Control	N	60	62	33	59	27	58	65	26	57	35
			%	24.9	25.7	13.7	24.5	11.2	24.1	27	10.8	23.7	14.4
4.	It was not easy to carry out physics practical activities during the lessons	Experimental	N	43	70	24	45	29	2	35	5	68	101
			%	20.4	33.2	11.4	21.3	13.7	0.9	16.6	2.4	32.2	47.9
		Control	N	72	60	30	48	31	78	70	29	36	28
			%	29.9	24.9	12.4	19.9	12.9	32.4	29	12	14.9	11.7

Table 4.6.1(b): Responses on attitude developed towards physics practical questionnaire [Experimental Group; N=211, Control Group; N=241].

SN	STATEMENT	Group		PPAE 1					PPAE 2				
				SA	A	U	D	SD	SA	A	U	D	SD
5.	I enjoyed carrying out physics practical activities taught by the teacher during the lessons	Experimental	N	61	65	36	30	19	95	66	16	24	10
			%	28.9	30.8	17.1	14.2	9	45	31.3	7.6	11.4	4.7
		Control	N	65	71	37	47	21	69	76	32	45	19
			%	27	29.5	15.4	19.4	8.7	28.6	31.5	13.3	18.7	7.9
6.	I could not miss the physics practical lessons taught by the teacher	Experimental	N	47	69	21	39	35	99	72	3	26	11
			%	22.3	32.7	10	18.5	16.5	46.9	34.1	1.5	12.3	5.2
		Control	N	62	75	25	57	22	66	76	31	36	32
			%	25.7	31.1	10.4	23.7	9.1	27.4	31.5	12.9	14.9	13.3
7.	I could easily make conclusions based on the findings from the practical work.	Experimental	N	23	43	26	70	49	77	89	5	24	16
			%	10.9	20.4	12.3	33.2	23.2	36.5	42.2	2.4	11.4	7.6
		Control	N	20	26	38	97	60	24	31	32	102	52
			%	8.3	10.8	15.8	40.2	24.9	10	12.8	13.3	42.3	21.6

According to table 4.6.1 (a) and (b), At the beginning of the study, during PPAE 1, both the experimental and control groups struggled to fully grasp the physics concepts taught during lessons. Only about 34.6% of students in the experimental group using EPW and 35.3% in the control group using conventional methods found the lessons understandable. However, by PPAE 2, there was a notable improvement in comprehension among the experimental group, with 64.9% reporting that the concepts were clear, compared to just 48.1% in the control group. This demonstrates that the technology-supported learning environment of the EPW enhanced students' conceptual clarity more effectively than traditional hands-on approaches.

Initially, many students in both groups found physics practical lessons monotonous, with 60.2% of the experimental group and 61.4% of the control group reporting boredom during PPAE 1. After exposure to the EPW, this perception changed significantly among experimental group students 59.7% later disagreed that lessons were boring, indicating a major shift in engagement. Conversely, the control group showed only modest improvement, with 28.6% finding the lessons more engaging by PPAE 2. This suggests that the EPW made learning more interactive, stimulating curiosity and interest in physics practical work compared to conventional teaching methods.

At the start of the study, 55.0% of students in the experimental group and 50.6% in the control group agreed that physics practical skills were beneficial to real-life applications. By PPAE 2, the experimental group's perception increased sharply to 77.7%, while the control group improved slightly to 51.0%. The consistent rise in the experimental group's scores highlights how technology-aided practical work helped students recognize the usefulness of physics beyond the classroom, linking theory to real-world problem-solving more effectively than traditional

methods.

During PPAE 1, over half of the students in both groups found performing physics practical activities difficult, these were 53.6% in the experimental group and 54.7% in the control group. However, by PPAE 2, the experimental group's view had reversed dramatically, with 80.1% stating that practical activities had become easy to perform. Meanwhile, the control group's perception of difficulty persisted, with 61.4% still finding practicals challenging. This highlights that the EPW not only improved skill acquisition but also simplified experimentation through structured, guided and error-reducing interfaces.

Enjoyment of teacher-led practical lessons increased markedly among students using the EPW. In the experimental group, enjoyment rose from 59.7% in PPAE 1 to 76.3% in PPAE 2, while in the control group, it remained nearly unchanged at around 56%. Likewise, commitment to attending physics practical lessons strengthened in the experimental group because 81.0% stated they could not afford to miss lessons compared to 58.9% in the control group. These findings show that the EPW made physics more enjoyable, motivating students to participate consistently and view practical work as essential to learning.

At the beginning of the study, only 31.3% of experimental students and 19.1% of control students felt confident drawing conclusions from practical results. By PPAE 2, this confidence rose dramatically in the experimental group to 78.7%, while the control group's improvement was minimal, reaching only 22.8%. The ability to interpret experimental data accurately and meaningfully improved significantly with the use of the EPW. Overall, the study's regression results confirmed that the EPW promoted better comprehension, engagement, and reporting accuracy, reflecting stronger positive attitudinal and performance outcomes than the

conventional method. A linear regression analysis was performed to assess the variations in practical report scores prior to and following treatment, as well as the relationships between attitudinal factors and practical report scores, as shown in table 4.6.2.

Table 4.6.2: Descriptive analyses between mean rating on students’ attitude change and their practical scores [Experimental Group; N=211, Control Group; N=241].

	Group	N	Mean		Std. Deviation	
			PPAE 1	PPAE 2	PPAE 1	PPAE 2
Practical Report Scores	Experimental	211	15.37	27.99	6.92	3.118
	Control	241	15.33	14.49	3.426	3.284
Mean Rating	Experimental	211	1.7536	3.0125	0.416	0.599
	Control	241	1.95	1.893	0.809	1.021

According to table 4.6.2, the average practical report mean scores from students in both groups were roughly equivalent prior to treatment, showing a difference of .04 marks. Post-treatment, students in both groups experienced an enhancement in their average practical report scores, with an increase of 12.62 marks in the experimental group and 0.16 marks in the control group. This demonstrated an impact of employing EPW in hands-on activities on the practical report scores in comparison to traditional practical execution methods.

The linear regression analysis produced correlation results to determine the strength and direction of the linear relationship between mean ratings from the Likert scale regarding accuracy in practical report writing and the practical report scores. The correlation results are presented in table 4.6.3.

Table 4.6.3: Correlation output between mean rating on students' attitude change and their practical scores [Experimental Group; N=211, Control Group; N=241].

		Group	PPAE 1 Practical Report Scores	PPAE 2 Practical Report Scores
Pearson Correlation	Mean Rating	Experimental	0.046	0.249
		Control	0.043	0.071
Sig. (1-tailed)	Mean rating	Experimental	0.241	0.0298
		Control	0.21	0.407

As indicated in table 4.6.3, the correlation among students in both groups was less before treatment than the correlation value achieved post-treatment. The students in the experimental group achieved correlation values of .046 prior to treatment and .249 following treatment. Conversely, the control group students obtained correlation values of .043 and .071 prior to and following treatment, respectively. This demonstrated an increase in correlation values among students in both groups, particularly in the experimental group, which showed a rise of .203 units compared to the control group's .028 units. To demonstrate the degree of attitudinal change explained by the use of an electronics practical workbench, a summary model table was created from regression analysis, validating the correlation value (R) and the model's power (R²), as presented in table 4.6.4.

Table 4.6.4: Regression analysis summary model between mean rating on students' attitude change and their practical scores [Experimental Group; N=211, Control Group; N=241].

Indicators	Group	PPAE 1	PPAE 2
R (Correlation value)	Experimental	.037a	0.58
	Control	.042a	0.049
R ² (Power of the Model)	Experimental	0.001	0.476
	Control	0.0026	0.0059

a. Predictors: Practical Report Scores.

b. Dependent Variable: Mean Rating of attitudinal components.

The research observed that for each unit rise in practical report scores prior to treatment, the average rating of the attitudinal components increased by .037 units for students in the experimental group and by .042 units for those in the control group. Following treatment, the rise of one unit in practical report scores indicated an increase in mean ratings for the attitudinal components by .54 units and .007 units for students in the experimental and control groups, respectively. The scores from the practical report could account for 0.1% and 0.26% of the attitudinal elements among students in both the experimental and control groups prior to treatment. Following treatment, practical report scores accounted for 47.6% and 0.59% of the attitudinal aspects among students in both the experimental and control groups, respectively. This indicated that the application of EPW in hands-on tasks influences the score of practical reports, leading to a shift in attitude. This is due to students in the experimental group showing a greater positive shift in the average rating values of attitudinal components due to the practical report scores. It was noted that the percentage of attitudinal components explained by practical report scores was greater in the experimental group compared to the control group. The relationship's direction between practical report scores, featuring mean ratings from a questionnaire likert scale and attitudinal elements was established through linear regression. The presence of a significant difference between the practical report scores and the attitudinal components was also confirmed using linear regression. A table of coefficient outputs was created and displayed in terms of coefficient value, t-value and P-value as illustrated in table 4.6.5.

Table 4.6.5: Regression Analysis Coefficients output between mean rating on students' attitude change and their practical scores [Experimental Group; N=211, Control Group; N=241].

		Unstandardized Coefficients (B)		t-value		Sig.	
		PPAE 1	PPAE 2	PPAE 1	PPAE 2	PPAE 1	PPAE 2
Mean Rating	Experimental	0.219	4.61	0.442	0.854	0.549	0.027
	Control	-0.158	0.052	-0.033	0.014	0.0521	0.506

a. Dependent Variable: Mean Rating of attitudinal components.

According to table 4.6.5, as the mean scores of the practical report rose, the mean rating units for attitudinal components also grew for students in the experimental group. These resembled results found simultaneously among the students in the control group. Following treatment, the average scores on practical reports for students in the experimental group improved mean ratings for the attitudinal aspects by 4.39 units, whereas the students in the control group only saw an increase of 0.21 units. This confirmed that the use of EPW affects the practical report scores, leading to a favorable change in attitude. The research additionally evaluated the t-values obtained from linear regression analysis both prior to and following treatment. The t-values acquired provided more compelling evidence against the null hypothesis for students in the experimental group compared to those in the control group following treatment. This is due to the t-value being greater for students in the experimental group (.854) compared to those in the control group (.014) following treatment. This opposed the t-values recorded prior to treatment in both groups, where the t-values were significantly lower, particularly among students in the control group, where the t-value was -.033, falling beneath the significance threshold of .05. The proof against the null hypothesis was subsequently demonstrated by p-values found in coefficient table 4.6.5, which fell below the significant threshold of .05 post-treatment for participants in the

experimental group. This contradicted the p-values measured prior to treatment in both student groups and also within the control group student's post-treatment. In every instance, the p-values exceeded the significant threshold of .05. Consequently, the null hypothesis was dismissed by comparing the coefficient values, t-values and p-values derived from the linear regression analysis results prior to and following treatment.

In the FGD, students were inquired if they found it easy to complete the first and second practical tasks. A few students admitted that the practical was challenging for them, stating difficulties with using equipment for the first time, malfunctioning tools, insufficient time and flawed procedural instructions. A few students were cited as follows:

ST-CON-PAE1: "It was not easy to carry out the first practicals,with me I had just been seen those materials in the lab, like ammeter, voltmeter and others, but I had not used them before,.. so I struggled to connect those wires which were not working well,..i don't know what was wrong..."

ST-EXP-PAE1:..do you know why it was not easy for me in practical 1, mmm..mara.....you are told to reset ammeter to zero, mara..eee...check where an apparatus has rusted and scrub, of which were not there in the procedure..." so I could set up the circuit, then I remember that I need to resent, I need to scub, in the long run time was going..

The same students answered the same questions for the second practical; some acknowledged that it was still difficult for them, citing faulty equipment, insufficient resources and inadequate time. A few of the students were cited in the following manner;

ST-CON-PAE 2: In the second practical, I tried my level best but some of the apparatus I was using were not even working, imagine I requested for an ammeter replacement three times,..eee.. I also replaced my cell holders of which one of them did not even have a terminal plate, so, time was not enough for me....."

Conversely, some of those students admitted that the practical was still simple for them, highlighting positive aspects of the procedures that contributed to their success during practical tasks. A few of the students were cited as follows:

ST-EXP-PAE 2: "...the practical work was easier to me because, after we were taught to do it using a computer, the computer itself could help you identify the apparatus you want to use, it could tell you if you have connected certain terminals incorrectly, aaa...and it could allow you to adjust the scale or values you want to use... so it was easier compared to the first one we did...."

This indicated that EPW impacted changes in attitudes towards physics, especially the practical aspect of learning the subject. This was primarily among the students in the experimental group. Additional aspects of attitudes evaluated during the FGD included whether students preferred the first or second practical work and whether their experiences in either the first or second practical work were beneficial and relevant to human life. All participants who replied for both the first and second practical among students in the experimental group indicated their discontent in the first practical but expressed satisfaction in the second practical. This was in contrast to the majority of students in the control group, most of whom expressed dissatisfaction in both the first and second practical.

A significant shift in attitude was noted among students in the experimental group at PPAE2 compared to those in the control group. This was validated when a larger number of students concurred that the concepts presented in the lessons were easily understandable, practical skills were beneficial and disagreed that they were not applicable in human life, while also noting that carrying out physics practical activities during the lessons was challenging. The majority of students in the experimental group found pleasure in participating in the physics practical activities led by the teacher and did not want to miss any lessons.

The mean scores of the practical report were greater for students in the experimental group compared to those in the control group at PPAE 2. A correlation analysis from the linear regression statistical test showed a stronger positive relationship between the use of EPW in performing physics tasks and the attitudinal factors, ultimately leading to an improvement in practical report scores. Simultaneously, linear regression demonstrated a statistical significance between the application of EPW in performing physics tasks and the attitudinal elements. This demonstrated that employing EPW in hands-on tasks influences the score of practical reports, which leads to a shift in attitude. This is due to students in the experimental group showing a greater positive shift in the average rating values of attitudinal elements as a consequence of the practical report scores. It was noted that the portion of attitudinal components explainable by practical report scores was greater in the experimental group than in the control group.

These findings align with those of Nnorom (2015), who highlighted that a crucial method for engaging learners more in their education involves ensuring that materials resonate with the user, who is the student and that EPW is included in this. Murugan and Osman (2018) suggested that students' interests are integral to the classroom, so integrating ICT should influence learners' motivation. The research examined the effect of an electronics practical workbench on students' attitude shift towards physics when utilized for physics practical work. This was grounded in the student's emotions and comprehension of the concepts presented, their enthusiasm for the physics practical lessons and how significant and relevant the concepts taught were to them. It also concentrated on the ease or challenge of the physics practical tasks for them. Most of the students in the experimental group at PPAE 2 found the practical activities easy to perform, enjoyable and the concepts presented were clear, which prevented them from missing any

classes. They mentioned that the practical skills were beneficial and can be used in daily life. Along with these, they found it quite simple to reach an informed conclusion.

This was not true for students in both groups at PPAE 1 and for those in the control group at PPAE 2, who showed mostly feelings opposite to those of their peers in the experimental group at PPAE 2. The majority of students in the control group observed that the concepts presented in the lessons were difficult to grasp since they found the lessons somewhat boring; they believed that the practical skills emphasized during the lessons were not beneficial and had limited relevance in real-life contexts. Many students in the control group found it difficult to perform the practical activities during the lessons, which led to a lack of enjoyment in those lessons and they would happily skip them when they could. Simultaneously, even those who were able to engage in the practical tasks were unable to draw conclusions from the results of the practical work.

Additional confirmatory results were shown through the linear regression descriptive analysis test (table 4.6.3), which demonstrated that students in the experimental group achieved a higher practical mean score compared to those in the control group at PPAE 2, in contrast to the lower practical mean scores observed for both groups at PPAE 1. A positive relationship was found between practical report scores and the teaching method among students in both groups during PPAE 1 and PPAE 2. Nonetheless, at PPAE 2, the correlation among students in the experimental group was significantly greater than that observed in the control group. According to the regression analysis summary model results in table 4.6.4, the application of EPW can account for a greater percentage of practical scores in the experimental group than the percentage of scores that the traditional practical teaching method can account for in the control group.

Simultaneously, the regression coefficient results in table 4.6.5 indicated a statistically significant outcome regarding the use of EPW in physics practical sessions at PPAE 2, which differed from the feedback received when students were instructed through traditional practical teaching methods at PPAE 1 and for those in the control group at PPAE 2. The research consequently revealed that EPW as a hands-on teaching method greatly impacts students' attitudes toward physical practical tasks. This is the reason the relationship between the average scores of practical reports and the elements of attitude towards practical work was more favorable in the experimental group of students. This also led to elevated average scores for practical reports as they began to appreciate and enjoy performing physics practical tasks.

According to the research results, the null hypothesis asserting that the electronics practical workbench (EPW) does not significantly influence students' attitudes toward physics practical work is dismissed. The research showed that students in the experimental group at PPAE 2, who interacted with EPW, displayed a significant positive change in attitude compared to those in the control group and classmates at PPAE 1. These students discovered the lessons to be more captivating, the concepts simpler to grasp and the skills more applicable to real-life situations. Statistical analyses, such as linear regression, verified a significant positive relationship between the employment of EPW and enhanced attitudinal factors, along with elevated average scores in practical reports. The regression model also showed that EPW explained more variance in practical performance compared to conventional methods. Consequently, the data indicates a statistically notable effect of EPW on improving students' attitudes and outcomes in physics practical activities.

The use of the EPW led to a significant positive change in students' attitudes toward physics compared to conventional practical methods. Students in the experimental group showed marked improvement in comprehension of physics concepts, rising from 34.6% at PPAE 1 to 64.9% at PPAE 2, whereas the control group's gain was modest from 35.3% to 48.1%. The experimental group also reported increased enjoyment and engagement, with nearly 60% rejecting the notion that lessons were boring, greater appreciation of practical skills for real-life applications at 77.7% compared to minimal change in the control group and reduced perception of difficulty in conducting experiments by 19.9% while majority of students in the control group were still finding them challenging. Confidence in interpreting experimental results and motivation to participate in practicals also grew substantially among EPW students, supported by a significant increase in practical report scores of 11.2 marks compared to 0.1 in the control group. Therefore, the findings indicate that EPW not only enhanced conceptual understanding and hands-on competence but also fostered enthusiasm, motivation and a positive disposition toward physics, whereas traditional methods produced only limited attitudinal gains.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

This chapter provides aim of the study, methodologies and a summary of the research. This part has also covered the study's conclusion, recommendations and proposed variables for future research.

This study evaluated the effects of using an electronics practical workbench (EPW) on students' academic achievement physics practicals, concentrating on measurement accuracy, development of scientific processes and practical skills, and shifts in students' attitudes toward physics. The study assessed whether the EPW could improve students' experimental accuracy, elevated their proficiency in scientific and technical abilities, cultivated students' positive attitude toward the subject. These were assessed by contrasting outcomes of students taught practical work by use of EPW against those taught the same concepts through practical conventional teaching methods. This approach sought to determine the effectiveness of EPW as a transformative teaching instrument in enhancing the quality and results of physics practical work.

The research adopted a quasi-experimental research design, incorporating a pre-test and post-test non-equivalent group framework to assess the influence of an electronics practical workbench on students' physics hands-on skills, attitudes towards physics and academic achievement. The study was carried out in Nairobi County, Kenya, and it focused on form three physics students 67 public secondary schools, out of which a stratified random sample of 21 schools was selected. Participants were categorized into experimental and control groups, where the experimental group was taught practical work using an electronics workbench, while the control group

followed conventional teaching approaches. Data was collected through various tools, such as the physics practical achievement examinations (PPAE), science process skills observation checklist (SPPSLOC), attitude developed towards physics practical questionnaire (ADTPPQ), and discussions with student focus groups. Piloting was conducted in four schools to evaluate the validity and reliability of the instruments, with Cronbach's alpha and split-half reliability coefficients affirming internal consistency.

Data collection was conducted in accordance with stringent ethical guidelines, adhering to approvals from both institutional and national educational bodies. Data of both quantitative and qualitative types were gathered and examined. Quantitative data were analyzed using non-parametric statistical techniques including the Mann-Whitney U test and Ordinal Logistic Regression, suitable for the ordinal and continuous data types gathered from achievement tests, checklists and questionnaires. Thematic analysis was conducted on qualitative data gathered from interviews and focus groups. The approach facilitated in-depth evaluation of students' scientific process abilities, hands-on skills and perceptions of physics practical activities, allowing the researcher to gauge actual teaching effects in a digitally supported but resource-limited educational setting.

5.2. Summary of the Findings

To determine the difference in accuracy level of measurements in the practical report, to examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process and practical skills. It also assessed the influence of electronics practical workbench on students' attitudinal change towards physics in comparison of

the findings from students taught practical work using EPW and those taught the same conventionally.

5.2.1. Accuracy Level of Measurements in the Practical Report

The study's findings revealed clear differences in the accuracy levels of measurements between students taught using the EPW and those taught through conventional methods. While both groups began with low practical mean scores at PPAE 1, the experimental group displayed remarkable improvement by PPAE 2, with 75% of their schools achieving higher mean scores ranging from 15.0 to 24.9. In contrast, the control group showed only slight improvement, with several schools still recording low scores. When evaluating the accuracy of current, potential difference (p.d.), and electromotive force (e.m.f.) readings, the experimental group outperformed the control group in nearly all measurement categories. For instance, 92.4% of experimental students correctly measured current within the 0.55–0.59 A range, compared to only 39.8% in the control group. Similarly, correct p.d. and e.m.f. readings improved by 28.0% and 41.8% respectively in the experimental group, while the control group either stagnated or declined, demonstrating that the EPW significantly enhanced students' measurement precision and overall experimental accuracy.

Further statistical analysis reinforced these results, showing that measurement accuracy strongly correlated with improved practical report scores in the experimental group. Post-intervention, correlations between p.d. accuracy and practical report performance rose sharply to .63 for one cell and .56 for two cells ($p = .0001$), while the control group's correlations remained weak and statistically insignificant. Regression analysis further indicated that 44.4% ($R^2 = 0.444$) of the variation in practical scores among the experimental group could be explained by their improved

current-reading accuracy, compared to just 3.5% ($R^2 = 0.035$) in the control group. Moreover, the experimental group's regression coefficient ($B = 6.561$, $t(210) = 3.07$, $p < .05$) confirmed that increased reading accuracy led to substantial score gains, a pattern absent in the control group. Collectively, these findings demonstrate that the use of the electronics practical workbench significantly boosted students' precision, analytical understanding and reporting performance in physics practical work, far beyond what was achieved through conventional methods.

5.2.2. Basic science process skills

The study's findings revealed clear differences between students who learned using the Electronics Practical Workbench (EPW) and those who used conventional practical methods in acquiring key science process skills such as observation, measurement, and communication. At the beginning of the study (PPAE 1), both groups struggled to identify and classify basic circuit components, although the experimental group showed slightly better results. Only 48.3% of experimental students correctly identified the poles of dry cells and even fewer recognized cell holders, voltmeters, or switches. Similarly, the control group also recorded low scores, with 58.9% identifying dry cells and only 13.3% correctly identifying switches. However, by the end of the study (PPAE 2), the experimental group demonstrated significant progress across all assessed skills since over 75% of them could correctly identify and classify major apparatus like cells, voltmeters and switches, while 67.8% successfully branded connecting wires by color. In contrast, the control group's performance improved only slightly, with less than half accurately identifying key components, showing that traditional methods were less effective in enhancing observational and classification skills.

The use of the electronics practical workbench also greatly improved students' measurement and communication skills. Statistical results showed that the experimental group's ability to identify and correctly use apparatus had a significant positive effect on their practical report scores at PPAE 2 ($p < .05$), while no significant change occurred in the control group. Questionnaire data supported these findings, 68% of experimental students agreed that taking measurements was easy, compared to only 11.6% in the control group, and over half (55.9%) found it easy to interpret and explain their results, compared to just 14.5% of control students. Regression analysis further revealed that after treatment, the experimental group improved by 12.36 marks in their report scores, with EPW accounting for 13% of this improvement, while the control group improved by only 0.06 marks. Overall, the findings confirmed that using the EPW significantly enhanced students' scientific process skills, improved their confidence and accuracy during practical tasks and strengthened their ability to interpret and communicate results outcomes that were not achieved through conventional practical teaching methods.

5.2.3. Acquisition of Practical Skills

The findings showed that students who conducted practical work using the EPW demonstrated a much stronger acquisition of practical skills, particularly in setting up experiments and manipulating apparatus, than those taught through conventional practical methods. At the start (PPAE 1), both groups struggled with proper setup and use of equipment, but by PPAE 2, the experimental group showed remarkable progress. The proportion of students able to correctly use apparatus rose from 37.0% to 67.3%, while the control group improved only slightly from 27.0% to 32.7%. Similarly, accurate measurements increased from 37.6% to 58.8% in the experimental group, compared to minimal progress in the control group. The experimental group also

exhibited better technical precision in identifying correct color coding of connecting wires improved from 30.3% to 62.6%, and proper circuit connections (series and parallel) rose to 75.4% in PPAE 2, far exceeding the control group's 30.7%. Students using EPW also displayed stronger safety awareness and organization, with nearly 90% seeking instructor approval before activating circuits and 96.7% maintaining tidy work areas, unlike only 22.4% in the control group.

In terms of data analysis, calculations, and report writing, the experimental group again outperformed the control group. By PPAE 2, 59.6% of experimental students effectively applied equations in practical calculations compared to only 9.2% of control students. They also demonstrated deeper conceptual understanding, with 74.4% correctly identifying Ohm's Law and 56% accurately describing the voltage-current (V-I) relationship, both notably higher than the control group's performance. The experimental group's report-writing skills were strengthened by their superior ability to present data graphically: 80.6% correctly labeled graph axes and 53.6% calculated gradients accurately, roughly double the control group's success rates. Statistical tests, including the Mann-Whitney U, confirmed that manipulative precision and analytical abilities in the experimental group had a significant positive impact on their practical report scores. Overall, the integration of the EPW led to more accurate, well-structured and scientifically sound practical reports, while the control group showed only marginal improvements through traditional methods.

5.2.4. Students' attitudinal change towards physics

The study revealed that integrating the Electronics Practical Workbench (EPW) into physics practical lessons significantly enhanced students' learning outcomes and attitudes toward the

subject. Compared to the control group taught through conventional methods, the experimental group demonstrated substantial gains in comprehension, engagement and enjoyment. Students who used the EPW showed a marked improvement in understanding physics concepts, with comprehension rising from 34.6% to 64.9%, while the control group's improvement was minimal. Similarly, interest and enthusiasm toward physics practical work increased notably among the experimental group; initial perceptions of boredom decreased dramatically, and a majority began to view lessons as engaging and relevant. These findings suggest that hands-on, technology-supported learning through the EPW made physics lessons clearer, more meaningful, and easier to follow.

The results also showed strong attitudinal and performance-related benefits linked to the use of the EPW. Students in the experimental group increasingly recognized the real-life relevance of practical skills, reported reduced difficulty in conducting experiments, and demonstrated heightened motivation to attend lessons. Their confidence in interpreting experimental results improved sharply from 31.3% to 78.7% and statistical analyses confirmed significant gains in practical report scores, with an average increase of 11.2 marks. In contrast, the control group exhibited negligible improvements across most indicators. Overall, the findings highlight that incorporating the EPW not only deepened conceptual understanding but also fostered confidence, motivation, and positive attitudes toward physics, underscoring the transformative impact of technology-enhanced, experiential learning environments compared to traditional methods.

5.3. Conclusion

In the first objective, the study was to determine the difference in accuracy level of measurements in the practical report between students conducting practical work by electronics practical workbench and those conducting it by conventional method. The study found out that using an Electronics Practical Workbench (EPW) in physics teaching significantly enhances students' measurement accuracy compared to conventional practical methods. Statistical analyses revealed that the EPW improved students' ability to accurately measure current, potential difference and electromotive force, while also boosting their practical report scores and conceptual understanding. By minimizing errors and providing consistent digital tools, the EPW helped students achieve measurements closer to true values, addressing challenges such as inadequate or faulty lab equipment. Overall, the EPW proved to be a more effective approach for improving accuracy in physics practical work, thereby supporting better academic performance.

In the second objective, the study was to examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of basic science process skills among students taught using workbench and those taught conventionally. The study found out that EPW greatly enhances students' development of science process skills such as observation, measurement and communication, when compared to traditional practical techniques. The EPW proved to be a well-organized, engaging and technology-enhanced setting, which assisted students in accurately recognizing, taking exact measurements and interpreting measured data efficiently, thus minimizing frequent problems such as parallax mistakes and apprehension around using electrical devices. This not only improved students' confidence and involvement but also tackled issues arising from defective equipment and insufficient resources

to purchase such equipment in schools. In general, the EPW demonstrated greater efficacy in cultivating fundamental scientific abilities and enhancing passion in physics hands-on activities. It also demonstrated effectiveness in fostering science process skills required for effective physics practical activities.

In objective three, the study was to examine the differential effects of electronics practical workbench as a method of conducting practical work on acquisition of practical skills among students taught using workbench and those taught conventionally. The research observed that the EPW significantly improves students' development of practical skills, especially in conducting experiments, using equipment, interpreting data, and composing practical reports when compared to traditional practical approaches. The experimental group demonstrated steady, notable enhancement in these aspects, indicating that EPW fosters both conceptual comprehension and procedural rigor. In summary, the significant connection between manipulation abilities and elevated report scores underscores EPW's success in cultivating vital practical skills in physics practical work.

In objective four, the study was to determine the influence of electronics practical workbench on students' attitudinal change towards physics compared to conventional practical methods. The study concludes that using the Electronics Practical Workbench (EPW) in physics practical teaching leads to a significant positive shift in students' attitudes toward physics compared to conventional methods. Students exposed to EPW showed greater enthusiasm, confidence, engagement, and clarity in understanding concepts, which translated into improved performance and practical report scores. The findings indicate that EPW not only enhances skill acquisition but also fosters a more positive and motivated outlook toward learning physics.

5.4. Recommendations

Based on the study findings, it is recommended that educational policymakers implement a national strategy to integrate EPW into secondary school physics curricula. This integration should prioritize the provision of EPW software, digital infrastructure and necessary training for teachers, particularly targeting schools with limited laboratory resources. Such an initiative would address long-standing inequalities in access to quality practical experiences and ensure that all students benefit from the improved accuracy and understanding physics concepts demonstrated through EPW-based instruction. National-level licensing and standardization of EPW use would promote uniformity in practical skill development and strengthen the reliability of students' physics practical assessments across different educational settings.

Ministry of Education should take a leading role in integrating EPW into the national physics curriculum. The Ministry should develop clear implementation guidelines, allocate adequate funding and coordinate nationwide adoption to ensure consistent and effective use of the technology. Partnerships with software developers and educational technology providers should be established to align EPW with local curriculum requirements and ensure accessibility across diverse school contexts. Furthermore, the Ministry should support longitudinal research to evaluate the long-term impact of EPW on students' observation, measurement and communication skills, as well as its influence on equity and interest in STEM careers. By adopting EPW, the education system can move toward a more inclusive, efficient and technology-enhanced model of practical science instruction that strengthens basic science process skills and overall learning outcomes.

Physics teachers should be prioritized in the successful integration of EPW through structured Continuous Professional Development (CPD) programs. These CPD initiatives should focus on equipping teachers with the pedagogical and technical competencies needed to effectively implement EPW-based instruction, including hands-on simulations, equipment management, safety practices and strategies for engaging students in digital learning environments. Training should also emphasize aligning EPW use with curriculum and assessment objectives, fostering reflective learning and troubleshooting technical challenges. By empowering teachers with these skills, schools can ensure consistent, high-quality practical instruction that enhances students' procedural competence, confidence and overall mastery of practical physics skills across different educational contexts.

The study also recommends that the Kenya Institute of Curriculum Development (KICD) should formally integrate the Electronics Practical Workbench (EPW) into the national physics curriculum by embedding EPW-focused modules, practical activities and performance metrics into teaching and assessment resources. This integration would provide students with interactive, hands-on learning experiences that enhance conceptual understanding, procedural skills, confidence in measurement, data analysis and report writing. Aligning national assessments with these EPW-based skills would further reinforce their importance, helping to foster positive attitudes toward physics and making the subject more engaging, accessible, and motivating for students.

5.5. Suggestions for further studies

1. The current study may have excluded rural schools with limited ICT infrastructure. A study should be conducted to explore EPW's effectiveness in rural and under-resourced school contexts. Given the transformative potential of EPW in overcoming laboratory material shortages, it's critical to explore its applicability in more resource-constrained environments. The study should focus on investigating how EPW can be adapted and implemented in rural or remote schools lacking electricity, stable internet or sufficient teacher ICT training. The study may adopt mixed methods with quantitative analysis of student performance in addition to qualitative interviews with teachers and students.
2. Although EPW improved attitudes and skills, the long-term sustainability of these outcomes remains unknown. Therefore, a longitudinal study with multiple follow-up assessments on skill retention and attitude sustainability post-EPW intervention should be conducted. This should focus on examining whether the improvements in practical skills, measurement accuracy and positive attitudes persist across time such as six months to many years post-intervention. The researcher may consider using repeated-measures ANOVA to assess changes over time, including a delayed post-test and possible cross-group with control-to-intervention switch. This can be done considering students population previously exposed to EPW and a matched control group not yet exposed.
3. Considering that EPW's structured environment may limit students' exposure to experimental unpredictability, potentially affecting their adaptive reasoning and critical thinking. A study should be carried out on integrating adaptive problem-solving scenarios into EPW to simulate realistic lab uncertainties. This should focus within EPW simulations that introduce common lab issues like faulty equipment, parallax effects or ambiguous data for comparing standard EPW vs. EPW with built-in anomalies and assessing students' problem-solving strategies, emotional

regulation, and conceptual adaptability. This can be conducted among Senior secondary or early tertiary-level physics students preparing for real-world laboratory or engineering contexts.

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APPENDICES

APPENDIX I: PHYSICS PRACTICAL ACHIEVEMENT EXAMINATION (PPAE) 1

School Code:.....

ADM. No.....

PRE-TEST

QUESTION 1

You are provided with the following

- Six dry cells of 1.5V each
- Cell holders
- A voltmeter 3 V
- 1 Ammeter 3 A
- 8 Connecting wires (4 with crocodile clips)
- A switch

Proceed as follows

a) Connect the circuit as shown in figure 1 below

(2 Marks)

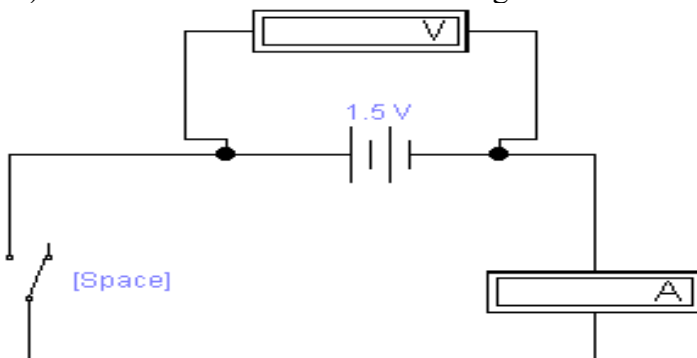


Figure 1

b) Starting with one dry cell, close the switch and measure the current I , potential difference, V and Electromotive force (e.m.f) E giving their units across the circuit.

- i) Current..... (1 Mark)
- ii) Voltage..... (1 Mark)
- iii) Electromotive Force (1 Mark)

c) Open the switch and add another dry cell.

d) Close the switch and read the voltmeter.

e) Repeat steps (c) and (d) with more 4 dry cells.

f) Enter the values as shown below in the Table below

(2 Marks)

Number of Dry Cells	1	2	3	4	5	6
Current I (mA)						
Potential Difference V (mV)						
Electromotive Force (E – V) in mV						

QUESTION 2

You are provided with the following

- Four dry cells of 1.5V each
- Cell holders
- A voltmeter 3 V
- 1 Ammeter 3 A
- 8 Connecting wires (4 with crocodile clips)
- A switch

Proceed as follows

- i) Connect the circuit as shown in figure 2 below (2 Marks)

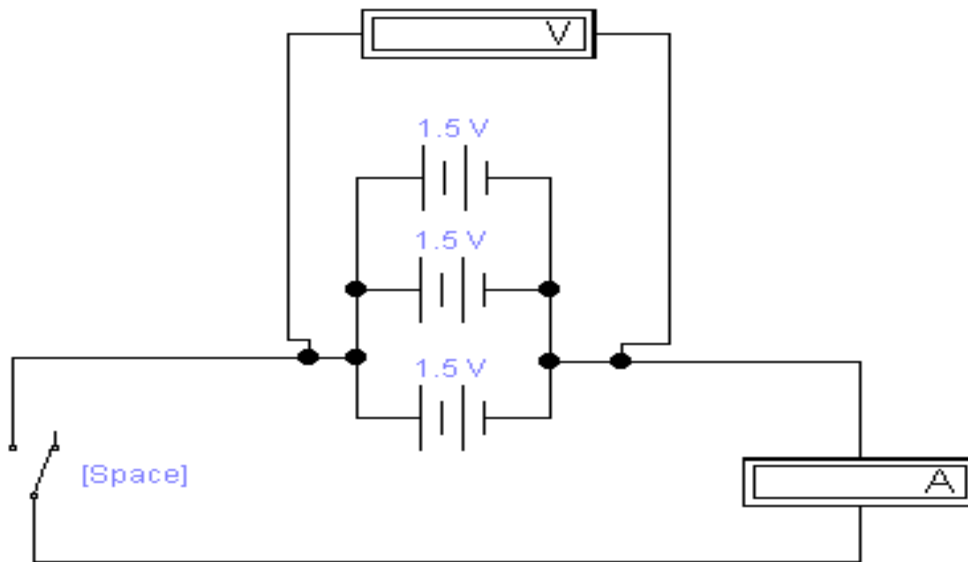


Figure 2

- ii) Starting with one dry cell, close the switch and measure the current I, potential difference, V and Electromotive force (e.m.f) E giving their units across the circuit.

- a) Current..... (1 Mark)
- b) Voltage..... (1 Mark)
- c) Electromotive Force (1 Mark)

- iii) Open the switch and add another dry cell.
- iv) Close the switch and read the voltmeter.
- v) Repeat steps (c) and (d) with other 3 more dry cells.

vi) Enter the values as shown below in the Table below (2 Marks)

Number of Dry Cells	1	2	3	4	5	6
Current I (mA)						
Potential Difference V (mV)						
Electromotive Force (E – V) in mV						

iv) What is the difference in values of current I, potential difference V and Electromotive force (e.m.f.) for dry cells arranged in question 1 and those in question 2? (2 Marks)

QUESTION 3

You are provided with the following

- Four dry cells of 1.5V each
- Cell holders
- Four bulbs of 3V; 1 Ohm each
- 5 voltmeter of 3 V each
- 5 Ammeter of 3 A each
- 30 Connecting wires (26 with crocodile clips)
- A switch

Proceed as follows

a) Connect the circuit as shown in figure 3 below (2 Marks)

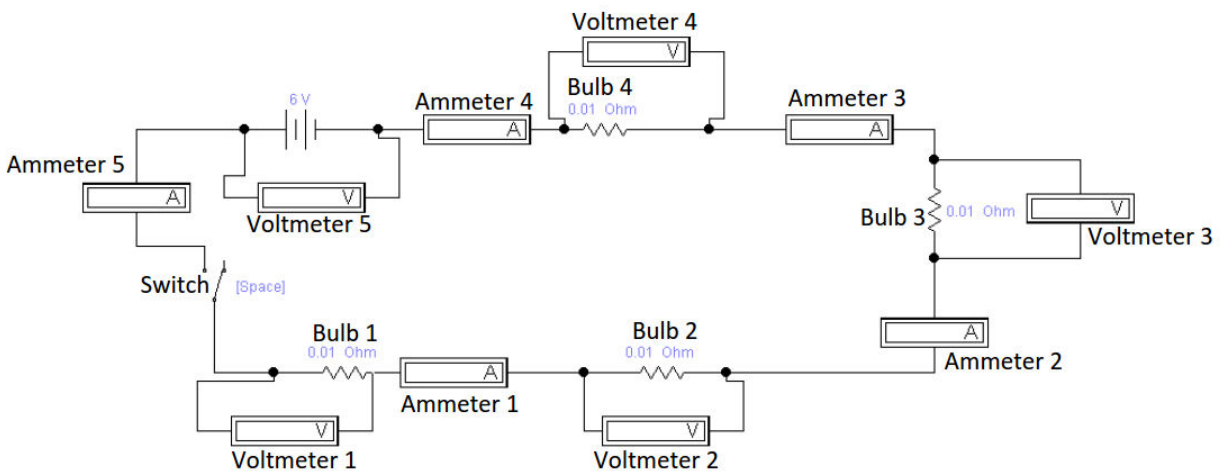


Figure 3

b) Starting with one bulb, close the switch and measure the current through Ammeter 1, potential difference in voltmeter 1 and Electromotive force (e.m.f) E across the circuit.

v) Current (Ammeter 1)..... (1 Mark)

- vi) Voltage (Voltmeter 1)..... (1 Mark)
 vii) Electromotive Force (1 Mark)

- c) Open the switch and add another bulb.
 d) Close the switch and read the current, voltage and electromotive force.
 e) Repeat steps (c) and (d) with more 4 dry cells.
 f) Enter the values as shown below in the Table below. (3 Marks)

Number of bulbs	1	2	3	4	5	6
Current I (μA)						
Potential Difference V (μV)						
Electromotive Force (E – V) in mV						

- g) Explain changes in brightness of the bulbs as you add the number of dry bulbs (2 Marks)

QUESTION 4

You are provided with the following

- Four dry cells of 1.5V each
- Cell holders
- Four bulbs of 3V; 1 Ohm each
- 5 voltmeter of 3 V each
- 5 Ammeter of 3 A each
- 30 Connecting wires (26 with crocodile clips)
- A switch

Proceed as follows

- a) Connect the circuit as shown in figure 3 below (2 Marks)

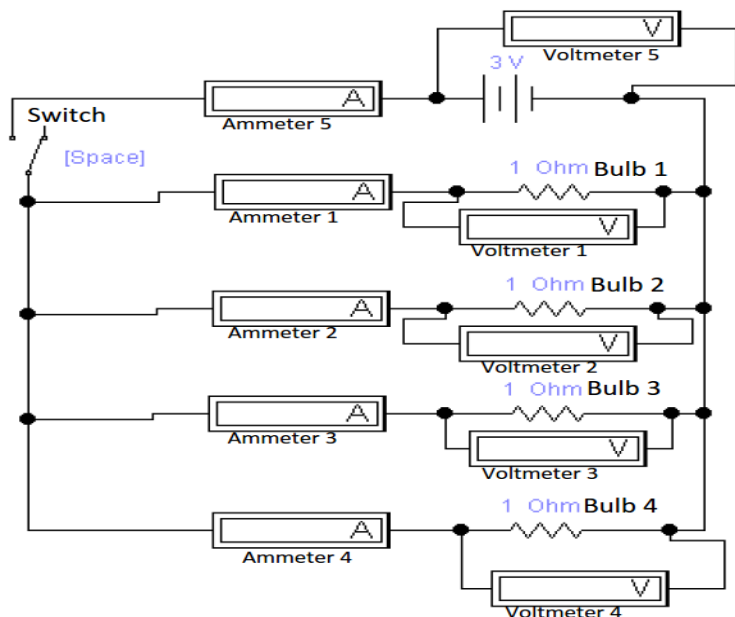


Figure 4

- b) Starting with one bulb, close the switch and measure the current through Ammeter 1, potential difference in voltmeter 1 and Electromotive force (e.m.f) E across the circuit.
- i) Current (Ammeter 1)..... (1 Mark)
 - ii) Voltage (Voltmeter 1)..... (1 Mark)
 - viii) Electromotive Force (1 Mark)
- c) Open the switch and add another bulb.
- d) Close the switch and read the current, voltage and electromotive force.
- e) Repeat steps (c) and (d) with more 4 dry cells. (3 Marks)
- f) Enter the values as shown below in the Table below. (3 Marks)

Number of bulbs	1	2	3	4	5	6
Current I (μA)						
Potential Difference V (μV)						
Electromotive Force (E – V) in mV						

- g) What is the difference in values of current I, potential difference V and Electromotive force (e.m.f.) for dry cells arranged in question 3 and those in question 4? (3 Marks)
- h) Explain changes in brightness of the bulbs as you add the number of dry bulbs (2 Marks).

APPENDIX II: PHYSICS PRACTICAL ACHIEVEMENT EXAMINATION (PPAE) 2

POST-TEST

QUESTION 1

You are provided with the following

- Three dry cells of 1.5V each
- Cell holders
- 2 voltmeters 3 V each
- 1 Ammeter 3 A
- 15 Connecting wires (12 with crocodile clips)
- A switch (Classification of Red and black connecting wires and crocodile clips, voltmeter, ammeters)

Proceed as follows

a) Connect the circuit as shown in figure 1 below

(2 Marks)

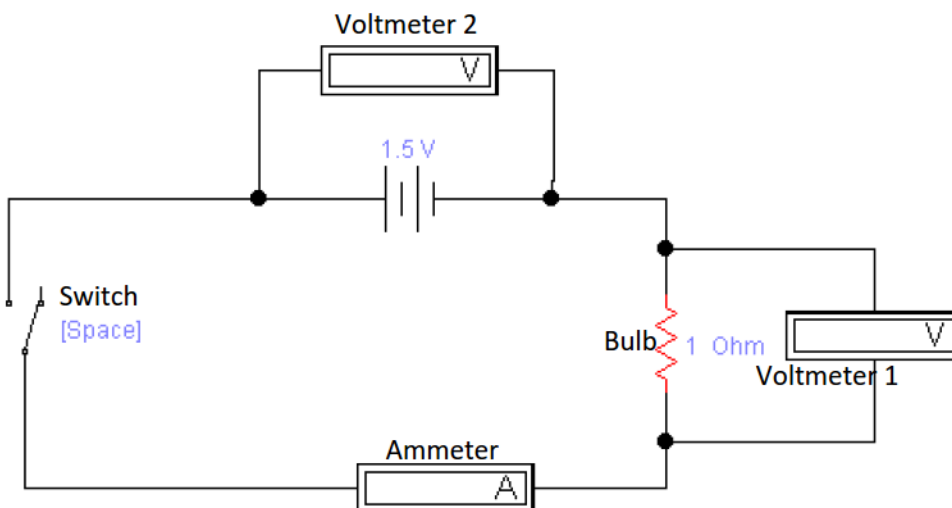


Figure 1

b) Starting with one dry cell, close the switch and measure the current I , potential difference, V and Electromotive force (e.m.f) (measurement skill; objective 2) E giving their units across the circuit.

- i. Current..... (1 Mark)
- ii. Voltage (a) Voltmeter 1.....(b) Voltmeter 2.....(2 Mark)
- iii. Electromotive Force (1 Mark)

c) Open the switch and add another dry cell.

d) Close the switch and read the voltmeter and ammeter.

e) Repeat steps (c) and (d) with more 3 dry cells.

f) Enter the values as shown below in the Table below

(2 Marks)

Number of Dry Cells	1	2	3
Current I (mA)			
Potential Difference V (mV) Voltmeter 1			
Electromotive Force (E – V) in mV using values of Voltmeter 2			

g) Explain changes in brightness of the bulb as you add the number of dry cells (battery)
(2 Marks)

QUESTION 2

You are provided with the following

- Three dry cells of 1.5V each
- Cell holders
- A voltmeter 3 V
- 1 Ammeter 3 A
- 18 Connecting wires (16 with crocodile clips)
- A switch

Proceed as follows

i. Connect the circuit as shown in figure 2 below

(2 Marks)

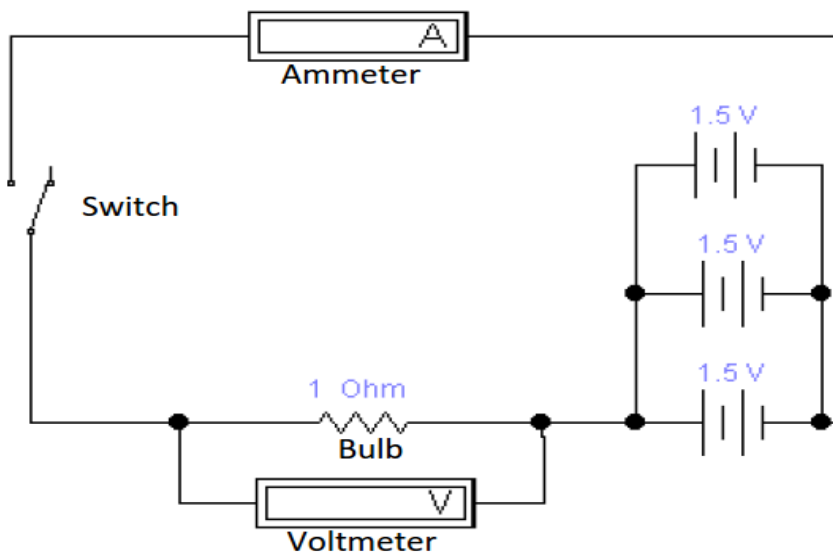


Figure 2

ii. Starting with one dry cell, close the switch and measure the current I, potential difference, V and Electromotive force (e.m.f) E giving their units across the circuit.

- d) Current..... (1 Mark)
e) Voltage..... (1 Mark)
f) Electromotive Force (1 Mark)

- iii. Open the switch and add another dry cell.
- iv. Close the switch and read the voltmeter.
- v. Repeat steps (iii) and (iv) with other 2 more dry cells.
- vi. Enter the values as shown below in the Table below (2 Marks)

Number of Dry Cells	1	2	3
Current I (mA)			
Potential Difference V (mV)			
Electromotive Force (E – V) in mV			

- I. What is the difference in values of current I, potential difference V and Electromotive force (e.m.f.) for dry cells arranged in question 1 and those in question 2? (2 Marks)
- II. Explain changes in brightness of the bulb as you add the number of dry cells (battery) (2 Marks)

QUESTION 3

You are provided with the following

- 3 dry cells of 1.5V each
- Cell holders
- 3 bulbs of 3V; 1 Ohm each
- 3 voltmeter of 3 V each
- 3 Ammeter of 3 A each
- 30 Connecting wires (26 with crocodile clips)
- A switch

Proceed as follows

- i. Connect the circuit as shown in figure 3 below (2 Marks)

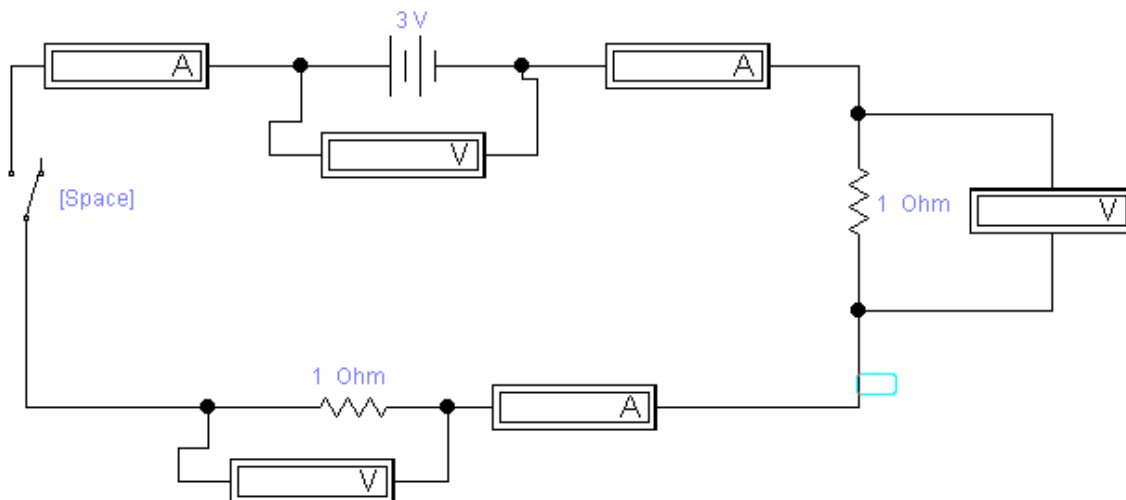


Figure 3

ii. Starting with one bulb, close the switch and measure the current through Ammeter 1, potential difference in voltmeter 1 and Electromotive force (e.m.f) E across the circuit.

- I. Current (Ammeter 1)..... (1 Mark)
- II. Voltage (Voltmeter 1)..... (1 Mark)
- III. Electromotive Force (1 Mark)

iii. Open the switch and add another bulb.

iv. Close the switch and read the current, voltage and electromotive force.

v. Repeat steps (c) and (d) with more 4 dry cells (OBJECTIVE 3 – Practical, manipulation).

vi. Enter the values as shown below in the Table below. (2 Marks)

Number of bulbs	1	2	3
Current I (μA)			
Potential Difference V (μV)			
Electromotive Force (E – V) in mV			

vii. Explain changes in brightness of the bulbs as you add the number of dry bulbs (2 Marks)

QUESTION 4

You are provided with the following

- 3 dry cells of 1.5V each
- Cell holders
- 3 bulbs of 3V; 1 Ohm each
- 3 voltmeter of 3 V
- 3 Ammeter of 3 A each
- 30 Connecting wires (4 with crocodile clips)
- A switch

Proceed as follows

i. Connect the circuit as shown in figure 3 below (2 Marks)

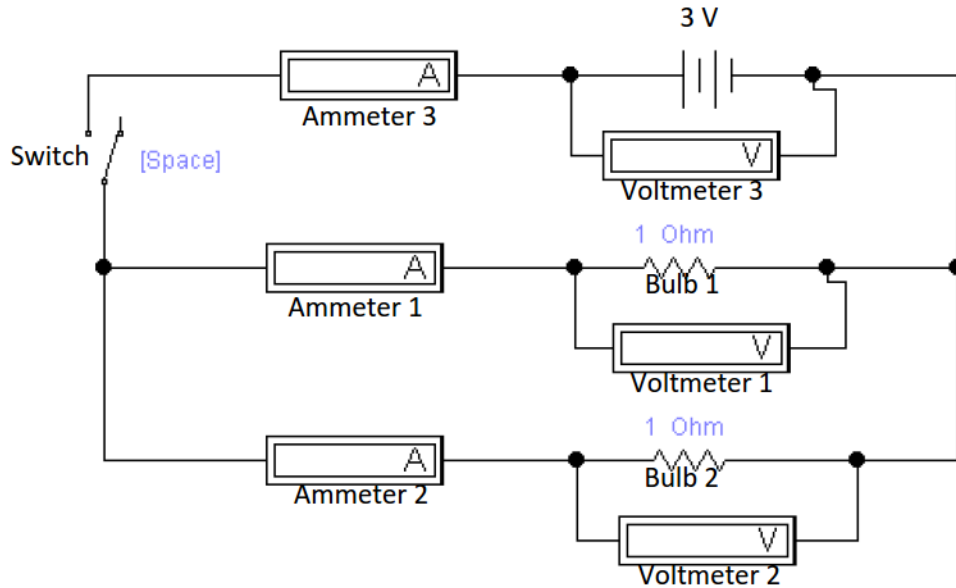


Figure 4

- i. Starting with one bulb, close the switch and measure the current through Ammeter 1, potential difference in voltmeter 1 and Electromotive force (e.m.f) E across the circuit
 - I. Current (Ammeter 1)..... (1 Mark)
 - II. Voltage (Voltmeter 1)..... (1 Mark)
 - III. Electromotive Force (1 Mark)
- ii. Open the switch and add another bulb.
- iii. Close the switch and read the current, voltage and electromotive force
- iv. Reading.
- v. Repeat steps (c) and (d) with more 2 dry cells.
- vi. Enter the values by filling in the Table below. (2 Marks)

Number of bulbs	1	2	3
Current I (μA)			
Potential Difference V (μV)			
Electromotive Force (E – V) in mV			

- vii. What is the difference in values of current I, potential difference V and Electromotive force (e.m.f.) for dry cells arranged in question 3 and those in question 4? (2 Marks)
- viii. Explain changes in brightness of the bulbs as you add the number of dry bulbs (1 Mark)

APPENDIX III: ATTITUDE DEVELOPED TOWARDS PHYSICS PRACTICAL QUESTIONNAIRE (ADTPPQ) I

Instructions

Do not write your name anywhere in the questionnaire. Indicate your school code, class/grade and gender in the spaces provide below; (for gender write 1 for male and 2 for female)

School Code **Form/Grade**..... **Gender**

The purpose of this questionnaire is to collect your views and opinions on the importance of physics practical lessons taught and practical work report writing activities after practical examination. Kindly respond to it by filling in the blank or ticking [$\sqrt{\quad}$] where appropriate. All the information will be treated with utmost confidentiality during and after the study.

(SA means Strongly Agree, A means Agree, U means Undecided, D means Disagree and SD means Strongly Agree)

A. PHYSICS PRACTICAL LESSON

SN	STATEMENT	SA	A	U	D	SD
1.	The physics concepts taught in the lessons were well understandable					
2.	The physics lessons were dull					
3.	The physics practical lessons were useful					
4.	The physics practical lessons were meaningless					
5.	The physics practical lessons were not important					
6.	The physics practical activities during the lessons were difficult					
7.	The physics practical activities taught by the teacher during the lessons were easy					
8.	The physics practical activities taught by the teacher during lessons were friendly					
9.	The physics practical activities taught by the teacher during lessons were simple					
10.	The physics practical activities taught by the teacher during lessons were interesting					
11.	I was comfortable with the physics practical lessons taught by the teacher					
12.	The physics practical lessons taught through electronics practical workbench were difficult.					
13.	The practical lessons taught through workbench were useless.					
14.	The physics practical lessons taught through workbench were					

	interesting.					
15.	The physics practical lessons taught through workbench were unfriendly					
16.	I could easily make a conclusion					

B. PHYSICS PRACTICAL REPORT WRITING ACTIVITIES

SN	STATEMENT	SA	A	D	SD	U
1	It was very easy to identify all the provided physics practical apparatus to carry out required measurements	5	4	3	2	1
2	It was very easy to use the provided physics practical apparatus to carry out required measurements					
3	It was very easy to carry out all required measurements in the practical					
4	I could give my reading values to the best accuracy					
5	It was very easy to identify the errors from obtained practical data					
6	It was very easy to provide all practical measurement results with best estimates.					
7	I could easily take care of appropriate errors that appeared in data I obtained					
9	Identifying sources of errors in that physics practical work was very simple for me.					
10	I could easily use the provided equations to carry out necessary calculations in that physics practical work.					
11	I clearly understood the aim of that practical work					
12	I knew the use of each and every apparatus provided in that practical work					
13	It was very easy for me to interpret the results					
14	It was very easy to explain how the errors may have affected the experiment and outcome					
16	I could easily explain the comparison of the results I got and what I was expecting.					

APPENDIX IV: ATTITUDE DEVELOPED TOWARDS PHYSICS PRACTICAL QUESTIONNAIRE (ADTPPQ)-II

Instructions

Do not write your name anywhere in the questionnaire. Indicate your school code, class/grade and gender in the spaces provide below; (for gender write 1 for male and 2 for female)

School Code Form/Grade..... Gender

The purpose of this questionnaire is to collect your views and opinions on the importance of physics practical lessons taught and practical work report writing activities after practical examination. Kindly respond to it by filling in the blank or ticking [] where appropriate. All the information will be treated with utmost confidentiality during and after the study.

(SA means Strongly Agree, A means Agree, U means Undecided, D means Disagree and SD means Strongly Agree)

A. PHYSICS PRACTICAL LESSON

SN	STATEMENT	SA	A	U	D	SD
	I could easily understand the physics concepts taught in the lessons					
2.	I found the physics lessons dull					
3.	I realized that the physics practical lessons very useful in day today life.					
4.	I was able to carry out the physics practical activities at ease during the lessons.					
5.	It was very interesting to carry out the physics practical activities taught by the teacher during lessons.					
6.	I enjoyed attending the physics practical lessons taught by the teacher					
7.	It was very easy to make conclusions based on the practical results obtained during practical work					

B. PHYSICS PRACTICAL REPORT WRITING ACTIVITIES

SN	STATEMENT	SA	A	D	SD	U
1	I could identify all the provided physics practical apparatus to carry out required measurements					
2	I could easily carry out required measurements using the provided physics practical apparatus.					
3	I could easily provide all practical measurement results with best estimates.					
4	I could easily use the provided equations to carry out necessary calculations in that physics practical work.					
5	I could easily identify the errors from my data					
6	It was very easy to take care of appropriate errors that appeared in my data					
7	I could easily identify sources of errors in that physics practical work.					
8	I used provided equations at ease to carry out necessary calculations in that physics practical work.					
9	I was very familiar with each and every apparatus provided in that practical work and their use					
10	Interpreting the results from the practical work was a simple task					
11	Explaining how the errors may have affected the experiment and outcome was very simple to me.					
12	Explaining the comparison of the results I got and what I was expecting was very simple.					

APPENDIX V: SCIENCE PROCESS SKILLS LEARNT CHECKLIST (SPSLC)

The purpose of this checklist is to collect information on the basic science process skills developed by students during physics practical work. This is administered after both pre-test and post-test practical. All the information will be treated with utmost confidentiality during and after the study. Indicate the number of students who could follow the criteria of writing accurate physics practical report.

Criteria	Yes			No		
	Male	Female	Total	Male	Female	Total
Observed whether components are connected correctly according to the circuit diagram (series or parallel).						
Checks connections, polarity, and meter placements before switching on the circuit.						
Was able to detect effects such as bulb brightness, meter deflections or heating of components when current flows.						
Uses correct significant figures and maintains neatness in data presentation.						
Was able to carry out all required measurements in the practical.						
Was able to organize results in tables with correct units and significant figures.						
Has identified the errors from obtained practical data.						
Chooses suitable scale/range to obtain accurate readings without damaging the instrument.						
Takes multiple readings to ensure accuracy and detect anomalies.						
Records readings neatly in well-labeled tables, showing variables and units.						
Ensures measurements are within the instrument's safe operating range.						
Uses accurate scientific terminologies						
Maintains correct spelling, grammar, and legibility.						

APPENDIX VI: PRACTICAL SKILLS LEARNT CHECKLIST (PSLC)

The purpose of this checklist is to collect information on the practical skills developed by students during physics practical work. This is administered after both pre-test and post-test practical. All the information will be treated with utmost confidentiality during and after the study. Indicate the number of students who could follow the criteria of writing accurate physics practical report.

Criteria	Yes			No		
	Male	Female	Total	Male	Female	Total
Was able to correctly connecting components in series or parallel as specified.						
Ensured that instruments are properly set to zero before taking measurements.						
I was able to use multimeters, voltmeters and ammeter appropriately.						
Was able to turn the circuit on and off correctly and adjusting components as needed.						
Was able to apply Ohm's Law or other relevant relationships correctly						
Have taken care of appropriate errors that may appear in their obtained data.						
Was able to plot voltage – current graphs and interpreting slopes or intercepts correctly.						
Could use provided equations to carry out necessary calculations in physics practical work.						
Was able to keep the workspace organized and dry, following lab safety rule.						
Has included interpretations of data in the results.						
Has provided discussion of the results.						

APPENDIX VII: MARKING SCHEMES FOR ACQUIRED SCIENCE PROCESS AND PRACTICAL SKILLS

A: Science Process Skills

1. Observation skills (10 Marks)

Criterion	Description	Marks
Identification of apparatus	Correctly identifies all required equipment for the circuit.	2
Circuit setup observation	Correctly observes and interprets the physical layout of the circuit.	2
Change recognition	Accurately notes the behavior of current and voltage	3
Attention to detail	Records subtle changes, e.g., brightness of bulbs	3

2. Measurement Skills (15 Marks)

Criterion	Description	Marks
Use of instruments	Properly uses ammeter, voltmeter or multimeter.	3
Accuracy of measurements	Measurements are precise and close to true values.	5
Recording measurements	Neatly tabulates readings with correct units.	3
Repetition and averaging	Performs multiple readings and calculates average where applicable.	2
Error awareness	Notes possible sources of error and uncertainties.	2

3. Communication Skills (10 Marks)

Criterion	Description	Marks
Presentation of results	Tables, graphs and diagrams are clear, properly labeled and organized.	4
Graphical analysis	Correct plotting of graphs with labeled axes, appropriate scale and units.	3
Interpretation of results	Clearly explains the meaning of results in terms of physics concepts.	2
Scientific language	Uses correct terminology, symbols, and units throughout.	1

B: Practical Skills**1. Setting up Practical Skills (10 marks)**

Criterion	Description	Marks
Identification of apparatus	Correctly identifies all required equipment for the circuit.	2
Correct assembly	Assembles the circuit accordingly without missing components.	3
Safety adherence	Observes laboratory safety procedures while setting up.	2
Organization and neatness	Components and wires arranged neatly for easy observation.	3

2. Manipulation Skills (15 marks)

Criterion	Description	Marks
Handling of instruments	Proper and careful use of meters, power supply and other tools.	3
Adjustments and controls	Correctly adjusts resistors, switches and connections to achieve desired readings.	3
Troubleshooting	Identifies and corrects faults in the circuit.	3
Precision and consistency	Maintains steady and accurate readings; avoids accidental disconnections.	3
Coordination	Demonstrates good hand-eye coordination while connecting components.	3

3. Report Writing Skills (15 marks)

Criterion	Description	Marks
Structure and organization	Includes title, objective, apparatus, procedure, results and conclusion.	3
Data presentation	Tables and graphs are clear, labeled with correct units	4
Analysis and interpretation	Explains trends and patterns; links observations to physics concepts.	4
Accuracy of calculations	Performs correct calculations, averages and derived quantities.	2
Scientific language	Uses correct terminology, symbols and units throughout.	2

APPENDIX VIII: FOCUS GROUP DISCUSSION (FGD)

The purpose of this FGD is to collect your views and opinions on the accuracy levels of the physics practical report written by physics students during practical work. It is also source for your opinion on basic science process skills developed by students during physics practical work. Kindly respond appropriately to the following questions as asked by the interviewer. All the information will be treated with utmost confidentiality during and after the study.

1. How simple or difficult was or easy for you to carry out the first and second practical work?
2. (a) Do you normally include graph in your practical report?
(b) How do you include graphs that highlight the most important data obtained?
3. How do you take care of errors that may occur during the practical?
4. How do you identify the errors from obtained practical data?
5. How do you identify sources of errors in physics practical work?
6. Were you able to use provided equations to carry out necessary calculations in physics practical work? Yes [] No [].
If NO, Explain why?
7. What are some of the challenges you encounter while carrying out calculations involved in the physics practical work?

THANK YOU FOR YOUR COOPERATION

APPENDIX IX: RESEARCH BUDGET

Estimated research Budget

Item	Description	Cost (Shs)	Total (Ksh)
Equipment 1. Computer 2. Printer 3. Software	Laptop Color Printer Electronics Workbench and Installation	47,000 12,500 56,000	115,500
Stationary 1. Computer stationery 2. Ordinary Stationary	Papers, Flash Disk, Toner. Papers, Pens, Files, Envelopes, Binding Reports and Photocopying among others.	14,000 9,200	23,200
Commuting and Accommodation 1. Traveling 2. Accommodation	Car Fuel Expenses for researcher. Car Maintenance cost. Transport expenses for research assistants Accommodation for both the researcher and the assistants	54,000 30,800 53,000 86,000	223,800
Overheads Allowances	Unforeseen Price increases in fuel costs/Maintenance and Miscellaneous cost. Allowances payable to the research assistants for the role played	25,000 109,000	134,000
Grand Total			496,500



REPUBLIC OF KENYA



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 845994

Date of Issue: 14/October/2021

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This is to Certify that Mr. ALPHAYO ABACHA OCHOLLA of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: APPLICATION OF ELECTRONICS' WORKBENCH IN TEACHING PHYSICS PRACTICAL WORK AND ITS INFLUENCE ON ACADEMIC ACHIEVEMENT AMONG FORM THREE STUDENTS IN NAIROBI COUNTY-KENYA for the period ending: 14/October/2022.

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15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

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