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VIRTUAL LABORATORIES IN SCIENCE: THEIR EFFECT ON LEARNERS' ACADEMIC PERFORMANCE AND ENGAGEMENT

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ABSTRACT

This study investigated the effect of virtual laboratories on the academic performance and engagement of Senior High School students in General Physics 2. Utilizing a quasi-experimental research design with a pretest–posttest approach, the study involved Grade 12 STEM students from Colegio de San Rafael Arcangel, Inc. for the School Year 2025–2026. The respondents were divided into two groups: an experimental group exposed to virtual laboratory-based learning activity sheets and a control group that received traditional instruction. Data were collected using a validated 50-item teacher-made test to measure academic performance and a survey questionnaire to assess student engagement in terms of behavioral, emotional, and cognitive dimensions. Additionally, the developed instructional material was evaluated using the DepEd LRMDS guidelines. Findings revealed that both groups improved in their posttest scores; however, the experimental group demonstrated significantly higher gains compared to the control group. The paired-samples t-test confirmed a statistically significant difference between pretest and posttest scores in both groups, with a greater effect observed in the experimental group. Moreover, students exposed to virtual laboratories exhibited very high levels of engagement across behavioral, emotional, and cognitive domains. The developed virtual laboratory-based learning activity sheets were rated "very satisfactory," indicating their quality, relevance, and effectiveness as instructional materials. The study concludes that virtual laboratories significantly enhance students' academic performance and engagement in science. It highlights the potential of integrating technology-based instructional tools in improving science education, particularly in resource-limited settings. The findings support the adoption of virtual

laboratories as an effective supplement to traditional teaching methods in secondary science education.

Keywords: *Virtual laboratory, physics, students' engagement, learning activity sheet*

INTRODUCTION

Science education plays a vital role in shaping students' intellectual, social, and practical competencies. It is not merely a subject to be learned but a discipline that fosters inquiry, critical thinking, and problem-solving skills essential in addressing real-world issues. According to Bybee (2013), science education equips learners with scientific literacy, enabling them to understand natural phenomena, make informed decisions, and actively participate in a knowledge-driven society. This highlights its importance not only in academic achievement but also in preparing students for future careers in science, technology, engineering, and mathematics (STEM). Laboratory provide a great avenue to facilitate hands – on learning specially in science education it promotes critical thinking skills and inquiry approach on students cognitive and participation inside the classroom. Students are more engage and participative while collaborating to one another.

According to, Fernández et al. (2022), students develop stronger scientific skills when they are actively engaged in laboratory and inquiry-based activities. The researchers highlighted that practical experiences in science education contribute to better understanding, analytical thinking, and problem-solving abilities among secondary students. Similarly, Urdanivia Alarcon et al. (2023), inquiry-based science teaching promotes scientific reasoning, critical thinking, and the construction of scientific knowledge by connecting learning experiences with real-world situations. The acquisition of scientific concepts becomes more meaningful and effective when students are engaged in practical or hands-on applications. Laboratory activities serve as vital learning environments that enable learners to concretize abstract ideas, thereby addressing misconceptions and reducing difficulties in understanding complex topics in science. Studies indicate that practical laboratory experiences greatly improve student involvement while fostering a comprehensive understanding and application of the material. For example, inquiry-based learning has been shown to enhance students' critical thinking and problem-solving skills by engaging them in active exploration rather than rote memorization.

Science laboratories have been widely considered the foundation of successful science education, offering students chances to link theoretical ideas with hands-on experiences. Nonetheless, traditional laboratory environments still encounter considerable difficulties that impact schools, educators, and students. With SDG 4: Quality Education, which emphasizes the promotion of inclusive, equitable, and quality education for all. Science laboratories have long been recognized as essential components of effective science education because they allow students to connect theoretical concepts with practical experiences. However, traditional laboratory settings continue to face several challenges, such as limited resources, lack of equipment, safety concerns, time constraints, and restricted accessibility, which affect both teachers and

learners. These limitations frequently result in congested labs where students must share scarce equipment, heighten safety hazards and diminish the quality of practical learning. From the viewpoint of learners, these circumstances restrict active involvement in experiments, which diminishes engagement, obstructs the cultivation of critical inquiry abilities, and complicates the understanding of abstract ideas. But incorporating technology-driven instructional methods align with SDG 9: Industry, Innovation and Infrastructure, it supports the advancement of innovative educational practices and contributes to the modernization of science education through digital infrastructure and technological integration.

In the Philippine context, the importance of science education is strongly supported by national laws and educational policies. Republic Act No. 10533, also known as the Enhanced Basic Education Act of 2013, mandates the implementation of the K to 12 Basic Education Program, which aims to develop learners who are holistically prepared for higher education, employment, and entrepreneurship. The legislation highlights teaching methods that are centered around learners, based on inquiry, and contextualized, especially in subjects like Science, Mathematics, and Technology. It also promotes the integration of information and communication technology (ICT) in education to enhance learning, making it more engaging, interactive, and suited to the demands of 21st-century students. Aligned with this law, the Department of Education (DepEd) K to 12 Science Curriculum highlights the importance of scientific inquiry, experimentation, and hands-on learning. The curriculum guide stresses that students should not only learn scientific facts but should also experience science through investigation, experimentation, and problem-solving activities. It explicitly promotes the use of innovative and technology-based strategies to support learning, especially in schools where resources for physical laboratories are limited.

Several studies have highlighted the potential of virtual laboratories in enhancing the teaching and learning of Science. Tongco et al. (2021) developed the e-SCILAB virtual simulation on waves for Grade 7 science and reported significant improvements in students' conceptual understanding, retention, and engagement, demonstrating how virtual environments can effectively supplement limited physical laboratory access. Similarly, Monta and Perdio (2025), laboratory-based science instruction remains essential in developing students' scientific understanding and practical skills. However, science teachers in public schools encountered challenges such as inadequate laboratory facilities, insufficient instructional materials, and limited access to scientific equipment. These studies confirm that virtual laboratories not only mitigate resource constraints in Science classrooms but also enhance learner engagement, concept understanding, and skill acquisition. Secondary education is a crucial stage in developing students' scientific skills such as observation, experimentation, and analysis, which serve as the foundation for higher-order thinking.

Although the significance of laboratory work is acknowledged, numerous schools still face significant difficulties in conducting consistent and effective laboratory activities. Through real classroom observations in nearby secondary schools, science teachers frequently encounter challenges like restricted laboratory space, non-functional

equipment, inadequate experimental materials, and oversized class sizes. In certain classes, students must solely watch demonstrations rather than conduct experiments themselves due to insufficient materials for everyone. This scenario restricts students' engagement and diminishes chances for inquiry-driven education. To address these gaps, this research aims to thoroughly explore the effect of virtual laboratories on student engagement and academic performance in Science. It specifically seeks to establish how virtual lab experiences affect learners' comprehension of scientific concepts, their problem-solving skills, and their ability to apply knowledge, which make up the cognitive aspect of learning. Concurrently, the study investigated the emotional aspect by analyzing how virtual laboratories enhance students' motivation, curiosity, and ongoing interest in science.

This research also provided empirical evidence regarding the effectiveness of virtual laboratories as a novel educational tool for improving science education by tackling both aspects. Additionally, the research emphasizes its significance within Philippine secondary schools, where limited resources and the necessity for adaptable, technology-based teaching highlight the requirement for alternatives to traditional laboratory arrangements.

Research Questions

This study assessed the effect of virtual laboratories in Science specifically in General Physics 2 on the academic performance and engagement of Senior High School students for the School Year 2025 – 2026. Specifically, it sought to answer the following questions:

1. What are the result of the pretest and posttest of the control and experimental group?
2. What is the level of learners' engagement with virtual laboratories in terms of:
    2.1 Behavioral,
    2.2 Emotional, and
    2.3 Cognitive aspects?
3. Is there a significant difference between the pretest and posttest results of the control and experimental groups?
4. What are the perceived benefits and challenges of using virtual laboratories in teaching General Physics 2?
5. What instructional material can be developed based on the findings of the study?

METHODOLOGY

Research Design

The researcher utilized a quasi-experimental research design employing a pretest–posttest approach to determine the effect of virtual laboratories on the academic performance and engagement of Senior High School students in General Physics 2. The study involved two groups of respondents: the experimental group, which was exposed

to virtual laboratory-based learning activity sheets, and the control group, which received traditional instruction without the use of virtual laboratories.

The quasi-experimental design was considered appropriate because the respondents were grouped according to their existing class sections and random assignment was not possible. Both groups were given a pretest before the implementation of the intervention to determine their baseline knowledge and comparability. After the treatment period, a posttest was administered to measure the changes in academic performance. Student engagement was also assessed through a survey questionnaire focusing on behavioral, emotional, and cognitive dimensions of engagement. This design enabled the researcher to compare the effectiveness of virtual laboratories and traditional instruction in improving students' learning outcomes and engagement in Science, specifically in General Physics 2.

Locale of the Study

The study was conducted in a private secondary educational institution in Pili, Camarines Sur during the School Year 2025–2026. The institution offers Senior High School education with Science, Technology, Engineering, and Mathematics (STEM) strand programs. The school was selected due to limited physical laboratory facilities, however it provides access to digital learning resources and supports the integration of technology-based instructional strategies in science teaching. The research focused on the General Physics 2 subject under the STEM strand, where virtual laboratory activities were integrated as supplementary instructional tools.

Respondents

The respondents of the study were Grade 12 STEM students enrolled in General Physics 2 during the School Year 2025–2026. Two sections participated in the study. One section served as the experimental group and was exposed to virtual laboratory-based instruction, while the other section served as the control group and received traditional instruction. The respondents were selected through purposive sampling since the study specifically required Grade 12 STEM students who were taking General Physics 2. The two intact sections were chosen based on accessibility and comparability of academic background. The respondents were composed of male and female students within the Senior High School level. Their participation was voluntary, and confidentiality of responses and results was strictly observed throughout the conduct of the study.

Data Gathering Instruments

The researcher utilized two main research instruments: a teacher-made test and a survey questionnaire. A validated 50-item teacher-made test was used to measure the academic performance of the respondents in General Physics 2. The test covered selected competencies and topics included in the lessons delivered during the experimentation period. The instrument consisted of multiple-choice questions designed to assess students' comprehension, application, and mastery of scientific concepts. Table

of Specifications (TOS) was prepared to ensure alignment between the test items, learning competencies, and cognitive levels. The instrument underwent validation by experts in Science education to ensure content validity and appropriateness of the items. Revisions were made based on the suggestions and recommendations of the validators. Pilot testing and item analysis were also conducted to determine the reliability and quality of the test items. The finalized instrument was administered as both pretest and posttest to the control and experimental groups.

A survey questionnaire was utilized to assess students' engagement with virtual laboratories. The questionnaire measured three dimensions of engagement: behavioral, emotional, and cognitive engagement. The instrument consisted of statements rated using a Likert scale to determine the extent of students' engagement during the implementation of virtual laboratory activities. The questionnaire also included items that identified the perceived benefits and challenges experienced by students in using virtual laboratories in Science instruction. The survey questionnaire was validated by experts to ensure clarity, relevance, and appropriateness of the statements. Necessary revisions were incorporated prior to administration.

Data Gathering Process

Prior to the conduct of the study, the researcher asked permission from the school administration to administer the research instruments and conduct the experimentation. After approval was granted, the respondents were oriented regarding the objectives and procedures of the study. The researcher administered the pretest to both the control and experimental groups to determine their initial level of academic performance in General Physics 2. After the pretest, the experimental group was exposed to virtual laboratory-based learning activity sheets integrated into the lessons, while the control group received traditional instruction using the usual classroom teaching strategies without virtual laboratory exposure. During the implementation period, the researcher facilitated the lessons and monitored the participation of the students. The virtual laboratories allowed students to perform simulated experiments, manipulate variables, observe outcomes, and engage in guided learning activities.

At the end of the treatment period, a posttest was administered to both groups using the same validated teacher-made test. The survey questionnaire was also distributed to the respondents in the experimental group to assess their level of engagement and perceptions regarding the benefits and challenges of virtual laboratories. All collected data were organized, tabulated, analyzed, and interpreted to answer the research questions of the study.

Development and Evaluation of the Instructional Material

The researcher developed Virtual Laboratory-Based Learning Activity Sheets (VL-LAS) intended for General Physics 2 lessons. These instructional materials integrated virtual laboratory simulations with guided learning activities, exercises, and reflective questions aligned with the competencies in the Science curriculum. The developed

instructional material underwent evaluation using the Department of Education Learning Resource Management and Development System (DepEd LRMDS) evaluation guidelines for print and digital learning resources. The evaluation focused on the following criteria: content quality, format, presentation and organization, and accuracy and up-to-datedness. Validators composed of Science educators and subject specialists assessed the instructional material. Their feedback and recommendations were incorporated to improve the quality, relevance, and effectiveness of the VL-LAS prior to implementation.

Statistical Treatment of Data

The data gathered in this study were analyzed using appropriate statistical tools. Percentage, weighted mean, and descriptive interpretation were utilized to determine the level of students' engagement in terms of behavioral, emotional, and cognitive dimensions, as well as the perceived benefits and challenges of virtual laboratories. The paired-samples t-test was used to determine the significant difference between the pretest and posttest scores within each group. Meanwhile, the independent-samples t-test was employed to determine the significant difference between the academic performance of the control and experimental groups after the treatment. These statistical tools determine the effectiveness of virtual laboratories in improving students' academic performance and engagement in General Physics 2.

Scope and Limitations of the Study

This study focused on determining the effect of virtual laboratories on the academic performance and engagement of Grade 12 STEM students in General Physics 2 during the School Year 2025–2026. The study was limited to two sections of students in a private secondary educational institution in Pili Camarines Sur. The study specifically examined students' academic performance through pretest and posttest scores and measured engagement in terms of behavioral, emotional, and cognitive dimensions. The intervention was limited to the use of virtual laboratory-based learning activity sheets as supplementary instructional materials.

The findings of the study were limited only to the respondents involved and may not be generalized to other grade levels, subject areas, or educational institutions. External factors such as students' internet connectivity, individual learning styles, home learning environment, and technological accessibility were beyond the control of the researcher and may have influenced the results of the study. This limitation is attributed to the specific context in which the study was conducted, including the characteristics of the selected sample, the instructional setting, and the duration of the intervention.

RESULTS AND DISCUSSION

Results of the study are organized according to the research questions and are presented using tables and statistical analysis.

Table 1. Mean and PL of the Pretest and Posttest of the Control and Experimental Group

	Pretest		Posttest	
	Mean	**PL**	**Mean**	**PL**
Control Group	15.67	31.67%	31.67	63.35%
Experimental Group	18.38	37.95%	37.95	75.90%

Table 1 presents the mean score and performance level of both the control and experimental group during the pretest and post-test. The control group has a total mean score of 15.67, corresponding to a 31.67% of performance level, while the experimental group achieved a total mean score of 18.38, with a 37.95% performance level. This shows that the experimental group achieved a slightly higher mean score and performance level than the control group. These indicate that both groups had relatively low prior knowledge and understanding of the lesson before the intervention. After the experimentation of the developed instructional material, the post-test results showed a noticeable improvement. The control group increased its mean score to 31.67, equivalent to a percentage level of 63.35%. Similarly, the experimental group demonstrated a greater increase with a mean score of 37.95 and a percentage level of 75.90%. The higher post-test performance of the experimental group suggests that the intervention used in the study was more effective in enhancing students' understanding and learning outcomes compared to the traditional approach used with the control group.

The findings imply that while both groups received and benefited from the learning process provided by the teacher, the experimental group exhibited greater improvement after being exposed to virtual laboratories and indicating the positive effect of the implementation of the instructional material. The findings are consistent with several studies which reported that virtual laboratories significantly improve students' academic performance. For instance, Bazie et al. (2024) found that students exposed to virtual laboratories performed better than those who relied on lecture-based instruction. Similarly, Fitriah and Zawanis (2024) emphasized that virtual labs enhance conceptual understanding and higher-order thinking skills.

Table 2. Level of Student Engagement; Behavioral

Indicators	Mean	SD	Interpretation
I actively participated in Science activities using virtual laboratories.	4.73	0.45	Strongly Agree
I followed instructions carefully when using virtual laboratories.	4.90	0.30	Strongly Agree

I completed assigned tasks during virtual laboratory sessions.	4.73	0.45	Strongly Agree
I was attentive during lessons that involved virtual laboratories.	4.88	0.46	Strongly Agree
I exerted effort to complete experiments using virtual laboratories.	4.90	0.33	Strongly Agree
OVERALL MEAN:	**4.81**		**Strongly Agree**

Legend:

Mean Range	Interpretation
4.21 – 5.00	Strongly Agree
3.41 – 4.20	Agree
2.61 – 3.40	Neutral
1.81 – 2.60	Disagree
1.00 – 1.81	Strongly Disagree

Results in table 2 revealed that students strongly agree that using virtual laboratories in learning Physics positively influenced their behavioral engagement, with a mean score of 4.81. This high mean score signifies that most of the students continuously demonstrated active participation while using the virtual laboratories during their activities. It also reflects that the students who are exposed in using virtual laboratories are highly attentive, cooperative, and actively involved in completing the task. The results imply that virtual laboratories effectively promote observable learning behaviors such as participation, on-task behavior, and engagement. Students were not passive learners; instead, they became active participants in the learning process.

The data analysis in table 2 supports the findings of Byukusenge et al. (2022) found that virtual lab environments encourage active participation and sustained attention among learners. Similarly, Fitriah and Zawanis (2024) reported that interactive digital tools improve students' task involvement and engagement in science classes. These studies affirm that technology-based learning environments, such as virtual laboratories, foster active student participation. This also mean that virtual laboratory simulation integrated with instructional material provide an alternative intervention to enhance student participation of making physics concepts easier and more understandable. The data also reflects that learning physics concepts with the developed material will be more convenient since it is accessible not only on computers but also on Android devices that most of them have and easy to operate.

Table 3. Level of Student Engagement; Emotional

Indicators	Mean	SD	Interpretation
I enjoyed learning Science through virtual laboratories.	4.83	0.45	Strongly Agree

Virtual laboratories made Science lessons more interesting.	4.90	0.30	Strongly Agree
I felt motivated to learn when using virtual laboratories.	4.88	0.33	Strongly Agree
I felt confident while performing experiments in virtual laboratories.	4.73	0.45	Strongly Agree
I felt less anxious performing experiments using virtual laboratories than traditional labs.	4.55	0.55	Strongly Agree
OVERALL MEAN:	**4.78**		**Strongly Agree**

A noticeable increase was observed in table 3 and shows that students strongly agree that using virtual laboratories in dealing with Physics concepts positively affects their emotional engagement, as reflected by a mean score of 4.78. This high rating indicates that the students felt more interested, motivated, confident, and comfortable during problem-solving activities using virtual laboratories. It also suggests that learners developed positive emotional responses during the learning process, making them more engaged and less anxious when dealing with complex concepts especially in physics subjects. Additionally, the findings indicate that virtual laboratories contributed to a more enjoyable and less stressful classroom experience.

The findings are supported by previous studies which highlight the role of virtual laboratories in enhancing emotional engagement. Mahendra and Killis (2025) found that virtual laboratory use increases students' motivation and enjoyment in science learning, while Bazie et al. (2024) reported that interactive technologies promote positive emotional responses and reduce learning-related anxiety. This further suggests that the use of virtual laboratories can foster positive emotional responses that may encourage students to become more enthusiastic in learning Science, especially in Physics subject.

Table 4. Level of Student Engagement; Cognitive

Indicators	Mean	SD	Interpretation
Virtual laboratories helped me understand Science concepts better.	4.85	0.36	Strongly Agree
I was able to think critically while using virtual laboratories.	4.73	0.45	Strongly Agree
Virtual laboratories encouraged me to analyze experimental results.	4.88	0.33	Strongly Agree
I could easily connect virtual experiments to real-life situations.	4.80	0.41	Strongly Agree

Virtual laboratories helped me apply what I learned in Science.	4.93	0.27	Strongly Agree
OVERALL MEAN:	**4.84**		**Strongly Agree**

Table 4 shows that students strongly agree that using virtual laboratories in learning Physics enhances their cognitive engagement and understanding of the subject matter, with a mean score of 4.84. With its mean score it indicates that student are able to think critically, understand concepts more clearly and deeply, and be able to apply the subject matter during the activities. This implies that virtual laboratories promote deeper learning by encouraging students to engage meaningfully with the content. It further suggests that these tools help develop higher-order thinking skills, such as critical thinking and problem-solving, which are essential in understanding complex Physics concepts. These findings highlight the effectiveness of virtual laboratories in enhancing cognitive engagement. Similarly, study of Fitriah and Zawanis (2024) found that virtual laboratories improve students' critical thinking and conceptual understanding, and affirm that virtual laboratories are effective tools in fostering meaningful learning in science education.

Table 5. Summary of Variables

Indicators	Mean	Interpretation
Behavioral Engagement	**4.81**	**Strongly Agree**
Emotional Engagement	**4.78**	**Strongly Agree**
Cognitive Engagement	**4.84**	**Strongly Agree**

Table 5 reflects that respondents show a very high agreement across the different measured variables. Behavioral, emotional, and cognitive engagement achieved a mean score closer to 5, which means that students were actively engaged, emotionally prepared, and mentally engage in the learning process. These findings supports numerous studies that integration of virtual laboratories in physics activities improve their classroom performance

Table 6. Result of t-test for Two Independent Groups on the Posttest Results of the Control and Experimental Group

	CONTROL GROUP	*EXPERIMENTAL GROUP*
Mean	31.675000	37.95
Variance	52.994231	26.56153846
Observations	40	40
Pooled Variance	39.777885	
Hypothesized Mean Difference	0	
df	78	

t Stat	-4.449466
P(T<=t) one-tail	0.000014
t Critical one-tail	1.664625
P(T<=t) two-tail	0.000028
t Critical two-tail	1.990847

The data in table 6 presents the results of the independent samples t-test conducted to determine whether there was a significant difference in the posttest scores of the control and experimental groups. The findings revealed that the experimental group obtained a higher mean score of 37.95 compared to the control group with a mean score of 31.67. The computed t-value was -4.4494, which exceeded the critical t-value of 1.9908 at the 0.05 level of significance. The difference in mean score between the two groups indicates that the experimental group who were exposed to virtual laboratories during activities performed better than the control group. Additionally, since the absolute value of the computed t-value is greater than the critical value, it shows that the observed difference between the two groups is statistically significant.

This signifies that the null hypothesis is rejected, and there is enough evidence to support that the integration of virtual laboratories had a significant effect on students' performance. The higher mean score of the experimental group suggests that the use of virtual laboratories was effective in improving students' understanding and learning outcomes in Physics. The data analysis in table 6 are supported by previous studies which found significant differences in performance between students exposed to virtual laboratories and those taught using traditional methods. Bazie et al. (2024) reported that students who used virtual laboratory tools achieved significantly higher posttest scores compared to those in conventional learning environments. Similarly, Balacuit (2023) and Mosqueda (2023) found that the integration of virtual laboratories in science instruction resulted in statistically significant improvements in students' academic performance. These studies support the present findings that virtual laboratories are effective instructional tools in enhancing students' achievement in Physics.

Table 7. Result of the Paired t-test of the Pretest and Posttest of the Experimental Group

	PRETEST	***POSTTEST***
Mean	18.375	37.95
Variance	22.80448718	26.56153846
Observations	40	40
Pearson Correlation	0.378967203	
Hypothesized Mean Difference	0	
df	39	
t Stat	-22.33965428	
P(T<=t) one-tail	3.91442E-24	

t Critical one-tail	1.684875122
P(T<=t) two-tail	7.82884E-24
t Critical two-tail	2.02269092

Table 7 revealed the paired sample t-test results for the experimental group with a pretest mean score of 18.37 to posttest mean score of 37.95 among the 40 respondents. The computed t-value of -22.33 with 39 degrees of freedom is far below the 0.05 level of significance. This indicates that there is a statistically significant difference between the pretest and posttest scores of the experimental group. Therefore, the null hypothesis of no significant difference is rejected. The findings suggest that the use of virtual laboratory-based simulation in general physics 2 administered to the experimental group was effective in significantly improving students' performance and engagement, as evidenced by the marked increase in posttest scores compared to their pretest results.

The findings of the study, presenting that there is a significant difference in the posttest scores and performance levels between the control and experimental groups, are highly consistent and align findings from many studies in the field of educational technology, particularly those involving the integration of virtual laboratory in learning science. Study of Bazie et al. (2024) found that students exposed to virtual laboratories demonstrated significantly higher academic achievement compared to those who received traditional lecture-based instruction. The researchers explained that virtual simulations enhanced conceptual understanding by allowing repeated experimentation and immediate feedback.

Table 8. Perceived Benefits of Virtual Laboratories

Indicators	Mean	SD	Interpretation
Virtual laboratories allow experiments that are difficult to do in real labs.	4.73	0.45	Strongly Agree
Virtual laboratories are safe to use for learning Science experiments.	4.90	0.30	Strongly Agree
Virtual laboratories save time during Science lessons.	4.80	0.41	Strongly Agree
Virtual laboratories help visualize abstract Science concepts.	4.88	0.33	Strongly Agree
Virtual laboratories enhance my overall learning experience in Science.	4.80	0.41	Strongly Agree
OVERALL MEAN:	**4.82**		**Strongly Agree**

Table 8 presents the perceived benefits of using virtual laboratories in learning Physics. The data show that students strongly agree with the benefits, as indicated by a mean score of 4.82. The high mean score suggests that using virtual laboratories is

useful, safe, time – efficient, and effective in helping them visualize difficult or abstract scientific concepts. It reflects a positive evaluation of virtual laboratories as a learning tool. This also implies that the students perceived virtual laboratories as meaningful and practical in supporting their learning.

The results also reflect that integrating virtual laboratories in learning and science teaching provide an educational advantage and make complex topic in physics easier to understand. The findings are supported by different studies which highlight the advantages of virtual laboratories in science education. Research of, Byukusenge et al. (2022) reported that virtual laboratories provide a safe and efficient environment for conducting experiments while improving conceptual understanding. Similarly, Fitriah and Zawanis (2024) emphasized that virtual labs help students visualize abstract concepts and enhance learning efficiency. Moreover, Bazie et al. (2024) found that students perceive virtual laboratories as useful and practical tools that improve their overall learning experience. These studies support the present findings that virtual laboratories offer significant benefits in enhancing students' understanding of Physics.

Table 9. Perceived Challenges in using Virtual Laboratories

Indicators	Mean	SD	Interpretation
I experienced technical problems while using virtual laboratories.	2.53	0.72	Disagree
Internet connectivity affected my use of virtual laboratories.	2.63	0.59	Neutral
Virtual laboratories are difficult to use without teacher guidance.	2.65	0.74	Disagree
Virtual laboratories cannot fully replace hands-on laboratory activities.	2.55	0.71	Disagree
Limited access to devices made it difficult to use virtual laboratories.	2.75	0.78	Neutral
OVERALL MEAN:	**2.62**		**Neutral**

Findings in table 9 reveal the perceived challenges encountered in using virtual laboratories in learning Physics. The data reveal that students have a neutral response, with a mean score of 2.62. The result of the mean score indicates that while there is experienced some concerns, such as interconnectivity issues, technical-know-how and the need for teacher guidance, these encountered challenges were not strongly perceived as serious obstacles. This implies that although certain limitations exist in the use of virtual laboratories, these challenges are only moderate and manageable. The findings suggest that such issues do not significantly hinder the effectiveness and usefulness of virtual laboratories in enhancing students' learning in Physics.

Research of, Byukusenge et al. (2022) reported that while technical and accessibility issues may arise, virtual laboratories still provide meaningful learning experiences. Similarly, Bazie et al. (2024) noted that challenges such as connectivity and device limitations exist but do not significantly reduce the effectiveness of virtual learning tools. In addition, Fitriah and Zawanis (2024) highlighted that proper teacher guidance can help mitigate these challenges and ensure successful implementation. These studies support the present findings that despite some limitations, virtual laboratories remain effective instructional tools in science education.

Table 10. Summary Result of the Curricular Validation of the Developed Instructional Material

Factors	Highest Possible Points	Passing points based on the LRMDS guidelines	Total points given by the evaluators	Remarks
1. Content	21	28	27.7	Passed
2. Format	54	72	71.7	Passed
3. Presentation and Organization	15	20	19.7	Passed
4. Accuracy and Up-to-datedness of Information	24	24	23.8	Passed
Total	**144**	**144**	**142.9**	**Passed**

The data in Table 10 indicate that the evaluated work achieved an overall score of 142.9 out of a possible 144 points, resulting in a “passed” rating based on the LRMDS guidelines. Across all four criteria, content, format, presentation and organization, and accuracy and up-to-datedness of information, the scores given by the evaluators were consistently high and closely aligned with the required passing points. Specifically, content obtained 27.7 out of 28, format scored 71.7 out of 72, presentation and organization received 19.7 out of 20, and accuracy and up-to-datedness achieved 23.8 out of 24. Although each factors fell marginally below the exact passing benchmarks by small fractions, all were still considered satisfactory and met the required standards.

Overall, the findings suggest that the virtual laboratory – based learning activity sheet in general physics 2 is of high quality, well-structured, and reliable, with only minimal areas for improvement.

Conclusions

Based on the findings the following conclusions were drawn:

1. Based on the findings of the study, it was concluded that the use of virtual laboratories significantly improved the academic performance of Grade 12 STEM students in General Physics 2. Students who were exposed to virtual laboratory activities obtained higher posttest scores compared to those who underwent

traditional instruction, indicating that virtual laboratories are effective supplementary tools in Science learning.

2. It also concluded that virtual laboratories promoted a very high level of student engagement in terms of behavioral, emotional, and cognitive aspects. The interactive and learner-centered nature of the activities encouraged students to actively participate, become more motivated, and develop deeper understanding of scientific concepts and problem-solving skills.
3. Moreover, it signifies that there was a significant difference between the performance of the control and experimental groups before and after the treatment. The rejection of the null hypothesis indicates that exposure to virtual laboratories contributed significantly to the improvement of students' academic performance and engagement in Science.
4. The findings further revealed that students perceived virtual laboratories as beneficial in enhancing understanding, participation, motivation, and critical thinking skills. Although some challenges such as unstable internet connection, limited devices, and technical difficulties were encountered, these did not outweigh the educational benefits gained from the implementation of virtual laboratories.
5. Based on the findings, the developed virtual laboratory-based learning activity sheet was found to be effective and acceptable based on the DepEd LRMDS evaluation criteria. Therefore, the instructional material may be utilized as a supplementary learning resource to support the teaching and learning of General Physics 2 and other Science subjects.

Recommendations

Relative to the findings and conclusions of the study, the following are the recommendations of the researcher:

1. Schools and educators are encouraged to integrate virtual laboratory-based learning activity sheets into the teaching of General Physics 2, as findings indicate that these materials significantly enhance student engagement and academic performance.
2. Teachers may adopt and further contextualize the developed virtual laboratory simulations to suit diverse learning needs, ensuring that lessons remain interactive, learner-centered, and aligned with curriculum standards. And educational institutions should provide adequate technological resources, such as reliable internet access and appropriate devices, to support the effective implementation of virtual laboratories in classroom instruction.
3. Training and professional development programs should be conducted and encourage teachers to attend to strengthen their skills in designing, implementing, and maximizing virtual laboratory tools in science instruction.
4. Researchers are encouraged to replicate this study in other subject areas or educational levels to further validate the effectiveness of virtual laboratory-based learning materials and explore their broader applicability. Further studies may also examine long-term retention of knowledge and skills gained through virtual

laboratories, as well as compare their effectiveness with hands-on laboratory experiences.

Compliance with Ethical Standards

The researcher strictly adhered to ethical standards throughout the conduct of the study. Informed consent was obtained from all participants prior to their involvement, and they were fully informed about the purpose, procedures, and scope of the research. The respondents were assured of their voluntary participation and their right to withdraw from the study at any time without any form of penalty. Anonymity and confidentiality of all responses were strictly maintained, and no identifying information was disclosed in any part of the study. The provisions of the Data Privacy Act were observed to ensure the secure handling, storage, and processing of all collected data. The well-being of the respondents was prioritized, ensuring that no physical, emotional, or psychological harm was caused during data collection. Furthermore, the researcher declared that no conflict of interest existed in the conduct of the study, and all findings were interpreted objectively without bias. All sources of information were properly acknowledged to avoid plagiarism, and the results were used solely for academic and research purposes. In addition, any use of artificial intelligence tools in the preparation or analysis of this study was fully disclosed to ensure transparency and academic integrity.

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