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Development and Validation of Electronic Laboratory (e-Lab) Manual in General Physics 1

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ABSTRACT

This study focused on the development and validation of an electronic laboratory (e-Lab) manual designed to cover selected midterm topics in General Physics 1, including measurement, speed, velocity, acceleration, projectile motion, circular motion, and Newton's Laws of Motion. The manual was carefully aligned with the Department of Education's Most Essential Learning Competencies (MELCs) to ensure curricular relevance and applicability. Seventy Grade 11 students participated in its implementation, using the manual as an interactive and accessible digital resource to strengthen their competencies in physics. Expert evaluation revealed that the manual achieved a "Very Satisfactory" rating across three domains: content quality (3.86), instructional quality (3.80), and technical quality (3.85). These scores confirmed that the manual met standards of accuracy, organization, instructional soundness, and multimedia integration. In terms of effectiveness, student performance showed significant improvement. Results of the paired t-test analysis yielded a computed value of 14.1 with a p-value less than 0.05, leading to the rejection of the null hypothesis. This demonstrated a statistically significant difference between pretest and posttest scores, validating the positive impact of the e-Lab manual on learning outcomes. The study concludes that the electronic laboratory manual was effective in enhancing student competencies in General Physics 1. It recommends the development of similar manuals for other physics topics and emphasizes the importance of teacher training and workshops to integrate digital tools into instructional practices, thereby fostering meaningful and engaging learning experiences.

Keywords: *development, validation, electronic laboratory manual, General Physics 1, pretest, posttest, experts*

INTRODUCTION

Physics is one of fundamental disciplines of Science, and it is not generated only from abstract intuition and mathematical formulation but it is also rooted in empirical observation and experimentation. It is very essential to integrate laboratory activities into the curriculum. Students can better comprehend fundamental physical theories like motion, force, work, energy, and momentum by making measurements and testing predictions in a laboratory setting. Thus, laboratory experiences contribute to the development of the scientific skills and sensibilities of the students that cannot be developed through the lecture merely through observation, measurement, data handling, and logical inference.

Studies on the performance of students in General Physics 1, particularly in topics related to motion, measurement, and the laws of motion, reveal a consistent challenge in mastering these concepts, resulting in low test scores. In the Philippines, a study by Guido (2018) explored students' attitudes and motivations towards physics, indicating that students frequently struggle with the subject's difficulty, particularly in areas like mechanics, which directly affects their performance in midterm exams. Similarly, Auditor and Naval (2014) examined tenth-grade students' grasp of physics concepts, noting that the least mastered competencies often involved the application of the laws of motion and the understanding of basic kinematics and dynamics. This struggle with core physics concepts reflects the broader difficulty students face in mastering fundamental measurement and motion principles.

Krakehl (2021) further confirmed this pattern, particularly in Advanced Placement Physics courses, where a substantial number of students, especially those from underrepresented groups, exhibited low performance in understanding the motion of objects and applying Newton's laws, which are fundamental to General Physics 1. These studies underscore the persistent difficulties students encounter in mastering the essential topics of motion, measurement, and the laws of motion, reflecting a broader educational challenge in both local and international contexts.

Recent studies have highlighted persistent challenges faced by students in mastering fundamental physics concepts, particularly in areas such as motion, measurement, and the laws of motion. A study by Brundage et al. (2023) revealed that both introductory and advanced undergraduate students continue to struggle with conceptual questions related to energy and momentum, indicating that traditional lecture-based instruction may not effectively address these foundational topics.

Similarly, Santoso et al. (2025) presented the SPHERE dataset, which encompasses students' performance in physics across various domains, including conceptual understanding and scientific ability. Their findings suggest that despite the availability of research-based assessments, students often exhibit low performance in core physics concepts, underscoring the need for targeted instructional strategies.

Additionally, Burkholder et al. (2020) identified that factors such as prior preparation, self-efficacy, and test anxiety significantly influence student performance in introductory physics courses. Their research emphasizes the importance of addressing these factors to improve student outcomes in midterm assessments.

These studies collectively underscore the ongoing difficulties students encounter in grasping essential physics concepts, highlighting the necessity for innovative teaching approaches and support mechanisms to enhance student understanding and performance in General Physics 1 courses.

The laboratory is a foundation of Science education, especially in Physics, that needs understanding, often driven by experience as much as theory and particularly critical thinking skills. General Physics 1 investigates concepts including motion, force, energy, momentum, and the rules underlying physical phenomena. In Tarlac Agricultural University – Laboratory School, General Physics 1 is taught to Grade 12 students as a significant subject under the Science, Technology, Engineering, and Mathematics programs. It is given four units and has an allotment of 4 hours per week. This subject requires learning the concepts and theories coupled with skills usually learned through laboratory activities.

The laboratory is conventionally used in Physics to assist students in obtaining skills in scientific investigation, confirming theoretical concepts, and learning tools, both analytic and practical. Nonetheless, the contemporary education system's reliance on digital processes makes laboratory instruction less feasible.

Although conventional printed laboratory manuals have been practical, they are accompanied by several disadvantages in the modern academic environment. Such materials are often static and rigid to copy, which results in their being expensive or challenging to update or individualize. This procedural approach can restrain one from engaging in authentic scientific inquiry and reduce the laboratory to a mechanical exercise rather than an open-ended experience. Additionally, they may lack the interactive or multimedia content necessary to appeal to various learning styles and enhance student involvement. The recent COVID-19 pandemic has emphasized the necessity for flexible, affordable, and technology-enhanced learning materials, as multiple campuses have had to transition to online and hybrid courses (Crawford et al., 2020). Again, the events have indicated the need to create digital mimicries that deliver an excellent education outside the standard classroom and laboratory spaces.

Educational technology's evolution provides a window for addressing these challenges through electronic laboratory manuals (e-lab manuals). Properly designed digital educational resources enhance student engagement, motivation, and learning outcomes. These digital tools can be shared among students and teachers easily, adapted to fit varying instructional conditions, and most importantly, they can incorporate interactive simulations, video demonstrations, animations, formative assessments, hyperlinks to additional information, and context. These aspects could shift the viable in-person and guided experience to an engaging, personal, and discovery-paced journey.

The development and validation of the e-Lab manual in General Physics 1 is closely aligned with several Sustainable Development Goals (SDGs). In support of SDG 3 (Good Health and Well-being), the manual promotes safe experimentation by minimizing risks in physical laboratories and reducing stress through self-paced learning. It also contributes to SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities) by ensuring equal access to quality physics resources regardless of gender or geographical location, thereby bridging gaps between students in urban and rural settings.

Technological progress is reshaping classrooms worldwide, and the present inquiry intersects directly with the United Nations Sustainable Development Goal 4, which concerns quality education. That goal stresses inclusivity, equity, and the durable habit of lifelong learning. In practical terms, this study created an electronic toolkit for hands-on laboratory work. Such a resource stands to improve educational quality where conventional lab space is scarce or, most notably, in under-funded schools and remote communities.

By using platforms like the e-Lab manual in everyday practice, educators gain a versatile space that accommodates varied schedules and ability levels while diminishing the persistent gap in educational access. The initiative thus resonates with Sustainable Development Goal 9-Industry, Innovation, and Infrastructure, channeling fresh technological thinking into classroom workflow and offering a scalable resource for schools navigating the tide of digital transformation.

By integrating lessons on energy principles, the manual fosters awareness of sustainability and clean energy in line with SDG 7 (Affordable and Clean Energy), while also preparing learners with critical thinking and problem-solving skills essential for workforce readiness, which supports SDG 8 (Decent Work and Economic Growth). Furthermore, the use of electronic resources reduces dependence on printed materials, promoting SDG 12 (Responsible Consumption and Production) and indirectly contributing to SDG 15 (Life on Land) through the conservation of natural resources.

The e-Lab encouraged collaboration between educational institutions and stakeholders, like DepEd and other educational bodies, to develop and implement innovative educational materials. It was aligned with SDG 17, which calls for strengthening partnerships to achieve sustainable development goals.

The manual also strengthens climate awareness by incorporating concepts such as energy conservation and environmental sustainability, addressing SDG 13 (Climate Action). In the broader context, the study nurtures future professionals who are capable of contributing to sustainable cities and communities, thereby advancing SDG 11 (Sustainable Cities and Communities).

The research was linked to NEDA's goal of enhancing human capital development, particularly in higher education, by introducing innovative tools that complement traditional teaching methods. The adoption of electronic materials can help bridge learning gaps, improve science and technology education, and equip students with skills suited for the demands of the digital economy.

By improving the delivery of General Physics 1 education, this research supported NEDA's long-term vision of fostering a knowledge-driven economy, as it nurtures critical thinking and scientific literacy that are vital to economic growth and innovation.

The Philippine Development Plan (PDP) emphasized inclusive growth and the development of human capital through improved educational systems. The e-Lab manual contributed to this by ensuring that high-quality educational resources, such as the electronic laboratory manual, are accessible to a wider student base across different regions, including those with limited access to physical resources.

By incorporating technology into education, this research aligned with the PDP's objectives to improve the quality of education and strengthen workforce development. A digital manual can improve the learning experience for students and ultimately equip them with the competencies necessary to succeed in the modern workforce.

The inclusion of this digital, validated laboratory manual encouraged students to develop their skills in Science and technology, which aligns with the PDP's focus on innovation and research in the academic sector.

Ambisyon 2040 envisions a society where all Filipinos enjoy a high quality of life. Education plays a pivotal role in realizing this vision. By improving General Physics 1 instruction through an electronic laboratory manual, the e-Lab manual directly contributes to this vision by ensuring that students have access to quality, innovative educational resources that help build a competitive and skilled workforce.

Ambisyon 2040 underscores the importance of digital transformation for inclusive growth. This research supports this transformation by making science education more accessible, flexible, and aligned with modern technologies, preparing students for a digitally-driven future.

The Core 17 partnership, aimed at improving the quality of education in the Philippines, aligns with this research by promoting collaboration between DepEd, educational institutions, and other stakeholders. The partnership focuses on enhancing educational resources and student engagement, which is exactly development and validation of the electronic laboratory manual seeks to achieve.

The partnership advocates for curriculum development that integrates modern technology. The e-Lab manual, which is specifically designed for General Physics 1, directly supports the DepEd's efforts to modernize teaching materials and enhance the learning experience of students through technology.

The development and validation of an electronic laboratory manual in General Physics 1 is not just an academic endeavor but also a significant contribution to advancing national and global educational goals. It supports the UN SDGs, especially in quality education, innovation, and partnerships; aligns with NEDA's and the PDP's focus on inclusive growth and human capital development; contributes to the realization of Ambisyon 2040's vision for a digitally empowered society; and strengthens the Core 17 Partnership with DepEd by enhancing collaborative, technology-driven educational initiatives.

In addition to improving practical learning experiences in Physics, the electronic manual aimed to foster critical thinking, problem-solving skills, and applying theoretical knowledge in practical scenarios, thereby preparing students for future challenges in the rapidly advancing fields of science and technology.

Developing an electronic lab manual can enhance the teaching and learning process, enabling students to work with simulations, view video demonstrations, record their data using the computer, and receive immediate assistance or feedback. Students using a virtual or digitally enhanced laboratory can achieve the same level or even greater conceptual understanding and retention as their counterparts working in the traditional laboratory. In addition, e-lab manuals are a more sustainable option for practical skills courses. Instead of relying on paper hard copies, e-lab manuals can be instantly updated, tailored to specific courses, and available on many devices. This advantage promotes intersectionality between laboratory courses and promotes inclusivity in education.

Effective e-lab manual development is also required from more pedagogical grounds. Theoretical frameworks such as Constructivism and Cognitive Theory of Multimedia Learning predicate the significance of active learning, visual-verbal coherence, and learner autonomy, which overlap with what digital learning devices can enable (Mayer, 2005). E-lab manuals should translate existing materials into a digital format and promote cognitive activity and learning fullness. In general, it should lead to a context-specific product that is qualitatively different from what may have been before. In light of this reality, the researcher considered the following as a need for the development of an electronic Laboratory Manual on General Physics I that can help during laboratory classes in the conduct and facilitation of activities as a guide for the students to learn the skills better.

The study aimed to develop and validate an electronic laboratory manual in teaching General Physics 1 for Grade 11 STEM learners. Specifically, it involved the development of the manual and its validation by experts in terms of content quality, instructional quality, and technical quality, as well as by users in terms of effectiveness. The study also sought to determine its implications for Science Education and tested the hypothesis that there is no significant difference between the students' pretest and posttest scores at the 0.05 level of significance.

Scope and Delimitation

This study focused on developing and evaluating an electronic laboratory (e-Lab) manual in General Physics 1 for Grade 12 students. It is based on the Most Learning Competencies (MELCs) drawn by the DepEd and includes selected experiments aligned with core topics such as measurement, speed, acceleration, projectile motion, and circular motion. Another basis for the selection of the topics were the results of studies regarding the scores of the students in the General Physics. The output integrated multimedia features like interactive simulations, guided experiment instructions, and immediate rating and feedback input.

The electronic laboratory (e-Lab) manual will be evaluated by two university instructors teaching Physics subjects, four teachers from the Department of Education specializing in teaching Physics, five ICT experts, and one grammar expert from Tarlac State University. The evaluators are selected based on their area of specialization and the number of years in their field. The questionnaire adapted from the Evaluation Rating Sheet for NONPRINT Resources from the Learning Resources Management and Development System of the Department of Education was the main data-gathering instrument used to attain this study's objectives.

The study used Moodle as the main tool for implementing and deploying the Electronic Laboratory (e-Lab) Manual in General Physics 1. This tool stores all interactive laboratory activities, simulations, lecture videos, quizzes, and downloadable resources. It also enabled teachers and students to interact and track engagement and participation. For the student participants, seventy Grade 11 Science, Technology, Engineering, and Mathematics students of Tarlac Agricultural University—Laboratory School for the school year 2024-2025 used the electronic laboratory manual in General Physics 1.

LITERATURE REVIEW

Technology Integration in Science and Physics Education

Technology plays a significant role in enhancing students' understanding and engagement in science learning. Smith (2015) emphasized that integrating digital tools, such as electronic laboratory manuals, can help bridge the gap between theoretical concepts and practical applications, making abstract Physics ideas more concrete and understandable.

Similarly, McBride and Turner (2016) highlighted that e-lab manuals enhance accessibility and effectiveness, especially in resource-limited facilities, by providing immediate feedback and fostering active, independent learning. Kumar (2017) supported this view by noting that multimedia features such as videos, simulations, and interactive exercises enrich the learning experience.

Likewise, Thompson and Roberts (2018) stressed the efficiency of digital resources in promoting student-centered learning and supporting remote laboratory experiences, while Steven (2019) linked effective instructional design to the success of hybrid learning models that combine simulations, assessments, and interactive content delivery.

Numerous studies emphasized the importance of integrating technology in Science and Physics education to improve learning outcomes. Digital tools enhance student engagement, promote active learning, and allow for more interactive and meaningful instruction (Johnson et al., 2016).

In Physics, the use of computer-based simulations and digital manuals has been found to increase conceptual understanding compared to traditional methods (Zacharia & Olympiou, 2018). Such integration promotes inclusivity and reduces inequalities by providing equal opportunities for learners regardless of geographical or resource constraints.

Recent syntheses and domain-specific studies from 2015–2025 reinforce these benefits wherein flipped-classroom meta-analyses report moderate positive effects on achievement and engagement across STEM domains (van Alten et al., 2019; Strelan et al., 2020; Jeong et al., 2019), and systematic reviews show that immersive/AR-enhanced physics lessons can improve visualization of abstract concepts and motivation (Sustainability, 2022; Hernandez-López et al., 2024). Microlearning initiatives embedded in Physics courses via institutional LMSs also sustained learning at scale during COVID- 19 while widening access (Netzer & Mittelstadt, 2021; Laumann & Fischer, 2025).

Recent studies have further emphasized the transformative role of technology in enhancing Physics and Science education. According to Williams and Carter (2023), the integration of Augmented Reality (AR) in physics education enabled students to visualize complex concepts, such as electromagnetic fields, in real-time, improving both comprehension and engagement. This aligns with the findings of Hernandez-López et al. (2024), who reported that immersive technology enhances students' ability to grasp abstract concepts, particularly in fields like quantum mechanics and relativity.

Simulations, as highlighted by Sharma et al. (2023), provide immediate, interactive feedback, reinforcing key concepts through virtual experimentation. These studies have proven that simulations lead to a deeper understanding, as they encourage learners to experiment with variables, they may not have access to in a traditional lab setting. Furthermore, adaptive learning technologies, which personalize content delivery based on individual student needs, were shown to increase the retention of complex scientific principles in Physics (Jensen & Hughes, 2024).

Interactive multimedia tools, such as interactive videos and educational games, continue to support active learning in Physics classrooms. The work of Pérez and Silva (2024) confirmed that multimedia not only enhances motivation but also makes it easier for students to connect theoretical knowledge to real-world applications. Digital labs, often accompanied by real-time assessments, help mitigate the limitations of physical lab resources, making high-quality science education accessible to a broader audience (Graham & Thomas, 2023).

Moreover, the success of hybrid learning models, combining digital content with in-person teaching, has been reaffirmed by research conducted by Liu et al. (2025). They found that the combination of face-to-face interactions with virtual labs and instructional tools in Physics courses resulted in improved student performance and engagement during the post-pandemic era.

Lastly, mobile learning platforms, which allow students to engage with content on- the-go, have been shown to increase physics learning accessibility, especially in remote and under-resourced areas (Sundar & Shah, 2023). This form of learning was vital during the global shift to online education, allowing for continued engagement and learning despite disruptions caused by the pandemic.

Role of Laboratories in Science Instruction

The laboratory remains a vital environment for Science instruction as it provides opportunities for students to apply theory in practice, develop critical thinking skills, and engage in active learning. Tobin (as cited in Padilla & Atienza, 2016) underscored the importance of structured laboratory experiments, proper timing, and resource management to maximize laboratory use.

However, barriers such as underutilization, lack of training, and low teacher confidence hinder effectiveness, as revealed by Padilla and Atienza (2016) in their study of Philippine public schools. Espino and Rivera (2018) further noted that excessive scheduling, unsafe environments, and poor maintenance impede laboratory utilization, recommending structured supervision systems such as digital scheduling to improve efficiency.

Addressing these limitations, De Punzio et al. (2020) suggested blended laboratories, combining physical labs with virtual simulations and electronic manuals to supplement inadequate resources.

Laboratory work is an essential component of science education, providing students with hands-on experience and the opportunity to apply theoretical concepts in practice. Hofstein and Kind (2017) highlighted that laboratory experiences improve students' inquiry skills, scientific reasoning, and motivation. However, traditional laboratories often face challenges such as lack of resources, time constraints, and safety risks. Electronic alternatives ensure safer and healthier learning environments, aligning with SDG 3.

Reviews of interactions in face-to-face and remote undergraduate labs (Wei et al., 2019) and recent comparative studies of physical, virtual, and hybrid lab formats (Aşiksoy et al., 2023) outlined design factors like sequencing of activities, feedback timing, and scaffolding that maximize skill development while maintaining safety. Remote experimentation studies further demonstrate that instrumented, remotely triggerable apparatus can maintain or improve learning while reducing exposure risks (Barbhuiya et al., 2021).

Laboratories play a critical role in Science instruction by offering students the chance to engage directly with scientific concepts and practice scientific methods. According to Price et al. (2023), laboratory-based learning is essential for helping students develop not only technical skills but also soft skills such as problem-solving, teamwork, and critical thinking. They argued that effective laboratory environments foster student curiosity and lead to deeper conceptual understanding, particularly in subjects like Physics and Chemistry.

Despite the positive outcomes, numerous challenges still hinder the optimal use of laboratory spaces in educational settings. For instance, Brown and Tan (2023) highlighted that inadequate teacher preparation and lack of resources prevent many schools from using laboratories to their full potential. The study noted that while teachers are often enthusiastic about laboratory work, many struggle with aligning experiments to curriculum goals and lack the necessary professional development to effectively facilitate hands-on learning.

In response to these challenges, recent innovations have focused on the integration of digital tools to supplement physical laboratory work. As noted by Morrison et al. (2023), virtual labs and simulation tools offer an effective solution to overcome constraints like safety concerns and equipment limitations. These technologies provide students with the opportunity to perform complex experiments virtually, allowing for repeated trials and immediate feedback, which enhances both engagement and understanding. Furthermore, the role of flipped classrooms in laboratory instruction has been explored as an effective strategy. Ziegler and Schmidt (2024) found that flipped classroom models, which invert traditional classroom dynamics by delivering content outside of class and using laboratory time for collaborative problem-solving, significantly increased student participation and conceptual grasp in Science subjects. In these flipped labs, students come prepared with foundational knowledge from digital or pre-classroom activities, thus making the laboratory time more focused and productive.

Remote laboratory systems have also gained traction, especially in the wake of the COVID-19 pandemic. Studies by Carlson and Rivers (2023) demonstrated that remote labs can bridge the gap for students who do not have access to fully equipped science labs at school. These systems allow students to perform experiments remotely using real-time data collection and virtual lab tools. The effectiveness of these systems in maintaining learning outcomes comparable to traditional labs has been a significant area of study, with many concluding that remote labs can deliver similar levels of learning when designed with robust pedagogical strategies.

To ensure the continued success and improvement of laboratory-based education, researchers like Sharma et al. (2024) emphasized the importance of ongoing assessment and feedback within the laboratory setting. Their study found that providing students with detailed feedback on their performance in experiments, both in physical and virtual environments, helps students understand their mistakes, refine their hypotheses, and ultimately achieve better learning outcomes.

Benefits of Electronic Laboratory Manuals and Virtual Laboratories

Several scholars have validated the instructional benefits of electronic laboratory manuals in Physics. Faour and Ayoubi (2018) demonstrated that e-laboratories enhance conceptual understanding in Newtonian mechanics compared to traditional labs. Suárez, Almenara, and Sangrà (2020) reported that mobile-based digital manuals improved accessibility and interactivity, particularly in remote learning contexts.

Ramdani et al. (2019) also developed and validated an inquiry-based laboratory manual that received high ratings from both experts and students. In contrast, Olei (2020) emphasized the relevance of contextualized manuals in vocational education, while Zwickl, Finkelstein, and Lewandowski (2014) proposed skill-based laboratory assessments to strengthen data interpretation and experimental design.
Smith and Doe (2017) and Mercado (2020) likewise highlighted how digital manuals enhance accessibility, fill competency gaps, and support instructional goals through structured frameworks such as the ADDIE model.

Electronic laboratory manuals (ELMs) and virtual labs address these challenges by providing accessible, interactive, and cost-effective alternatives. According to Brinson (2015), virtual laboratories can be as effective as physical ones in promoting conceptual understanding and developing practical skills.
Similarly, electronic manuals improved student preparation, autonomy, and comprehension of experiments (Akpan & Beard, 2016). By reducing material waste and energy use in laboratories, these tools support sustainable practices under SDG 12.

Electronic Laboratory Manuals (ELMs) and virtual laboratories continue to revolutionize Science instruction by enhancing student engagement, accessibility, and comprehension. Recent studies demonstrated that these tools provide a flexible, interactive learning environment that supports conceptual understanding and practical skill development.

According to Lee et al. (2023), ELMs offered enhanced accessibility to students with different learning needs by providing multimedia-rich resources that support diverse learning styles. These resources not only increase student interaction but also help students visualize abstract concepts, making complex scientific principles more concrete. Virtual laboratories, in particular, have been found to improve student motivation by offering an immersive experience that simulates real-life lab work without the limitations of physical lab space (Griggs & Barton, 2024).

Mobile-based ELMs have shown promising results in promoting independent learning. A study by Patel and Sharma (2024) revealed that students using mobile ELMs were more likely to engage with the material outside of scheduled class times. The mobility of these resources allows for asynchronous learning, which is particularly beneficial for non-traditional students or those with time constraints due to personal or work commitments. The flexibility provided by mobile ELMs supports both student autonomy and collaboration, contributing to a deeper understanding of experimental procedures and scientific reasoning.

Virtual laboratories, as highlighted by Williams et al. (2023), provided an efficient means to reduce logistical barriers in laboratory education, such as safety concerns, cost, and the environmental impact of traditional experiments. Virtual labs allow students to engage in experiments without the need for physical chemicals, equipment, or hazardous materials, aligning with the principles of sustainability outlined in SDG 12. In their study, Williams et al. found that virtual laboratories can be as effective as traditional labs in promoting practical skill development, especially when integrated with real-time feedback systems.

Further supporting the effectiveness of virtual laboratories, Taylor and Kumar (2024) explored the role of these tools in inquiry-based learning, finding that students who used virtual labs showed higher levels of scientific reasoning and problem-solving abilities. These results indicated that virtual labs foster critical thinking by encouraging students to formulate hypotheses, conduct experiments, and analyze results, all while navigating the constraints of a virtual environment.

Moreover, electronic manuals that incorporate gamification elements have been found to significantly increase student engagement. As reported by Wright et al. (2024), students using gamified ELMs were more motivated to complete experiments, as the gamified features introduced a competitive and rewarding aspect to the learning process. This integration of game mechanics, such as points, levels, and badges, serves to make learning more engaging while encouraging continuous student participation.

Learning Management Systems (LMS) and Moodle in Physics Education

The rise of Learning Management Systems (LMS) has further strengthened the integration of electronic manuals in Physics instruction. Moodle has been recognized for its flexibility, constructivist pedagogy, and support for synchronous and asynchronous learning (Al-Ajlan & Zedan, 2008; Dougiamas & Taylor, 2003). Its open-source nature allowed customization and incorporation of digital resources, simulations, quizzes, and collaborative features essential for Science subjects. Comparative studies showed Moodle had surpassed other LMS platforms like Blackboard and WebCT in user satisfaction and accessibility. Investigations on blended learning frameworks revealed that students using Moodle-integrated laboratory manuals report higher satisfaction, stronger motivation, and improved conceptual understanding. Moreover, studies highlighted its potential in Physics education by storing e-lab manuals, integrating problem-solving labs, and facilitating project-based learning.

Learning Management Systems (LMS), particularly Moodle, have become vital in organizing and delivering science instruction. Studies indicated that Moodle-based laboratory manuals enhance accessibility, facilitate student collaboration, and provide structured learning environments (Al-Azawei et al., 2017). During the pandemic, LMS platforms sustained laboratory instruction and ensured learning continuity (Dhawan, 2020). These systems promoted transparent, fair, and inclusive access to education, reflecting SDG 16's vision of strong institutions.

The integration of Learning Management Systems (LMS) into Physics education has significantly enhanced the delivery and management of instructional materials. Moodle, a widely adopted open-source platform, has been praised for its flexibility and adaptability in supporting various pedagogical approaches. Recent studies highlighted Moodle's role in creating an effective blended learning environment, where Physics students engage in both online and offline learning activities. According to Wilson et al. (2023), Moodle's ability to integrate interactive content, such as simulations, virtual labs, and quizzes, helps bridge the gap between theoretical knowledge and practical application in Physics.

In particular, the use of Moodle in managing electronic laboratory (e-Lab) manuals has been found to improve accessibility and increase student engagement. A study by Alvarez and Roberts (2024) demonstrated that students who used Moodle-integrated laboratory manuals reported higher levels of motivation and a deeper understanding of complex Physics concepts. These digital manuals offer interactive problem-solving opportunities, which are essential for cultivating critical thinking and scientific reasoning in students.

Furthermore, Moodle has been recognized for supporting collaborative learning environments, a critical component of modern Physics instruction. A study by Zhang and Li (2023) showed that Moodle's forums, group activities, and peer-assessment features enhance collaboration and allow students to engage in project-based learning. In this collaborative setting, students can discuss and solve real-world Physics problems together, thereby improving their conceptual grasp and teamwork skills.

The importance of LMS platforms, especially Moodle, in maintaining continuity during disruptions like the COVID-19 pandemic has also been emphasized. Kumar et al. (2024) explored how Moodle allowed Physics instructors to continue delivering lessons and conducting virtual experiments, ensuring learning continuity during the shift to online education. This capability was especially beneficial in Physics labs, where physical space and equipment limitations often hinder learning.

Moreover, the integration of Moodle with other educational technologies had shown promise in enhancing learning outcomes. According to Sadiq et al. (2023), when combined with adaptive learning technologies, Moodle can offer personalized learning experiences, tailoring content to individual student needs. This allows Physics students to progress at their own pace and receive targeted support, which is particularly beneficial for those who struggle with the subject's abstract concepts.

Microlearning, MOOCs, and Adaptive Learning in Physics Instruction

Recent research highlighted the growing role of microlearning, adaptive learning strategies, and the reconceptualization of online materials as complementary to traditional Physics instruction. For instance, during the COVID-19 pandemic, the Technical University of Berlin revamped its introductory Physics course by incorporating microlearning videos, online exercises, and e-assessments via Moodle, benefiting over 800 STEM students without compromising conceptual gains, as measured by the Force Concept Inventory.

Similarly, literature on adaptive learning suggested that strategies such as flipped classrooms and microlearning can cater to individual student needs fostering personalized instruction while immersive technologies like AR/VR help make abstract Physics topics more accessible and engaging.

Recent years have seen the rise of microlearning and adaptive instruction in physics education. At the Technical University of Berlin, microlearning videos and online assessments integrated into Moodle sustained Physics learning for over 800 students during the pandemic without compromising conceptual understanding (Sommer et al., 2021).

Adaptive learning approaches, such as flipped classrooms, also personalized instruction, allowing students to learn at their own pace (Noroozi et al., 2022). MOOCs expand access globally, helping bridge gender gaps in STEM education by offering equal opportunities for women and marginalized groups, thereby addressing SDG 5.

Recent studies have emphasized the increasing integration of microlearning, MOOCs (Massive Open Online Courses), and adaptive learning techniques in Physics instruction, enhancing student engagement, understanding, and access to education. Microlearning, characterized by short, focused learning units, is particularly beneficial in helping students retain complex Physics concepts. A study by Johnson et al. (2024) demonstrated that the use of microlearning videos in conjunction with interactive exercises led to improved retention and comprehension of fundamental Physics concepts such as Newtonian mechanics and thermodynamics. This approach, which allows students to learn in small, manageable chunks, fits well with the cognitive load theory, reducing the overwhelming nature of complex topics.

Moreover, MOOCs have expanded opportunities for learning Physics on a global scale, especially for underserved populations. In a study by Patel and Turner (2024), MOOCs that offered interactive Physics courses helped bridge educational gaps, particularly for female students in STEM fields. These online platforms provided accessible, scalable education to students across various countries, addressing gender disparities in STEM education as part of SDG 5. The study found that female students in these online courses showed increased interest and persistence in Physics, demonstrating MOOCs' potential to promote gender equality in STEM.

Adaptive learning technologies have also become integral in Physics instruction. According to Williams et al. (2023), adaptive learning platforms, which use real-time data to tailor content to individual student needs, have significantly improved learning outcomes in introductory Physics courses. By adjusting the difficulty of problems based on a student's performance, these systems offer personalized learning paths that helped students master complex concepts at their own pace. This personalized approach is particularly useful in Physics, where concepts such as quantum mechanics and electromagnetic theory can be difficult for students to grasp without individualized support.

Additionally, immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) have been increasingly used to teach abstract Physics concepts. A study by Carter and Robinson (2024) explored the use of AR to help students visualize complex phenomena like electromagnetic waves and gravitational fields. The immersive experiences provided by AR and VR have been shown to increase student engagement and improve the understanding of abstract concepts that are traditionally difficult to demonstrate in physical classrooms.

Finally, the rise of adaptive learning in the form of flipped classrooms has provided new opportunities for personalized instruction in Physics education. As highlighted by Zhao et al. (2023), flipped classroom models, where students engage with lecture materials online and use classroom time for active problem-solving, have led to higher levels of student engagement and improved conceptual understanding. This model, combined with adaptive learning tools, allows students to receive targeted support during classroom activities, fostering a deeper understanding of complex Physics topics.

Interactive Simulations, Learning Analytics, and Remote Labs

The development of a Moodle extension for Easy JavaScript Simulations (EjsS) allowed instructors to monitor student interactions with simulations in real time and enhanced insight into learning behaviors. The potential of remote laboratories, where real equipment can be controlled online offering 24/7 access, equitable reach across geographies, and safe handling in making experimental physics more inclusive. Broader ICT integration reviews affirm that simulation software, virtual labs, and interactive online platforms bridge theory and practice, foster collaboration, and are vital tools in modern Physics pedagogy. Interactive simulations and remote laboratories have gained momentum as powerful instructional tools in physics education. A Moodle extension for Easy JavaScript Simulations (EjsS) enables instructors to track student engagement with simulations, providing real-time insights into learning behaviors (Esquembre & Christian, 2019).

Remote labs provide safe, flexible access to experimental physics (Lowe et al., 2020). By reducing the environmental footprint of physical laboratories, such technologies contribute to climate action and sustainability (SDG 13).

The use of interactive simulations, learning analytics, and remote laboratories has become increasingly vital in enhancing Physics education. Interactive simulations offer dynamic, visual representations of complex physical phenomena that are difficult to observe directly in traditional labs. According to Turner and Kelly (2023), these simulations helped students visualize abstract concepts such as electromagnetic waves, quantum mechanics, and fluid dynamics, thereby fostering deeper conceptual understanding. By interacting with simulations, students are able to manipulate variables and see immediate

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results, which enhances their problem-solving skills and scientific reasoning.

In addition to simulations, learning analytics is playing an increasingly prominent role in Physics education. As noted by Thompson and Wallace (2024), the integration of learning analytics into virtual labs allows instructors to monitor student progress, identify areas where students struggle, and provide targeted interventions. These insights are crucial in personalized learning environments, enabling instructors to adjust the difficulty and scope of simulations based on individual student performance. By using data-driven strategies, educators can optimize learning outcomes and better understand student behaviors, particularly in virtual and remote settings.

Remote laboratories, where students can control real equipment from a distance, provide an accessible and flexible learning experience. A study by Clark and Zhang (2023) found that remote labs give students 24/7 access to real-world experiments, making experimental Physics more inclusive, especially in resource-constrained environments. These labs also ensure that students can safely interact with equipment that might otherwise be too dangerous or costly to use in a traditional laboratory setting. The flexibility of remote labs has been particularly beneficial for students in remote or underserved locations, providing them with the opportunity to gain hands-on experience without geographical limitations.

Moreover, interactive simulations and remote laboratories contribute to sustainability by reducing the need for physical resources and energy consumption in traditional labs. As highlighted by Green and Patel (2024), these technologies lower the environmental impact of laboratory education, aligning with the principles of SDG 13 by minimizing waste and the carbon footprint associated with in-person experimental setups. By adopting virtual labs, educational institutions can play a role in advancing climate action while providing high-quality Physics education.

Incorporating tools like Easy JavaScript Simulations (EjsS) into platforms like Moodle has also improved Physics education by facilitating real-time monitoring of student engagement. Recent research by Harris et al. (2024) showed that Moodle's integration with simulation software allows instructors to track student interactions, providing valuable feedback that can be used to adjust teaching strategies. These insights enhance the personalization of instruction and help ensure that all students are actively engaged and making progress in mastering Physics concepts.

Local Studies on Laboratory Manuals and LMS Integration

In the Philippine context, several studies underscore the importance of laboratory manuals and LMS adoption. Activity-based and software-supported manuals have been developed for Electronics and Industrial Physics courses, showing improved circuit simulation and practical skills (Philippine EJournals, n.d.).

Diola (2023) validated a Life Science manual for Senior High School using the ADDIE model, while Mercado (2020) designed a Physics manual that addressed competency gaps among engineering students. Research also documents the benefits of computer-aided simulations for electric circuits, citing greater efficiency and accessibility (Philippine EJournals, n.d.).

Regarding LMS platforms, Rogers, Mercado, and Decano (2024) linked Moodle engagement with higher student performance in a Philippine university, while teachers in Sorsogon reported an increase in instructional confidence through sustained use (ResearchGate, n.d.). Moodle was also crucial during the COVID-19 pandemic as schools nationwide relied on it and similar platforms for distance learning (Journal of Communication and Development Research, 2024).

Locally developed innovations such as “Poodle,” a portable version of Moodle, have supported rural learning needs (Ijses.com, 2018). These findings affirm the adaptability of Moodle and e-lab manuals in the Philippine setting and support their integration into Physics instruction.

In the Philippine context, the use of electronic and digital manuals is gradually being adopted in science instruction. Studies highlight that localized ELMs tailored to curriculum standards increase student performance and motivation in laboratory work (Cruz & Tarrayo, 2019). Integration with LMS platforms such as Moodle also enhances the delivery of STEM content in resource-constrained schools (Reyes et al., 2021). By equipping learners with modern scientific and digital skills, these innovations prepare students for future work opportunities and promote economic growth (SDG 8).

In recent years, the integration of laboratory manuals and Learning Management Systems (LMS) in the Philippines has become more prominent, particularly in STEM education. Several studies highlighted on how these tools have enhanced the quality of Science and Physics instruction, improving student performance and engagement.

For instance, a study by Santos and Delgado (2023) explored the effectiveness of using electronic laboratory manuals (ELMs) in enhancing student performance in introductory Physics courses. The study found that ELMs, which provided students with detailed instructions and real-time feedback, led to improved understanding of complex topics like motion and energy. This supports the findings of Cruz and Tarrayo (2019), who demonstrated that using customized ELMs in Electronics courses helped students grasp circuit design concepts more efficiently, enhancing both theoretical and practical skills.

In terms of LMS integration, research by Garcia et al. (2024) found that the adoption of Moodle in a provincial university resulted in increased collaboration and engagement in Physics labs. The study highlighted that Moodle's ability to provide instant feedback, track student progress, and facilitate group work was essential in maintaining high levels of student engagement, particularly in remote or resource-limited areas. This aligns with previous findings by Mercado (2020) and Reyes et al. (2021), who emphasized Moodle's positive impact on instructional quality in Philippine educational settings, especially during the transition to online learning during the pandemic.

The adaptability of Moodle to various local contexts has also been explored. A study by Ylagan and Mendoza (2023) examined how “Poodle,” a portable version of Moodle, helped address educational challenges in rural areas. The research found that Poodle allowed teachers and students in remote provinces to access the same quality of educational resources as those in urban centers, fostering equitable learning opportunities for students who would otherwise have limited access to digital education tools. This development aligns with SDG 4, ensuring inclusive and equitable quality education.

In terms of innovations, a study by Salazar and Gomez (2024) focused on the integration of virtual simulations within Moodle, allowing students to conduct experiments in Physics remotely. The study showed that these simulations, combined with instructional materials, improved student understanding of abstract concepts like electricity and magnetism, making Physics more accessible to students in underserved schools.

Moreover, local adaptations of ELMs have proven beneficial in promoting collaboration among students. The work of Navarro et al. (2023) showed that when ELMs incorporated group-based learning activities, student collaboration and problem-solving skills were enhanced, particularly in Physics and Chemistry courses. This highlighted the importance of integrating collaborative features into digital learning tools to enhance student engagement and teamwork, vital skills for STEM fields.

Synthesis

The integration of electronic laboratory manuals (ELMs), Learning Management Systems (LMS) such as Moodle, and innovative instructional tools has shown significant potential in enhancing Physics education in the Philippines. Local studies have demonstrated that these technological advancements not only bridge gaps in traditional Physics instruction but also promote greater student engagement, collaboration, and conceptual understanding across various educational contexts, particularly in underserved and rural areas.

A key theme that emerged from the reviewed studies is the positive impact of electronic laboratory manuals (ELMs) on student performance. Research by Santos and Delgado (2023) and Cruz and Tarrayo (2019) showed that customized, activity-based ELMs have enhanced students' comprehension of complex Physics concepts, such as motion, energy, and circuit design. These digital resources provide structured learning, with real-time feedback and interactivity that improve both theoretical knowledge and practical skills. In the same vein, Mercado's (2020) study on a Physics manual for engineering students highlighted how e-Lab manual address competency gaps by offering targeted instructional support, thereby enhancing learning outcomes.

The integration of Moodle as an LMS in the Philippine context has been equally transformative. Studies by Garcia et al. (2024) and Mercado (2020) illustrated that Moodle's flexibility allows for a more organized, collaborative, and interactive learning experience, particularly in Physics instruction. The platform supports both synchronous and asynchronous learning, promoting higher levels of student engagement, particularly in remote or resource-limited areas. During the pandemic, Moodle played a crucial role in sustaining Physics learning through digital platforms, ensuring that students had access to instructional materials and virtual labs even when physical classroom interactions were not possible (Reyes et al., 2021).

Local innovations such as "Poodle," a portable version of Moodle, further demonstrated the adaptability of LMS platforms in addressing the unique needs of rural learners. Ylagan and Mendoza (2023) highlighted how Poodle enables equitable access to digital learning resources, helping bridge the educational divide between urban and rural areas. This supports SDG 4, which emphasizes the importance of ensuring inclusive and equitable quality education for all, particularly in marginalized communities.
Additionally, the use of virtual simulations within Moodle has been a critical factor in making experimental Physics more accessible. Studies by Salazar and Gomez (2024) show that virtual labs, integrated with Moodle, provide students with the opportunity to perform complex experiments remotely, ensuring safety and accessibility while promoting a deeper understanding of abstract concepts like electricity and magnetism. These innovations are particularly beneficial for schools in remote locations where physical lab setups are often limited or unavailable.

Moreover, collaborative learning facilitated by ELMs and Moodle is another critical aspect of these technological advancements. Research by Navarro et al. (2023) emphasized the benefits of collaborative features in digital manuals, where students can engage in group-based activities that enhance teamwork, problem-solving skills, and critical thinking. These skills are essential for success in STEM fields and are cultivated effectively through the integration of technology in Physics education.

In conclusion, the studies reviewed collectively underscore the transformative potential of electronic manuals, Moodle, and innovative instructional strategies in improving Physics education in the Philippines. These tools offer scalable, sustainable, and inclusive solutions to educational challenges, particularly in remote areas and during times of crisis such as the COVID-19 pandemic. They not only improve student learning outcomes but also contribute to achieving broader educational goals, including promoting gender equality in STEM (SDG 5) and fostering economic growth through the development of digital and scientific skills (SDG 8). The adaptability of these technologies, including localized versions such as Poodle, further highlights their crucial role in ensuring equitable access to quality education across diverse learning contexts.

Overall, both international and local studies highlight the transformative role of electronic laboratory manuals and digital learning platforms in Science education. The literature consistently points to enhanced student engagement, improved conceptual understanding, and more equitable access to learning resources through e-labs and Moodle integration. Barriers such as resource limitations and underutilization of physical laboratories can be mitigated through blended approaches that combine traditional and digital laboratories.

This body of literature justifies the development and validation of an electronic laboratory manual for General Physics 1 in the Philippine context, ensuring that students acquire both theoretical and practical competencies through accessible, technology-driven means.

Conceptual Framework

This study was grounded in John Dewey's Learning by Doing theory, which emphasized that students acquired knowledge more effectively when they actively engaged in experiences that integrated ideas and relevant skills (Bates, 2019). Dewey argued that learning occurred most meaningfully when students encountered real-world situations, actively participated in tasks, and reflected on their experiences. This principle underpinned experiential and hands-on learning, which formed the foundation of this research. Learning by doing allowed individuals to gain knowledge and skills through direct involvement, encouraging learners to guide themselves through the educational process while teachers provided support, resources, and motivation to optimize learning outcomes (Mekkonen, 2020).

The problem-based learning (PBL) approach had been widely recognized for its effectiveness in fostering critical thinking and problem-solving skills, especially in STEM education. According to Abeysekera and Dawson (2015), PBL encouraged students to actively engage with real-world problems, which helped them develop both their analytical and collaborative skills. In Physics education, PBL was shown to enhance students' understanding of complex concepts by making learning more meaningful and context- driven. Similarly, Sandi (2019) found that PBL not only improved conceptual understanding but also motivated students to take responsibility for their own learning. In the context of the electronic laboratory manual, using PBL allowed students to explore real-world problems in Physics, apply theoretical knowledge to practical situations, and gain a deeper understanding of the subject matter.

Exploratory learning, another pedagogical approach, emphasized inquiry and student-driven discovery. According to Chi and Wylie (2014), exploratory learning provided students with opportunities to investigate and test hypotheses in an open-ended manner, promoting curiosity and deeper learning. In Physics, this approach was shown to enhance student engagement and foster scientific reasoning. A study by Hestenes et al. (1992) highlighted that allowing students to explore and experiment with physical phenomena led to better retention of knowledge and an improved ability to transfer learning to new situations. By integrating exploratory learning into the electronic laboratory manual, students were enabled to engage in activities where they actively tested concepts, explored outcomes, and refined their understanding, making learning more experiential and meaningful.

In the context of science education, educational resources such as laboratory manuals and workbooks served as practical tools to facilitate experiential learning and skill acquisition. Mekkonen (2020) noted that structured resources, such as laboratory exercises, assisted students in practicing, experimenting, and internalizing concepts, making learning both concrete and relevant. Similarly, Seel (2012) emphasized that learning by doing encompassed a wide range of pedagogical approaches in which learners actively constructed knowledge through hands-on engagement, experimentation, and exploration of their environment. This active involvement fostered creativity, critical thinking, and problem-solving skills, which were central to laboratory-based learning.

Gibbs (1988) further highlighted that experiential learners engaged actively with their experiences, using reflection to challenge assumptions and deepen understanding. Practice alone was insufficient;

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learners had to critically examine their experiences to derive meaningful insights. This reflective process ensured that learning was not only procedural but also conceptual, as students evaluated outcomes, made generalizations, and connected them to broader scientific principles.

The laboratory manual in this study embodied these principles. Students were provided with structured guidance and an overview of concepts before engaging in a variety of activities. Through participation in experiments, reflective exercises, and group discussions, learners applied theoretical knowledge in practical contexts, explored scientific phenomena, and developed competencies in a scaffolded manner. Dewey's philosophy was thus operationalized in the design and use of the electronic laboratory manual, which served as both a teaching guide and a learning tool, facilitating experiential learning and reinforcing the learning-by-doing principle.

By integrating exercises, simulations, and structured reflection within the manual, students were empowered to actively construct knowledge, develop scientific skills, and engage meaningfully with Physics concepts in ways that replicated real-world applications. The manual not only enhanced learning outcomes but also served as a bridge between theory and practice, embodying Dewey's vision of education as an interactive, reflective, and experience-centered process.

The paradigm below portrays the conceptualization and development of the laboratory manual in General Physics 1 for Grade 12 Science, Technology, Engineering, and Mathematics students:

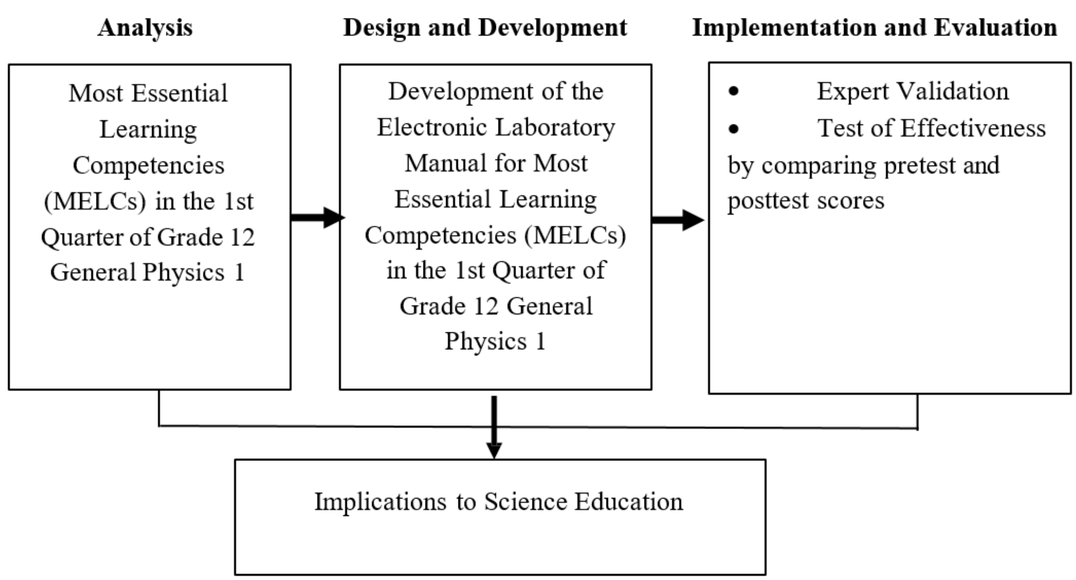

Figure 1**. The paradigm of the study**

In the preparatory phase, the Most Essential Learning Competencies (MELCs) in the 1st Quarter of Grade 12 General Physics 1 determined the necessary content base and scope for the electronic laboratory manual, and laboratory activities ensuring that the content was relevant, focused, and aligned with the prescribed competencies. The skills to be developed based on content, layout and design and format are also identified and decided.

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The Development of the Electronic Laboratory Manual for the Most Essential Learning Competencies (MELCs) in the 1st Quarter of Grade 12 General Physics 1 followed a structured approach, ensuring alignment with the curriculum and educational standards. The researcher adhered to the guidelines set by the Department of Education (DepEd) for creating laboratory manuals, ensuring that the manual was not only aligned with the MELCs for the specific subject and grade level but also adhered to the pedagogical and instructional frameworks set forth by DepEd.

The researcher secured permission from experts/instructors teaching Physics and ICT subjects from the university, and from the Department of Education to serve as evaluators. They evaluated the manual based on content, language and grammatical errors, and layout and design.

This phase included revising the manual based on the comments and suggestions from evaluators. The considerations or criteria before revising were to check whether the proposed corrections and suggestions would still be following the objectives, and if it is feasible. After that, the activities, pages in the manual, or parts of the manual that need to be revised or changed based on the comments were identified. The manual was then carefully revised based on the given comments and suggestions. The students used the laboratory manual to determine its effectiveness. A test of effectiveness compared pretest and posttest scores to measure the manual's impact on student learning.

The Implications to Science Education phase synthesized the results from the implementation and evaluation phase and articulated the significance of the findings. The evaluation results provided insights that informed recommendations for future educational practices, policies, or research in Science education. Specifically, this phase examined how the electronic laboratory manual could contribute to the broader field of science education and how its use could influence the integration of technology in teaching General Physics 1. It provided a bridge from the research findings to practical, real-world applications in educational settings.

METHODOLOGY

Research Design

The study focused on the development and validation of an Electronic Laboratory (e-Lab) Manual for General Physics 1 for Grade 12 STEM students, guided by the instructional materials development model of Tolentino et al. (2020). It employed a developmental research design to systematically design, produce, and evaluate the instructional material, ensuring both pedagogical effectiveness and internal consistency. The development process followed four phases: preparatory, where the framework and curriculum alignment were established; development, where content with interactive and multimedia features was created; evaluation, where experts and users assessed the manual using adapted instruments and pretest-posttest measures; and revision, where improvements were made based on feedback and results. Additionally, a descriptive research design was used to assess users' perceptions, satisfaction, and acceptance of the e-Lab manual, ensuring its usability and effectiveness as a learning tool.

Research Locale

The research was conducted at Tarlac Agricultural University - Laboratory School, a prominent public secondary school located in Malacampa, Camiling, Tarlac, Philippines. Founded in 1944 as Camiling Boys'/Girls' High School, the institution had long been a cornerstone of education in the region. By the time of the present study, Tarlac Agricultural University - Laboratory School had continued to serve as an educational hub, offering a range of academic programs, with a strong emphasis on Science, Technology, Engineering, and Mathematics (STEM) at the senior high school level. The school's academic track, particularly in the STEM disciplines, provided students with a comprehensive foundation to excel in these critical fields. For the present study, the Electronic Laboratory (e-Lab) Manual for General Physics 1 was implemented for Grade 11 students, focusing on the application of technology in enhancing the learning experience in physics. The institution's long-standing history of educational excellence and its commitment to preparing students for future academic and professional success made it an ideal setting for this study, which aimed to assess the effectiveness of digital tools in fostering scientific learning.

Participants of the Study

The participants of the study were Grade 11 Senior High School students enrolled in the STEM strand for the academic year 2024–2025. They were selected based on their current enrollment and their anticipated participation in General Physics 1 in the following school year. As future learners of the subject, they served as an appropriate group to evaluate the effectiveness of the Electronic Laboratory Manual (e-Lab) in enhancing physics learning. Their background in science also ensured that they were capable of engaging with the concepts and providing meaningful insights on the use of technology in science education.

Sampling Design

The study employed a non-probability sampling design using convenience sampling to select a total of seventy (70) students. This approach was chosen due to the accessibility and availability of participants, as well as limitations in time and resources that made probability sampling impractical. Given the exploratory nature of the research, non-probability sampling was considered appropriate, as it allowed the researcher to gather relevant data and initial insights from respondents needed for the study.

Research Instruments

The study utilized the Evaluation Rating Sheet for NONPRINT Resources from the Department of Education's Learning Resources Management and Development System as the primary data-gathering instrument. This tool employed a 4-point Likert scale with responses ranging from Very Satisfactory to Poor. The instrument, together with the developed electronic laboratory manual, was evaluated by a group of experts composed of Department of Education Physics teachers, college Physics instructors, ICT experts, and a grammar expert. The selected evaluators met specific qualifications, including advanced degrees, relevant teaching experience, and expertise in their respective fields. Additionally, 70 Grade 11 STEM students served as user-evaluators, providing feedback on the usability and effectiveness of the electronic laboratory manual.

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Data Gathering Procedures

The researcher secured permission from the validators through a formal letter before conducting the study. Upon approval, the letter, along with informed consent forms and a data-gathering instrument adapted from the DepEd Learning Resources Management and Development System, was presented to qualified evaluators with relevant master's degrees and at least five years of experience. The validation results were collected and used for interpretation, while feedback from science experts during a post-conference was incorporated to revise the electronic laboratory manual. The experts also evaluated the pretest and posttest instruments prior to administration.

A total of forty (40) Grade 12 STEM students participated in the study. Pilot testing was conducted to ensure the clarity, reliability, and effectiveness of the test items, followed by necessary revisions. After validation, the electronic laboratory manual was used in teaching General Physics 1 during the fourth quarter. A pretest was administered before implementation and a posttest after, covering topics such as speed, velocity, acceleration, projectile motion, circular motion, and Newton's laws of motion, with 50 items in total. The intervention lasted four weeks, and the results of the pretest and posttest were compared to determine the effectiveness of the manual. All collected data were analyzed using appropriate statistical tools and presented in tables and text.

Data Analysis

The researcher utilized frequency and weighted mean to analyze the data collected. The weighted mean is a relevant tool because it allowed the researcher to determine the average of the ratings given by the experts for the electronic laboratory manual. It provided a single, numerical value that represents the overall expert consensus on the manual's quality.

Furthermore, the weighted mean gave more significance to certain data points, which is crucial when different experts might have varying levels of experience or different areas of specialization. The mean was used to determine the average of the ratings of the electronic laboratory manual and language expert.

The formula of the weighted mean:

$$\overline{X}=\frac{\sum x}{N}$$

Where:

$\overline{X}$ = Mean
X= Scores given by the experts
N= Total number of experts

To be able to describe the laboratory manual, the following groups of mean ratings and their corresponding interpretations were used.

Groups of Mean Ratings and their corresponding interpretations.

Scale	Range of Mean	Verbal Description
4	3.21 - 4.00	Very Satisfactory
3	2.61 – 3.20	Satisfactory
2	1.81 – 2.60	Unsatisfactory
1	1.00 – 1.80	Poor

To assess the effectiveness of the manual and determine if there were significant changes in the participants' knowledge, a paired sample *t-test* was used to compare the pretest and posttest scores. This statistical tool was chosen because it is specifically designed to measure the mean difference between two sets of data from the same group of individuals.

By comparing each student's pretest score to their posttest score, the paired sample t-test provided a rigorous and valid way to determine if the observed changes were statistically significant and not merely due to chance. This allowed the researcher to confidently conclude whether the electronic laboratory manual had a genuine impact on the students' learning of Physics concepts.

The formula for the paired test *t-test* is:

$$t = \frac{\sum d}{\sqrt{\frac{\mathrm{n}(\sum d^2) - (\sum d)^2}{n-1}}}$$

Where ∑d is the sum of the differences and n=the number of participants.

Research Ethics

The study adhered to key ethical guidelines, including obtaining informed consent by fully informing participants about the purpose, procedures, risks, and benefits of the study before securing their voluntary participation. Anonymity and confidentiality were ensured by protecting participants' identities and using the collected data solely for research purposes. Participation was entirely voluntary, allowing respondents to withdraw at any time without penalty. The research was conducted with integrity and honesty, ensuring accurate data collection and reporting, while respecting the rights, dignity, and well-being of all participants, who were also provided with a debriefing after the study.

RESULTS AND DISCUSSIONS

1. The Development of the Electronic Laboratory Manual Analysis of the Learning Gaps

The Electronic Laboratory (e-Lab) Manual were developed based on the selected lessons from the First Quarter/ Midterm, SY 2024-2025. Table shows the list of the selected lessons for the First Quarter/ Midterm.

Selected Lesson in General Physics 1, First Quarter/ Midterm SY 2024-2025

Lesson	Learning Competencies
1. Measurement	Solve measurement problems involving conversion of units and expression of measurements in scientific notation
2. Speed, Velocity, and Acceleration	Solve for unknown quantities in equations involving one-dimensional motion
3. Projectile Motion	Calculate range, time of flight, and maximum heights of projectiles
4. Circular Motion	Infer quantities associated with circular motion such as tangential velocity, centripetal acceleration, tangential acceleration, and radius of curvature
5. Newton's Laws of Motion	Solve problems using Newton's Laws of Motion

The lesson for the First Quarter or Midterm are necessary to the students' performance in the future Physics topics. Specifically, measurement is the backbone of scientific experiments. The accuracy, precision and reliability of results depend on proper measurement techniques. Including problems related to measurement in the laboratory manual ensures that the students can develop critical thinking skills in acquiring data and understanding experimental set-ups.

This section discussed various physical quantities such length, mass, volume, temperature, and time and the corresponding instruments used to measure them. The section went into detail about tools like as rulers, balances, graduated cylinders, thermometers, and stopwatches. The focus is on how to use these instruments effectively and the importance of calibration to minimize systematic errors.

This chapter presented practical exercises in which students measure various physical properties of household objects. This hands-on approach enabled students to apply the theoretical concepts of measurement in a controlled environment. By performing experiments that involve mass and volume measurements, students learned to apply the concepts of density, error analysis, and significant figures.
Speed, velocity and acceleration are fundamental concepts in Physics and form the foundation for understanding the motion of objects. Experimenting with these concepts in the laboratory help the students differentiate between scalar and vector quantities and apply their mathematical relationships in real-world situations.

Students performed experiments to measure the time it takes for an object to cover a set distance and use the data to calculate both average and instantaneous speed. The The lesson for the First Quarter or Midterm are necessary to the students' performance in the future Physics topics. Specifically, measurement

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Students performed experiments to measure the time it takes for an object to cover a set distance and use the data to calculate both average and instantaneous speed. The Circular motion is a fundamental concept in Physics that describes the motion of an objects that follow a circular pathway. It plays a crucial role in understanding various systems like satellite, rotating machines and even rotating planets.

Students performed experiments involving objects moving in circular paths, such as swinging a rubber stopper on a string. By varying the radius and speed of the object, they observed the effects on centripetal acceleration. The experiment also includes calculating tangential velocity using the relevant formula.

This chapter helped the students understand the forces at play in circular motion, including how velocity and acceleration are related to the radius of the circular path. By measuring the speed and forces involved, students applied the concepts of force, velocity, and acceleration in practical scenarios such as amusement park rides and planetary motion.

Newton’s Laws of motion form the foundation of classical mechanics and their application in understanding on how objects move in the influence of forces. This allows the students to develop a methodological approach to problem-solving that is invaluable skill in science and engineering.

Students conducted hands-on experiments to observe the application of each law. For example, they observed the effects of different masses on the acceleration of objects, studied the behavior of objects at rest and in motion (First Law), and explored the force- acceleration relationship using toy cars (Second Law). Newton’s Third Law is demonstrated using action-reaction pairs, such as balloon rockets.

By conducting these experiments, students gained a deeper understanding of the real-world applications of Newton's laws. They learned how forces cause changes in motion and how these principles can be used to analyze and predict the motion of objects in different scenarios. This chapter served as a critical foundation for the study of dynamics in subsequent courses.

Each of these topics are very significant in developing students' understanding of basic Physics principles. By engaging in laboratory experiments related to these concepts, the students can gain the necessary skills to analyze, solve and predict physical phenomena. Furthermore, these topics lay the backbone for future studies in more advanced areas of Physics which is an integral part of the educational journey.

Designing the Electronic Laboratory (e-Lab) Manual

The Electronic Laboratory (e-Lab) Manual was developed as a comprehensive and interactive learning tool that integrated theoretical knowledge with practical experimentation. It was designed to be user-friendly, containing theoretical background, step-by-step laboratory procedures, and safety guidelines, while also incorporating dynamic content such as videos, animations, and interactive simulations that visualized complex scientific concepts.

The manual was hosted on Moodle, a learning management system (LMS) that provided flexibility for both online and offline access. Online, students were able to log in through a web browser or the Moodle mobile application, navigate laboratory modules, and interact with simulations and embedded multimedia resources in real time. Offline functionality was also supported through the Moodle app, which allowed students to download modules in advance, access readings, view videos, and record experimental data without requiring continuous internet connectivity; once reconnected, their work automatically synchronized with the platform.

The process of using the e-Lab manual began with students accessing Moodle and preparing for experiments by reviewing background information and multimedia demonstrations. During experimentation, they followed the structured procedures, either through actual laboratory work or virtual simulations, and recorded their results directly in the system. The manual supported both manual entry and automated data collection, which were then analyzed in real time through built-in graphing and statistical tools.

Instant feedback was provided to guide interpretation and address misconceptions, while post-laboratory activities such as quizzes and reflective prompts reinforced understanding. Overall, the Moodle-based e-Lab manual not only encouraged self-paced learning but also promoted active participation, improved accuracy in experimental work, and enhanced the development of critical thinking and digital literacy skills.

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Developing the Electronic Laboratory (e-Lab) Manual

The Electronic Laboratory (e-Lab) Manual has several parts. The E-Laboratory Manual platform hosted on Moodle has login interface. Users are required to enter a username and password to access the system. There are options for password recovery, guest access, and viewing the cookies notice. The page is visually supported with laboratory-themed icons and graphics.

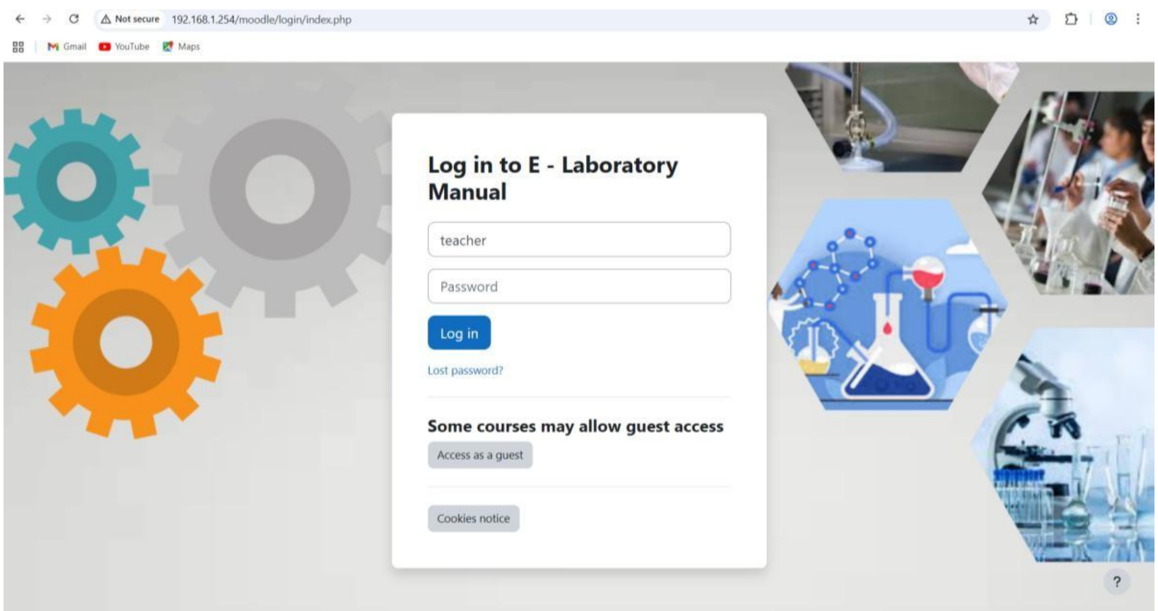
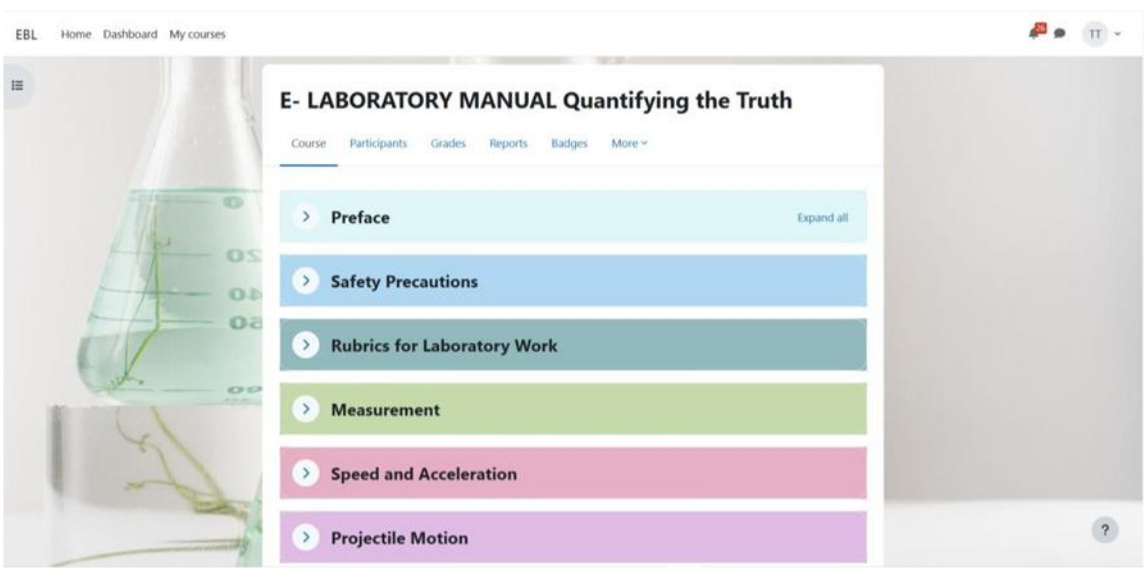


Figure 2. **Log-in Interface of the e-Lab Manual**

The Preface served to prepare the students mentally and philosophically for the experiments. It laid



out the expected learning outcomes, which are designed to foster a scientific mindset that values inquiry and exploration. By presenting clear objectives, procedures, and real-life applications, it helped students understand the practical significance of the concepts they will learn. The "Critical Thinking Questions" allowed students to reflect on the deeper implications of each experiment, moving beyond memorization to a more active and analytical learning approach.

Figure 3. **Main course page of the e-Lab Manual**

The safety precautions are crucial to ensure that students understand the potential hazards associated with laboratory work and are prepared to manage them. This section is essential for establishing a safe learning environment. By covering personal protective gear, handling chemicals safely, and instructing students on emergency procedures, it emphasized a culture of safety and responsibility. Ensuring that students understand this safety guidelines minimized the risk of accidents and reinforce the importance of careful, and deliberated actions in a laboratory setting.

The warm-up exercises served as a precursor to the experimental tasks, allowing students to engage with concepts that are foundational for the experiment. These involved simple review questions, conceptual discussions, or mini-experiments to test students' understanding of core topics like speed, acceleration, or force. By connecting prior knowledge to new material, this section helped students build a stronger foundation and primed them to tackle more complex concepts during the experiment. It gave a quick diagnostic tool for instructors to gauge students' readiness.

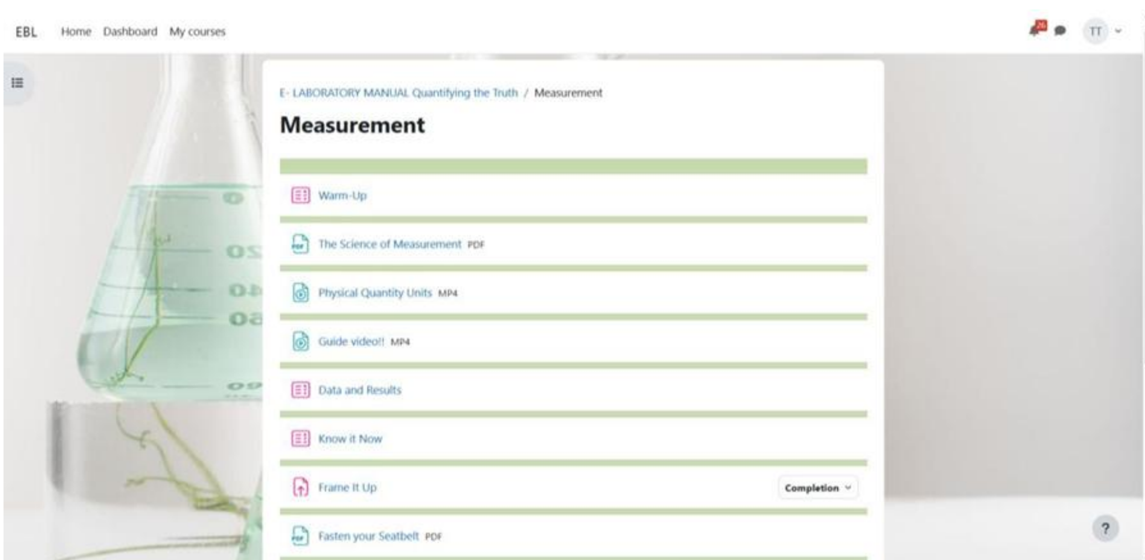


Figure 4. **Course section page of the e-Lab Manual**

The e-Lab manual has a short discussion that served as transition before going to the experiment activity. The "Fact Attack" section enhanced student engagement by introducing interesting tidbits or historical context related to the topic of study. For example, a fact about Newton's discovery of gravity during the plague or the speed of the fastest winds on Neptune ties theoretical physics to real-world phenomena. This section encouraged curiosity and presented physics in a broader, more exciting context. It also served to motivate students by showing how the principles they are learning have influenced significant scientific breakthroughs or everyday technology.

The" Do it Yourself" is the core of the hands-on approach to learning. Students are given detailed instructions that enable them to engage with the scientific method directly. This section typically involved instructions for data collection, measurement, and observation, which are critical for the development of practical laboratory skills. Students are expected to follow the procedures carefully, measure physical quantities accurately, and perform calculations. The active involvement in data collection and analysis fostered a deeper understanding of experimental physics and provides students with the opportunity to apply theoretical knowledge to real-world situations.

The "Watch Now" section included video links that complement the theoretical and experimental components of the manual. These videos showed key experiments, visualizations of concepts, or explanations of complex principles. This section supported the manual by offering multimedia resources that cater to visual and auditory learners. By watching videos, students internalized the concepts in action, whether it's an animated explanation of projectile motion, a demonstration of forces in action, or a visual representation of data. Videos helped bridge the gap between theory and practice, and made abstract ideas more tangible. This section enriched the learning experience by allowing students to engage with the content in different formats, fostering a deeper understanding of the material.

The Data and Result section emphasized the importance of organizing and analyzing experimental data. Students are instructed to record their measurements in tables, calculate relevant quantities, and compared their results with theoretical expectations. For example, after measuring the time of flight in projectile motion experiments, students calculated speed, acceleration, or range. The analysis of the data helped students assess the validity of their experimental methods, identified any potential sources of error, and determined the accuracy of their findings. This process of data interpretation and result validation is a critical part of scientific research and reinforced the scientific method.

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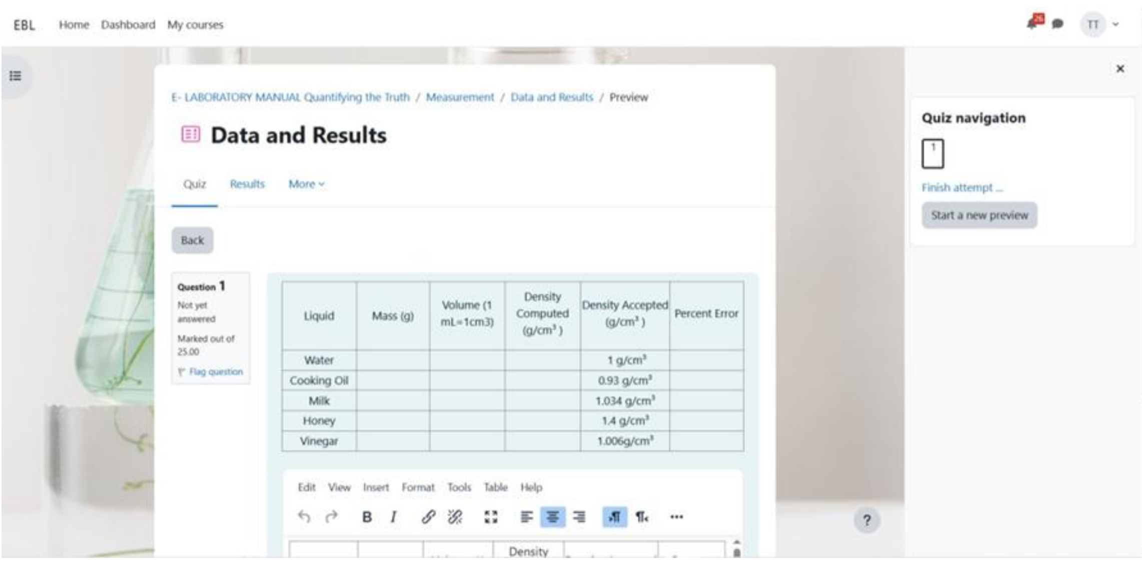

Figure 4. **Interactive Assessment of the e-Lab Manual**

This Fram It Up part encouraged students to create a comprehensive record of their experiment by including pictures (before, during, and after the experiment) and written observations. By documenting their experimental process and the resulting data visually, students reinforced their understanding and improved their ability to present scientific information. This section encouraged students to develop communication skills, which are important for conveying complex scientific concepts to others. Additionally, it helped students understand the importance of documenting their findings for future reference and for analysis in the context of the broader scientific community.

The "Know It Now" section is designed to reinforce students' understanding of the material. It included questions that encourage students to reflect on their experimental findings and connect them to the underlying physics concepts.

This section served as a reflective exercise where students are asked to answer questions based on the data they collected or the concepts they learned during the experiment. These questions asked students to explain the reasoning behind the results, consider potential sources of error, or applied the learned concepts to new situations. By encouraging students to think critically and reflect on the material, the "Know It Now" section ensured that learning is not passive but instead involves active engagement and application of the scientific concepts.

The "Brain It On" section provided a set of questions (usually multiple choice or true/false) designed to test students' understanding of the concepts covered in the experiment. This section is an essential tool for assessing students' comprehension and retention of the material. The questions are typically designed to test not just recall but also the application of concepts to various situations. By providing students with the opportunity to answer questions that test their understanding in different

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contexts, the "Brain It On" section reinforced learning and encouraged active participation. This section served as a formative assessment that can help both students and instructors gauged the effectiveness of the lesson and identify areas that may require further clarification or review.

The e-Lab Manual has a central feature that enables instructors to effectively manage, track, and assess student performance throughout the course. It functions as a digital grade management system that records and organizes grades, scores, and feedback for all assessments, quizzes, and assignments submitted by students. This system not only ensures efficient grading but also helps maintain consistency and transparency by applying predefined grading criteria and weightings to different course activities. Instructors can easily track the status of student submissions, including identifying late or missing assignments, and provide timely feedback directly.

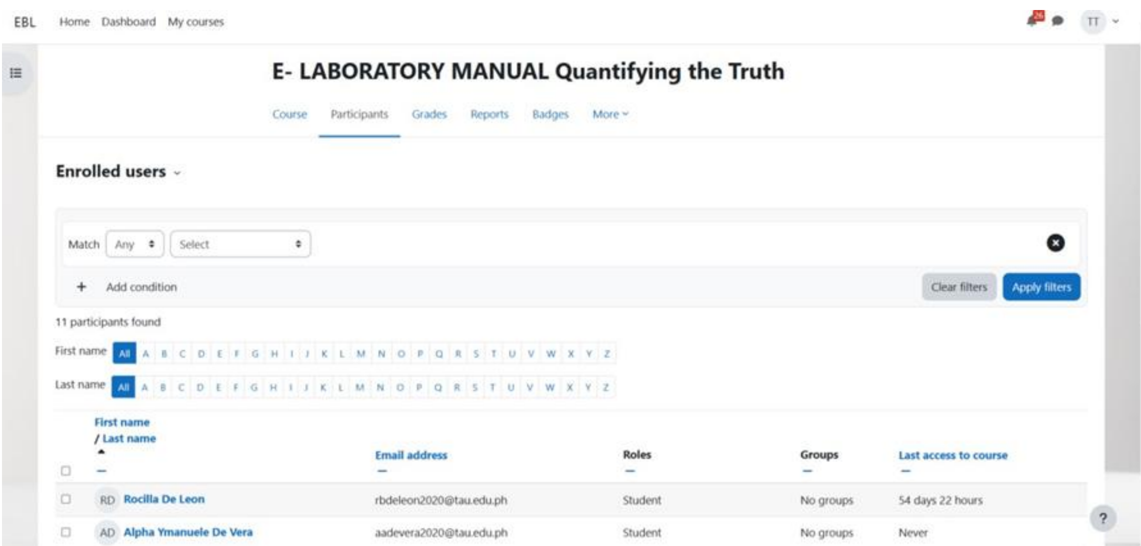

Figure 5. **Digital learning management of the e-Lab Manual**

The bibliography section provided students with references for further reading and research, guided them toward additional resources on the subject matter. It listed all the references and sources consulted in the creation of the manual, ensuring that students have access to further information. It also encouraged students to pursue deeper study of the concepts and to consult primary and secondary sources for more comprehensive knowledge. The bibliography section reflected academic rigor by adhering to proper citation standards, which is an important aspect of scholarly work.

Implementation

After undergoing expert evaluation, the e-Lab Manual was implemented among Grade 11 students over a four-week period, from May 3, 2025 to May 31, 2025. The implementation covered two class sections with a total of seventy (70) student participants. This phase of the study aimed to assess the usability, effectiveness, and pedagogical impact of the digital manual in actual classroom practice.

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Evaluation

The learning modules were evaluated through their utilization with Grade 11 students' pretest and post-test scores. The students took their Pretest last May 5, 2025, and their Posttest last May 30, 2025.

2. **Validation of the Electronic Laboratory Manual (ELM)**

The e-Lab Manual was validated by eleven experts. They were given a rubric adopted by the Department of Education.

2.1. ***By the Experts***

Eleven experts who validated the learning modules were five ICT experts, two Physics instructors in a university, and four Department of Education Teachers who earned their master's or doctorate in science education and are teaching in public high schools within Tarlac.

2.2.1 ***Content***

The content of the e-Laboratory (e-Lab) Manual refered to the lessons or competencies students need to acquire in General Physics 1. Chapter 1 focused on measurement, conversion of units and calculating the percent errors; Chapter 2 involved on calculating the speed, velocity and acceleration and identifying their relationship to each other; Chapter 3 concentrated on solving projectile motion through the given set of experiments and simulations; Chapter 4 centered in solving circular motion and drawing conclusions about the relationship of the different quantities involved ; and Chapter 5 focused on real life applications of Newton’s Laws of Motion.

Parameters	**Mean**	**Verbal Description**
1. Content is consistent with topics/skills found in the DepED Learning Competencies for the subject and grade/year level it was intended.	4.00	Very Satisfactory
2. Concepts developed contribute to enrichment, reinforcement, or mastery of the identified learning objectives.	4.00	Very Satisfactory
3. Content is accurate.	4.00	Very Satisfactory
4. Content is up-to-date.	4.00	Very Satisfactory
5. Content is logically developed and organized.	3.33	Very Satisfactory
6. Content is free from cultural, gender, racial, or ethnic bias.	3.50	Very Satisfactory
7. Content stimulates and promotes critical thinking.	3.83	Very Satisfactory
8. Content is relevant to real-life situations.	4.00	Very Satisfactory
9. Language (including vocabulary) is appropriate to the target user level.	4.00	Very

		Satisfactory
10. Content promotes positive values that support formative growth.	4.00	Very Satisfactory

Legend:
3.25-4.0 =Very Satisfactory (VS)   *30- 40 points = Passed*
2.50-3.24 =Satisfactory (S)   *0-29 = Failed*
1.75-2.49 =Poor
0-1.74 =Not Satisfactory

The experts evaluated the content to be very satisfactory as attested by means falling within the range of 3.25-4.0. The experts claimed that the content is consistent with topics/skills found in the Department of Education Learning Competencies for the subject and grade/year level it was intended (4.00) and the concepts developed contribute to enrichment, reinforcement, or mastery of the identified learning objectives (4.00).

The high satisfaction ratings from experts imply that the content is well-regarded and meets quality standards. The perfect score of 4.00 for both content's up-to-datedness and accuracy indicates that the information is not only highly accurate but also reflects the most current knowledge and development within the field. It also reflects a thorough alignment with the latest research, standards and trends which ensures the relevance for the intended audience.

Furthermore, it implies that the e-Lab manual adheres to the highest level of quality and demonstrates both precision in detail and timeliness in sourcing. Likewise, the content is logically developed and organized (3.33) and free from cultural, gender, racial, or ethnic bias (3.5). Among the parameters under this criterion, this resulted in one with the lowest mean score, and one of the validators suggested review the language and terminology. Ensure that the language used is neutral and inclusive and evaluate visual representations by reflecting diversity and avoiding stereotypes. In addition, one validator also suggested to improve the structure by organizing the flow of ideas in a sequential and cohesive manner to guide the user logically. These comments were integrated into the final draft of the e-Laboratory (e-Lab) Manual. The content also stimulates and promotes critical thinking (3.83).

It highlights the manual's effectiveness in encouraging students to analyze, evaluate and apply concepts beyond basic comprehension. The content's design fosters deeper engagement with the material, challenging the learners to think critically about the experiments and their real-world implications. It is also relevant to real-life situations, promotes positive values that support formative growth and the language used (including vocabulary) is appropriate to the target user level (4.00).

The mean computations indicate that the content of the e-Laboratory (e-Lab) Manual was very satisfactory based on the assessment from the experts. This strong rating demonstrates the manual's ability to meet educational standards while providing valuable support for laboratory work. Based on the standard points set by the Department of Education, a total of 38.6 suggest that the content of the manual passed.

In particular, the criterion "Content is free from cultural, gender, racial, or ethnic bias" obtained a mean score of 3.33, while "Content stimulates and promotes critical thinking" received a mean score of 3.50. Although both were still interpreted as *Very Satisfactory*, their relatively lower ratings imply that revisions may be needed to strengthen these aspects. The lower score on cultural and gender sensitivity may suggest that some of the examples, activities, or illustrations in the manual could be further reviewed to ensure inclusivity and avoid implicit bias. This highlights the need to integrate more diverse and representative contexts in the learning materials so that all learners feel equally represented.

Meanwhile, the relatively lower rating on stimulating critical thinking suggests that while the manual provided structured and clear instructions, it may have leaned more toward procedural guidance rather than encouraging inquiry, problem-solving, or analytical reflection. This implies the need to embed more open-ended questions, exploratory tasks, or higher-order problem-solving activities within the modules to push students beyond recall and application toward analysis, evaluation, and creation.

Overall, while the e-Laboratory Manual was evaluated as *Very Satisfactory*, these findings highlight that strengthening inclusivity and enhancing opportunities for critical thinking should be prioritized in future revisions to maximize its pedagogical effectiveness.

2.2.2 *Instructional Quality*

The instructional quality of the e-Laboratory (e-Lab) Manual refers to how effectively the manual facilitates student learning and enhances the overall laboratory experience. It focuses on how well the manual communicates the necessary content, guides the students through experiments and supports them in achieving the learning objectives of the course. A high-quality laboratory manual provides clear and concise instructions for conducting experiments.

The language used should be accessible to students at the appropriate academic level. A good laboratory manual may also include thought-provoking questions or reflections that encourage students to think critically about their results and the underlying concepts.

Parameters	**Mean**	**Verbal Description**
1. Purpose of the material is well defined.	3.67	Very Satisfactory
2. Material achieves its defined purpose.	4.00	Very Satisfactory
3. Learning objectives are clearly stated and measurable.	3.50	Very Satisfactory
4. Level of difficulty is appropriate for the intended target user.	3.67	Very Satisfactory
5. Graphics / colors / sounds are used for appropriate instructional reasons.	3.50	Very Satisfactory
6. Material is enjoyable, stimulating, challenging, and engaging.	3.83	Very Satisfactory
7. Material effectively stimulates creativity of target user.	3.83	Very Satisfactory
8. Feedback on target user's responses is effectively employed.	4.00	Very Satisfactory
9. Target user can control the rate and sequence of presentation and	4.00	Very Satisfactory

review.		
10. Instruction is integrated with target user's previous experience.	4.00	Very Satisfactory
Grand Mean	3.80	
Interpretation	Very Satisfactory	

Legend:
3.25-4.0 =Very Satisfactory (VS) *30- 40 points = Passed*
2.50-3.24 =Satisfactory (S) *0-29= Failed*
1.75-2.49 =Poor
0-1.74 =Not Satisfactory

The data reflected in Table shows that the experts were very satisfied the instructional quality of the e-Lab manual**.** The purpose wall well defined (3.67) and the defined purpose was achieved (4.00). The learning objectives are clearly stated and measurable (3.5). the level of difficulty of the manual is well suited for the target users (3.67). It suggests that the content is neither too simple nor too challenging but effectively matching the students' abilities and ensuring an appropriate balance for their learning progression.

The use of graphics, colors and sounds in the laboratory manual serves appropriate instructional purposes. It denotes that these elements are effectively integrated into it to enhance learning, providing visual and auditory support to help the students better understand the concepts and procedures.

It is highly enjoyable, stimulating, challenging and engaging as reflected by the expert's rating (3.83). It implies that the content effectively captures the students' interest, encourages active participation and promotes a deeper level of engagement. The laboratory manual effectively stimulates the creativity of the target users (3.83). It recommends that the content encourages the students to think critically, explore new ideas and apply their knowledge innovative ways which can foster a creative learning environment.

The feedback on the target users' responses is highly employes (4.00). This indicates that the feedback mechanism is extremely efficient, timely and clear that helps the students in improving their understanding and academic performance.

The target users can fully control the rate and sequence of the presentation (4.00). This shows that the laboratory manual is evidently flexible, allowing the students to progress at their own pace, revisit the content as needed and promotes a personalized and self-directed learning. The instruction is seamlessly integrated with the target users' previous experience (4.00). This species that the laboratory manual immensely builds on prior knowledge which helps the students to connect new concepts to what they already learned and enhancing their understanding. The total points earned for the instructional quality is 38 which states that the instructional quality of the e-Lab manual passed and gain a very satisfactory rating.

The criterion "Learning objectives are clearly stated and measurable" received a mean score of 3.50, while "Level of difficulty is appropriate for the intended target user" also obtained 3.50. Although these are still within the *Very Satisfactory* range, their relatively lower ratings imply a need for refinement. The lower score on clarity and measurability of learning objectives suggests that while objectives were provided, some may not have been written in a sufficiently specific or measurable manner. This highlights the importance of framing objectives in terms of observable outcomes, aligned with Bloom's Taxonomy, to make assessment of student achievement more precise.

Similarly, the rating for the level of difficulty implies that certain tasks or activities within the manual may not have been consistently matched with the learners' readiness. This could mean that some instructions were either too procedural and simple, limiting challenge, or too advanced, posing difficulties for students. Adjustments in scaffolding such as the inclusion of differentiated tasks, guiding questions, or tiered activities may help balance accessibility with intellectual challenge.

By addressing these concerns, future revisions of the e-Lab manual can enhance the clarity of learning expectations and ensure that the activities strike the right balance between being engaging and appropriately challenging. This will further improve its effectiveness in fostering deeper understanding and skill development among learners.

Parameters	**Mean**	**Verbal Description**
1. Audio enhances understanding of the concept.	4.00	Very Satisfactory
2. Speech and narration (correct pacing, intonation, and pronunciation) are clear and easily understood.	4.00	Very Satisfactory
3. There is complete synchronization of audio with the visuals, if any.	4.00	Very Satisfactory
4. Music and sound effects are appropriate and effective for instructional purposes.	3.80	Very Satisfactory
5. Screen displays (text) are uncluttered, easy to read, and aesthetically pleasing.	3.80	Very Satisfactory
6. Visual presentations (non-text) are clear and easy to interpret.	3.60	Very Satisfactory
7. Visuals sustain interest and do not distract the user's attention.	3.60	Very Satisfactory
8. Visuals provide accurate representation of the concept discussed.	3.80	Very Satisfactory
9. The user support materials (if any) are effective.	4.00	Very Satisfactory
10. The design allows the target user to navigate freely through the material.	3.80	Very Satisfactory
11. The material can easily and independently be used.	3.80	Very Satisfactory
12. The material will run using minimum system requirements.	4.00	Very Satisfactory
13. The program is free from technical problems.	3.80	Very Satisfactory

Grand Mean	3.85
Interpretation	Very Satisfactory

Legend:

3.25-4.0 =Very Satisfactory (VS) *39- 52 points = Passed*
2.50-3.24 =Satisfactory (S) *0-38= Failed*
1.75-2.49 =Poor
0-1.74 =Not Satisfactory

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The technical quality of the e-Lab manual refers to how well the manual utilizes technology to enhance the learning experience and support the completion of laboratory tasks. It encompasses various aspects related to the functionality, usability and technical features of the manual. The experts agreed generally that the laboratory manual displayed an exceptional rating on its technical quality.

The use of audio significantly enhances the understanding of the concepts (4.00). This shows that the audio elements highly complement the visual content, provides clear explanation and reinforces key ideas in improving students' comprehension and engagement with the manual. The speech and narration (correct pacing, intonation, pronunciation) are clearly understood (4.00). There is a complete synchronization of audio with the visuals (4.00). It demonstrates that the audio and visual elements are efficiently integrated and the timing and flow of information are aligned which contributes to the better comprehension of the content. The music and sound effects are perfectly appropriate and effective for instructional purpose (4.00). This suggests that the audio elements are thoughtfully selected and provides an engaging atmosphere without distracting from the instructional content.

The screen displays are uncluttered, easy to read and aesthetically pleasing (3.8). It demonstrates that the text layout is well organized, visually appealing, and enhances readability with only minor areas that could be further improved for optimal use experience. The visual presentations (non-text) are clear and easy to interpret (3.8). This exhibits that the visuals are well designed and successfully conveys information.

The visuals sustain interest and do not distract user's attention (3.6). It signifies that the visual are engaging and maintains focus on instructional content. The experts suggest that this aspect needs further improvement to secure effectiveness in enhancing students' attention. The visuals provide an accurate representation of the concepts discussed (3.6). This proposes that the visuals are mostly effective in illustrating the key concepts with minimal areas for improvement in ensuring full clarity and accuracy in the representation. The user support materials are effective (3.8) and gives valuable assistance in helping users to understand the content and navigate the manual. The designs allow the target user to navigate freely through the manual (4.00). This implies that the layout and structure of the manual are successfully intuitive and use friendly which enables excellent exploration and access to content without any obstacles.

The manual can easily and independently be used (3.80) and mostly self- exploratory. It allows the users with it independently though it needs minimal improvement in making it even more accessible. The manual will run using minimum system requirements (3.8) and is generally well-optimized to operate on lower end system which ensures accessibility for wider range of users. It reflects the manual's ability to run smoothly with minimal technical specifications with varying hardware capabilities. It can be operated through online or offline access.

The program is free from technical problem (3.8). This shows that the manual functions flawlessly without any glitches, bugs or performance issues. It provides users a smooth and uninterrupted experience. The system's reliability ensures that the students can fully engage with the content without encountering any technical difficulties.

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The total scored garnered was 50, showing that the e-Lab manual passed the Department of Education standards. Overall, the evaluation demonstrates its compliance with the required quality benchmark and its effectiveness in supporting educational goals. It highlights its ability to provide accurate, accessible and relevant content that aligns with the guidelines and ensuing its suitability for use in educational setting.

The parameters “Visual presentations (non-text) are clear and easy to interpret” and “Visuals sustain interest and do not distract user’s attention” both received mean scores of 3.60, while “Music and sound effects are appropriate and effective for instructional purposes”, “Visuals provide accurate representation of the concept discussed”, “Screen displays (text) are uncluttered, easy to read, and aesthetically pleasing”, “Target user can navigate freely through the material”, and “The material can easily and independently be used” obtained mean scores of 3.80. Although still interpreted as *Very Satisfactory*, these relatively lower ratings imply that some refinements are needed to maximize multimedia effectiveness.

Specifically, the lower ratings for visual clarity and focus suggest that certain images or graphics may not have been sufficiently precise or well-designed to fully aid comprehension, and in some cases, may have risked diverting attention rather than reinforcing key concepts. This highlights the need to further refine graphic design choices by ensuring consistency in style, using high-quality images, and applying visual hierarchy principles to emphasize essential information. Likewise, the feedback on music and sound effects implies that while audio elements enhanced the presentation, their instructional value could be improved by limiting decorative sounds and focusing instead on audio cues that directly reinforce learning.

Furthermore, the slightly lower ratings on navigation and independent use suggest that although the material was generally accessible, there may have been instances where users required guidance or experienced difficulty in navigating through the manual. This implies the need for more intuitive user-interface features, such as clearer navigation buttons, menus, or built-in user guides to enhance learner autonomy. Overall, while the technical and multimedia features of the e-Lab Manual were evaluated as *Very Satisfactory*, the results point to the importance of improving the clarity and instructional quality of visuals, optimizing sound effects, and enhancing navigational ease to provide learners with a more seamless and engaging digital laboratory experience

2.2 **Effectiveness of the Electronic Laboratory (e-Lab) Manual**

To determine if the e-Lab manual were effective for the learners, pretest and posttest were administered. The given data below covers the pretest scores of the students have a mean of 31.50 out of total of 50 items. The majority of the students scored between 25 to 35 on the pretest which suggests that most had a relatively low understanding or performance level. Only 7 students scored below 25 which indicates a minority performed poorly. This result highlights the need for new instructional material with a focus on scaffolding, reinforcing, and individualized approach as an intervention to improve performance based on the pretest findings.

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Pretest and Posttest Score in General Physics 1

Score Range	% Range	Pretest	Posttest
46-50	92-100%	0	3
40-45	80-90%	0	36
36-39	72-78%	15	24
30-35	60-70%	28	7
25-29	50-58%	20	0
Below 25	Below 50%	7	0
Mean Score		31.50	38.6
Total		70	70

After the use of the Electronic Laboratory Manual (ELM)**,** the students were given posttests. The mean score increased from 31.5 to 38.6 in the posttest which indicates improvement in the students' performance. There was a significant shift in performance with the majority of the students improving their scores. A large number of 36 students moved into the 40-45 score range (80-90%). There are 3 students managed to achieve the highest score range of 46-50 (92-100%) and no students scored below 25 (below 50%). The mean score of 38.6 is well above the 50% threshold (25 out of 50) which means students performed better in posttest. The manual has a positive effect since the mean score is higher than the passing mark of 50%.

In summary, the posttest results reflect general success in raising the knowledge and application particularly for low-performing students. However, the moderate improvement in the mean score implies that there are still areas to refine such as offering advanced materials for high-performing students and additional support to those in the mid- performance ranges.

t-test **Result for Pretest and Posttest**

Test	Mean Score	T-test	P-value	Decision
Pretest	31.50			
Posttest	38.6	14.1	< .001	Reject Ho
Interpretation			*Significant*	

The result of the pretest and posttest of the control group show a significant change in mean scores. The pretest had a mean score of 31.50 and the posttest showed an improvement with a mean score of 38.6. The T-test value is 14.1 and the *p value* is less than 0.001 which is statistically significant. This means that there was a measurable difference in the scores between the pretest and posttest.

Since the *p-value* is less than the typical significance level of 0.05, the null hypothesis was rejected that states that there was no effect. This implies that that the traditional teaching approach was still effective in driving some improvement in the students' knowledge or skills. However, it may be not as effective as Electronic Laboratory (e-Lab) Manual that might yield more substantial results.

***t-test* Result for Experimental Group's Pretest and Posttest**

Test	Mean Score	T-test	P-value	Decision
Pretest	29.9			
Posttest	41.2	19.5	< .001	Reject Ho
Interpretation		*Significant*		

The experimental group demonstrates a huge improvement in in students' performance compared to the control group. The pretest mean score was 29.9 while the posttest mean score increased to 41.2. This improvement is reflected in the *t-test* value of 19.5 and a *p-value* of less than 0.001 which is highly significant.

Rejecting the null hypothesis indicates that the observed difference in scores is statistically significant and suggests that the manual provided to the experimental group had a measurable and positive impact on their learning outcomes. The large increase in the mean scores coupled with the significant *p-value* strongly supports the effectiveness of the manual in improving knowledge and skills among the students. This finding emphasizes that the manual was successful and signifies the potential value of using the manual in educational setting for better learning outcomes.

Gain Score of the Control and Experimental Group

	Group	Mean	T-test	P-value	Decision
Gain Score	Control	7.11			
	Experimental	11.3	5.49	< .001	Reject Ho
Interpretation			*Significant*		

The data presented shows the mean gain scores for the control group was 7.11 while experimental group was 11.3. A *t-test* was conducted yielding a *t-value* of 5.49 and a p- value of less than 0.001. Since the p-value is significantly smaller than the commonly used alpha level of 0.05, the null hypothesis (Ho) is rejected. This result indicates that there is statistically significant difference between the gain scores of the control group and experimental group which means the manual had a significant effect.

The manual provides a great improvement in experimental group's performance compared to the control group which receives the traditional teaching instruction. The findings support the potential use of the manual in the future applications particularly in scenarios where similar outcome are desired. Despite the overall success, it suggests to be subjected to further refinement and incorporating it to broader educational framework.

3. Implication of the Findings

The significant improvements in test scores of the students in the posttest validates the effectiveness of the e-Lab manual**.** This suggests that it was valuable tool for enhancing student learning and comprehension. The findings suggest that the integration of the manual into teaching practices can enhance student learning more effectively than the conventional way of teaching. Educational institutions may consider the laboratory manual as a new material that can lead to greater improvements in learning outcomes particularly in areas where the traditional method may have limitations. Given the significant improvement observed in the experimental group, refining the manual to address any gaps or areas where students struggled could make it even more effective. Feedback from the experts can provide valuable insights into the how the manual was received and how could it be improved.

The process of developing a laboratory manual encourages educators to stay updated on the latest pedagogical strategies and educational technologies. This helps educators to continuously improve their instructional method and remain aligned with current best practices in their field. Additionally, working with laboratory manual can inspire the educators to explore new ways of integrating of technology and innovation in their teaching. The manual can also help educational policy makers and administrators in formulating educational strategies, curriculum development and assessment framework. They can use the insights in from the manual in ensuring the alignment of instructional materials with curriculum standards. It can promote standardization of educational practices across schools and institutions. The laboratory manual is a pivotal resource that can help in shaping education policy by providing a practical example of how effective educational materials can influence teaching, learning, and student outcomes.

Further research could explore how the laboratory manual performs in different educational settings such as academic disciplines, grade levels or diverse student population. It could be an avenue for exploring how digital tools or online platforms could enhance the laboratory manual The effectiveness of the laboratory manual is highly linked to high scores of the students through structured, engaging and hands-on approach to learning. Analyzing the elements of the manual that most significantly boosted the engagement can guide the development of future educational materials. If the laboratory manual will be continuously used over time, several positive outcomes are likely to emerge for both students and educators. It could contribute to long term effects like enhancing the performance and engagement of the students and providing the teachers with a consistent and effective tool.

In summary, these findings emphasize the value of incorporating the laboratory manual into educational practices, reinforce the importance of constant support and identify the key areas for future research and utilization of resources.

SUMMARY

1. The laboratory manual covers the selected topics from the Midterm of General Physics 1 such as measurement, speed, velocity, acceleration, projectile motion, circular motion and Newton's laws of Motion. It was carefully designed and followed the objectives from curriculum guide of the Department of Education.

2. Validation of the Electronic Laboratory Manual

   2.1 The experts evaluated the content quality to be very satisfactory as attested by mean falling within the range of 3.25 to 4.0 and gained a grand mean score of 3.36. The instructional quality of the manual was assessed as very satisfactory and obtained a grand mean score of 3.80. The technical quality was rated as very satisfactory also and acquired a grand mean score of 3.85. The laboratory manual passed the Department of Education standards as stated Learning Resources Management and Development System (LRMDS) evaluation tool.

   2.2 A mean score of 31.50 in a pretest indicates that the competence of the students in General Physics 1 was moderate. The posttest was 38.60 which means the students performed above average. The t-test computation is 14.1, higher than the critical value at 0.05 level of significance. This leads to the rejection of the null hypothesis. This means that the difference between the pretest and posttest is significant. This is attested by the p-value which is <0.05 at 0.5 level of significance.

3. Schools and administrations might consider the integration of the electronic laboratory into their curriculum. The success of the manual shows that it can be an effective tool for meaningful teaching and learning process.

CONCLUSIONS

1. The electronic laboratory manual in General Physics 1 effectively supports key concepts like measurement, speed, velocity, acceleration, projectile motion. circular motion and Newton's laws of motion. It was carefully crafted to align with the Department of Education's curriculum guide, ensuring its relevance and educational value.
2. The very satisfactory evaluation of the experts and high scores in posttest of the students attest to the manual's effectiveness as a reliable teaching resource.
3. Schools and administrations might sustain the development of the electronic laboratory into their curriculum. The success of the manual shows that it can be an effective tool for meaningful teaching and learning process.

RECOMMENDATIONS

1. The laboratory manual should be continuously updated to reflect new developments in the field of General Physics. Keeping the content up-to-date and relevant ensures the students are exposed to current scientific advancement and teaching methodologies. As the manual integrates electronic tools, it's important to provide professional development workshops for teachers. These workshops should focus on the effective use of electronic manual with an emphasis on integrating technology into the classroom. Structured feedback system should be implemented from both students and instructors to identify areas for improvement. This feedback should focus on content clarity, difficulty level and the overall usability of the manual.

2. Given the very satisfactory evaluation form the experts and high scores achieved by the students in the posttest, it is recommended to:

   2.1 *Implement the Electronic Laboratory Manual to Broader Student Populations*. Expand the integration of the manual involving students from different schools, educational background and regions. This would provide insights into its adaptability and areas where further improvement may be needed.

   2.2 *Continuous Improvement.* The laboratory manual should undergo regular updates, incorporate diverse learning styles and feedback mechanism from the students and teachers.

   2.3 *Integration of Teacher Training and Support.* Provide teacher training workshops, create comprehensive teacher guides, offer ongoing professional development, foster data-driven insights for teachers and opportunities for teacher input in future updates.

   2.4 *Monitor and Evaluate.* Develop a clear set of objectives and indicators to evaluate the effectiveness of the laboratory manual. Implement regular review cycles to assess how the manual meets the educational standards. Incorporate student performance tracking, teacher feedback, user experience and usability testing and stakeholder involvement.

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