

Face-To-Face Laboratory Experiments Versus E-Laboratory Experiments on Developing Students' Basic Science Process Skills and Interest Towards Learning Physics

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Abstract This study investigated the effects of face-to-face and e-laboratory experiments on students' basic science process skills and interest toward learning physics. A quasi-experimental pretest–posttest control group design was employed involving 47 Grade 12 STEM students from the Misamis Oriental Institute of Science and Technology, Inc. Two intact sections were randomly assigned as control group, which was exposed to face-to-face laboratory experiments, and an experimental group, which engaged in e-laboratory experiments. Data were gathered using two validated instruments: a 26-item researcher-made science process skills test involving concepts on Kinematics and Newton's Laws of Motion with acceptable internal consistency of KR-20 = 0.77, and an adapted questionnaire to quantify interest in learning physics. Descriptive statistics, including mean and standard deviation, summarized the science process skills and interest scores, while Analysis of Covariance (ANCOVA) tested differences between groups. After the intervention, students in the face- to – face laboratory experiment increased in basic science process skills, while the students in the e- laboratory experiments slightly decreased. ANCOVA confirmed a significant effect of laboratory method on students' basic science process skills. The results suggest that the face-to-face laboratory experiments was more effective in developing basic science process skills compared to e-laboratory experiments. In contrast, students' interest toward learning physics showed minimal changes, and ANCOVA results indicated no significant difference between the students' interest towards physics. These findings suggest that face-to-face laboratory experiments are more effective for developing basic science process skills, while both methods yield similar outcomes in student interest toward learning physics. Hence, it is recommended that schools should establish well-equipped laboratories to provide students with hands-on learning experiences that develop their basic science process skills and interest towards learning physics.

Keywords: basic science process skills, physics interest, face-to-face laboratory, e-laboratory, quasi-experimental design

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1. Introduction

School laboratory experiments play a central role in science education, and science cannot be taught meaningfully without providing students with opportunities for practical experiences in school laboratories [1,2]. Physics laboratory activities are considered an integral component of instruction because they enhance learners' conceptual understanding, demonstrate the relationship between theory and application, and promote reasoning, scientific skills, and the development of practical laboratory competence [3,4]. Furthermore, laboratory environments allow learners to interact directly with

teachers and peers, both physically and psychologically, thereby supporting cognitive and affective dimensions of learning.

Hands-on laboratory experiments have traditionally been implemented in schools. However, virtual laboratories have recently been adopted as a supplementary component of classroom instruction. Virtual laboratories offer several advantages over traditional laboratory settings. First, they eliminate the need to purchase expensive equipment and reduce exposure to potentially hazardous materials; second, processes that are not readily available in physical laboratories can be simulated; third, virtual laboratories can enhance students' interest and motivation to learn scientific concepts and practices [5]. Despite these benefits, virtual laboratories present notable limitations,

including the absence of physical interaction with learning materials and reduced opportunities to develop proficiency in using modern measuring devices [6]. Moreover, virtual laboratories may not fully replicate the tactile and sensory experiences associated with manipulating real equipment, which may constrain the development of hands-on measurement skills and authentic engagement with physical materials [7,8]

Several studies have examined the use of face-to-face and virtual laboratories in different combinations and sequences. Findings suggest that carefully designed integrations of hands-on and virtual laboratory experiences can produce learning outcomes comparable to those achieved through a single modality [9,10,11,12]. Recognizing that each laboratory modality possesses distinct affordances, researchers have increasingly explored their sequencing and combination. However, only a limited number of schools in the Philippines utilize virtual laboratories, and their implementation is predominantly observed at the tertiary level, where institutions encourage the use of virtual laboratory-based instructional materials such as PhET simulations. Furthermore, there remains a dearth of research comparing the influence of face-to-face and virtual laboratory conditions on the development of students' science process skills and interest in physics, particularly within the Philippine secondary school context.

Although the importance of laboratory activities in developing students' science process skills and interest in physics is widely acknowledged, it remains unclear whether e-laboratory experiments are as effective as face-to-face laboratory experiments in achieving these objectives. Science process skills are essential tools that enable students to investigate phenomena, interpret evidence, and construct scientific understanding. These skills reflect learners' ability to apply scientific methods in understanding, developing, and discovering scientific knowledge.

The taxonomy of science process skills, as outlined by [13,14], includes fundamental abilities such as observation, communication, measurement, classification, inference, and prediction. Researchers have emphasized the importance of systematically developing these competencies to enhance students' capacity to engage with the natural world [15]. Science process skills become meaningful when applied within scientific activities involving investigation and interpretation [16]. These competencies support learners' abilities to discover, verify, investigate, and scientifically explain phenomena. Laboratory activities can foster these skills by assisting students in acquiring background knowledge, identifying problems, constructing variables, designing experiments, and drawing accurate conclusions. However, international and national assessments have reported that Filipino students' science process skills remain underdeveloped [17,18,19], which has been associated with lower science achievement [20,21].

Moreover, physics is frequently perceived by students as one of the most difficult subjects in the science curriculum due to its substantial cognitive demands, particularly the requirement to integrate multiple representational forms such as equations, graphs, diagrams, and verbal explanations [22,23]. This perceived difficulty

often contributes to reduced interest and engagement, negatively affecting students' learning experiences. Interest in learning physics is crucial for sustaining motivation, enhancing engagement, and promoting persistence despite conceptual challenges. Students with higher levels of interest are more likely to engage deeply, invest effort in problem-solving, and maintain positive learning attitudes.

Longitudinal research indicates that students' interest in physics significantly influences their educational and career trajectories. Studies have shown that students' attitudes, interest, and perceived utility value of physics strongly predict their intention to continue studying physics and pursue STEM-related fields [24]. Academic interest has likewise been identified as a key determinant of postsecondary STEM enrollment [25]. Furthermore, students who value physics and recognize its career relevance demonstrate greater persistence in STEM programs [26]. These findings underscore the importance of fostering students' interest in physics to enhance engagement and support informed career decisions.

Hence, this study was designed to investigate the comparative effects of face-to-face laboratory experiments and e-laboratory experiments on students' basic science process skills and interest in learning physics. Specifically, within the Philippine educational context, this study aimed to determine whether e-laboratory activities can achieve learning outcomes comparable to those of traditional face-to-face laboratory experiments. The findings are expected to provide empirical evidence to inform instructional decisions regarding the effective use of laboratory modalities in physics education.

2. Methodology

The study employed a quasi-experimental pretest-posttest control group design to compare the efficacy of e-laboratory and face-to-face experiments.

The study was conducted at the Misamis Oriental Institute of Science and Technology (MOIST) in Balingasag, Misamis Oriental. Two intact Grade 12 classes enrolled in General Physics 1 during SY 2025–2026 were purposively selected. Both sections consisted of students under the STEM strand. One section was randomly assigned as the experimental group, while the other section served as the control group. The experimental group included 22 students, while the control group included 25 students.

The study utilized two instruments: a 26-item researcher-made test to assess students' basic science process skills, and a survey questionnaire adapted from Lee and Sulaiman [27], measured students' interest in learning physics. Three (3) physics specialists from the Department of Physics at Central Mindanao University, each with over eleven years of teaching experience and master's degrees, evaluated tools for content validity, providing corrections where needed. The multiple-choice test for science process skills was pilot-tested on third-year Bachelor of Secondary Education majoring in science students at the University of Science and Technology of Southern Philippines (USTP). After the pilot test, item analysis assessed difficulty and discrimination indices,

leading to the removal or revision of substandard items. The final test achieved an internal consistency reliability index of 0.77, as calculated using the Kuder–Richardson Formula 20 (KR-20), indicating acceptable reliability for measuring students' basic science process skills.

The researcher created laboratory activities for both experimental and control groups, aligned with DepEd MELCs for Grade 12 General Physics 1, focusing on Kinematics and Newton's Laws. The experimental group engaged in e-laboratories via platforms like PhET and Labster, enabling manipulation of variables in a virtual setting. In contrast, the control group performed hands-on experiments with physical equipment. Both activity sets were validated by experts to ensure that core scientific concepts and learning objectives remained consistent across modalities.

Data collection commenced with pre-tests administered to both control and experimental groups to assess students' baseline science process skills and interest in learning physics. Each test segment allowed 60 minutes for completion, including instructions. The experimental intervention lasted eight weeks, aligned with one academic quarter. The teacher-researcher met with classes daily, implementing a structured weekly plan that included lectures, laboratory experiments, and formative assessments. Students in small groups worked on specific activities, with the experimental group utilizing e-laboratories like PhET Interactive Simulations, while the control group engaged in traditional hands-on experiments. After covering all topics, a post-test was administered to both groups.

The mean and standard deviation were used to describe students' basic science process skills and interest in physics for both groups. An Analysis of Covariance (ANCOVA) was conducted to assess significant differences while controlling for pre-test scores. Also, prior to the inferential analysis, examination of the data has been made to ensure that the data has passed the assumptions for analysis of covariance.

3. Results and Discussion

Table 1. Pretest and Posttest Scores on Students' Basic Science Process Skills

Group	Pretest Posttest				
	N	Mean	SD	Mean	SD
Control	25	14.72	2.25	18.16	2.44
Experimental	22	14.27	2.57	13.77	4.14
Total	47	14.51	2.39	16.11	3.98

Note: Control group = face to face laboratory experiment; e- laboratory experiment; M = mean; SD = standard deviation.

Prior to the intervention, the control group ($n = 25$) obtained a pretest mean score of $M = 14.72$ with a standard deviation of $SD = 2.25$, whereas the experimental group ($n = 22$) had a pretest mean of $M = 14.27$ and $SD = 2.57$. The difference between the two groups' pretest mean scores was 0.45, indicating that the groups were almost equal in their basic science process skills before the intervention. The difference between the two groups in their mean scores can be considered negligible.

After the intervention, the control group's mean score

was $M = 14.72$, which increased to $M = 18.16$, showing a gain of 3.44 points from the pretest. This indicates that there was a comparable improvement in basic science process skills among students who participated in the face-to-face laboratory experiment. On the contrary, the experimental group's mean score slightly decreased from $M = 14.27$ to $M = 13.77$, representing a decrease of 0.50 points. Thus, comparing the mean scores gained between the two groups, the control group demonstrated greater improvement than the experimental group, indicating that the face-to-face laboratory approach was more effective in developing students' basic science process skills than the e-laboratory experiments.

These results confirm the claim of [1] that hands-on, face-to-face laboratory experiments provide a richer environment for developing students' science process skills compared to virtual or e-laboratory experiments. The traditional laboratory experiences allow students to directly manipulate materials, observe real phenomena, and engage in authentic scientific practices, which strengthens their procedural knowledge and critical thinking. Physical interaction with equipment and materials fosters deeper cognitive engagement, promotes problem-solving skills, and enhances the ability to design and conduct experiments [28]. Face-to-face laboratories also support immediate feedback and collaborative learning. Students working in a physical laboratory setting can ask questions in real-time, correct mistakes, and adjust their approach during the experiment, which leads to higher learning gains [29]. Similarly, [30] found that in-person laboratory experiences significantly improved students' procedural and applied skills in environmental engineering courses compared to online laboratories. Research also indicates that while virtual labs can increase engagement and conceptual understanding, they are most effective when combined with or used to prepare students for physical laboratory sessions [31,32].

Finally, quantitative analysis comparing traditional face-to-face and blended learning approaches indicate that students in face-to-face experiments often achieve stronger outcomes in practical and applied science competencies than those in online or blended settings [33].

Table 2. ANCOVA Results on Students' Basic Science Process Skills

Source	Df	SS	MS	F	<i>p-value</i>
Treatment					
Between	1	193.34	193.34	22.20	0.000
Groups					
Error	44	383.154	8.71		
Corrected total	45	576.494			

Note: BSPS = Basic Science Process Skills; SS = sum of squares; MS = mean square. $\alpha = .05$ level of significance. *Significant at $\alpha = .05$.

After adjusting for pretest scores, Table 2 presents the results of an analysis of covariance (ANCOVA) conducted to determine whether a significant difference existed between the experimental and control groups in students' basic science process skills. In the analysis, the posttest basic science process skills score served as the dependent variable, the type of laboratory method (face-to-face laboratory for the control group and e-laboratory for the experimental group) served as the independent variable, and the pretest scores were included as the covariate.

The ANCOVA results revealed a statistically significant effect of the laboratory method on students' basic science process skills, $F(1, 44) = 22.20, p < .000$. This indicates that, after controlling for pretest scores, a significant difference existed between the experimental and control groups at the .05 level of significance. The large F value relative to the error mean square ($MS = 8.71$), suggesting that the observed differences in students' science process skills are primarily due to the type of laboratory method rather than random variation.

These findings confirm that the type of laboratory method significantly influenced students' basic science process skills. Specifically, students exposed to face-to-face laboratory activities demonstrated higher posttest scores than those who participated in e-laboratory experiment. Consequently, the null hypothesis stating that there is no significant difference between the experimental and control groups is rejected. Overall, the results provide strong evidence that face-to-face laboratory experiment was more effective than e-laboratory experiment in developing students' basic science process skills.

These results are in line with existing literature. Through direct manipulation and hands-on interaction, face-to-face laboratories have been demonstrated to support procedural and psychomotor skill development through direct manipulation and hands-on engagement [39,40]. In similar [41] emphasized that face-to-face laboratories facilitate experimentation and observation, critical components of science process skills. In real laboratories as opposed to virtual ones, students frequently attain more procedural competence [42]. Additionally, students can practise experimenting in real-world settings in face-to-face labs, which promotes more consistent development of scientific thinking and skills [43,29]. According to a meta-analysis, virtual laboratories can enhance practice opportunities, engagement, and conceptual understanding, but they work best when combined with traditional laboratory experiences [44]. Finally, rich student-equipment and peer interactions in face-to-face settings are positively correlated with learning outcomes [45].

Table 3. Pretest and Post-test levels of Students' Interest toward

Group	Pretest Posttest				
	N	Mean	SD	Mean	SD
Control	25	33.40	4.65	33.04	5.05
Experimental	22	33.73	3.88	34.14	3.31
Total	47	33.55	4.27	33.55	4.32

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Note: Control group = face to face laboratory experiment; e- laboratory experiment;
M = mean; SD = standard deviation.
Interpretation Scale: 11–25 = Low Interest; 26–40 = Moderate Interest; 41–55 = High Interest

Before the intervention, the control group ($n = 25$) obtained a pretest mean score of $M = 33.40$ with a standard deviation of $SD = 4.65$, while the experimental group ($n = 22$) recorded slightly higher pretest mean of $M = 33.73$ ($SD = 3.88$). The overall pretest mean for all students was $M = 33.55$ ($SD = 4.27$), indicating that both groups demonstrated comparable and moderate levels of interest toward learning physics before the intervention.

There was small initial variation, as evidenced by the small difference in their mean scores.

After the intervention, the control group's mean slightly decreases from $M = 33.40$ to $M = 33.04$, reflecting a decrease of 0.36 points from the pretest. The result indicates that there was a slight decrease in students' interest toward learning physics among those who participated in the face-to-face laboratory experiment. On the contrary, the experimental group's mean score increased from $M = 33.73$ to $M = 34.14$, representing a gain of 0.41 points. Thus, comparing the mean scores gained between the two groups, the experimental group demonstrated a marginal increase in improvement than the control group, indicating that the e-laboratory experiment was more effective in developing students' interest toward learning physics than the face-to-face laboratory experiment, indicating minimal change in students' interest levels following the intervention because the magnitude of change in both groups was small.

These results support the claim that the use of online physics simulations and virtual laboratories can lead to higher levels of student interest, enjoyment, and engagement, even when the gains are modest compared to traditional laboratory experiences [34]. Such e-laboratories may provide an enriched learning experience that complements or enhances conventional laboratory instruction by offering interactive and flexible opportunities for students to explore physics concepts, thereby fostering positive attitudes toward learning the subject [35]. Recent research by [36] further showed that virtual laboratory activities can positively affect students' attitudes, engagement, and interest in physics learning, supporting the present result in which the experimental e-laboratory group demonstrated a marginal increase in interest compared with the control group. Similarly, [37] found that physics students taught with virtual laboratories exhibited significantly higher motivation than those taught without virtual labs, indicating that immersive digital tools can enhance affective engagement with physics content. In addition, [38] emphasized that students' interest and motivation to use virtual physics laboratories are significant factors that influence how students engage with these learning environments, and their results demonstrated differences among groups in both motivation and experience when comparing virtual versus traditional lab activities.

Table 4. ANCOVA Results of Students' Interest Towards Learning Physics

Source	Df	SS	MS	F	Pvalue
Treatment between Groups	1	10.369	10.369	0.69	0.409
Error	44	657.548	14.944		
Corrected total	45	667.917			

Note: ITLP = Interest Toward Learning Physics; SS = sum of squares; MS = mean square; $\alpha = .05$. *Significant at $\alpha = .05$.

After adjusting for pretest scores, Table 4 presents the results of an analysis of covariance (ANCOVA) conducted to determine whether a significant difference exists between the experimental and control groups in students' interest towards learning physics. In the analysis, the posttest interest toward learning physics score served

as the dependent variable, the type of laboratory method (face-to-face laboratory for the control group and e-laboratory for the experimental group) served as the independent variable, and the pretest scores were included as the covariate.

The ANCOVA results revealed no statistically significant effect of the laboratory method on students' interest toward learning physics, $F(1, 44) = 0.69, p = .409$. This indicates that, after controlling for pretest scores, there is no significant difference that exists between the experimental and control groups regarding students' interest toward learning physics at the .05 level of significance. The small F value relative to the error mean square ($MS = 14.94$) suggests that the observed differences in students' interest toward learning physics are due to random variation rather than the type of laboratory method employed.

These results indicate that the type of laboratory method did not significantly influence students' interest toward learning physics. Both face-to-face laboratory activities and e-laboratory experiments were comparably effective in maintaining students' interest in learning physics. Therefore, the null hypothesis stating that there is no significant difference between the experimental and control groups in terms of interest toward learning physics is accepted.

Overall, the results indicate that the laboratory method—whether face-to-face or e-laboratory—did not produce a statistically significant difference in students' interest toward learning physics after controlling for pretest scores. This suggests that both laboratory methods were equally effective in sustaining students' interest toward learning physics.

According to the literature currently in publication, inquiry-based laboratory activities, whether conducted face-to-face laboratory or virtually, can help students develop good emotional outcomes. [36] that in physics learning environments, both virtual and physical inquiry-based activities can produce comparable positive affective reactions. This is consistent with the interest development theory put forth by [46], who highlighted how students' interests change as a result of worthwhile and interesting educational experiences. [47] demonstrated that both virtual and physical laboratories can significantly increase students' enthusiasm in learning science.

The results reported that the physical laboratory activities, according to [1], increase students' motivation and interest through peer cooperation and direct material interaction. In a similar vein, [48] stressed that problem-solving exercises and active participation in face-to-face laboratory provide a sense of competence, enjoyment, and satisfaction, which in turn greatly increases students' enthusiasm for science. According to more recent research, relevant classroom and laboratory experiences are crucial for maintaining students' interest in physics [49].

This research showing that instructional elements frequently found face-to-face laboratory settings—like social interaction, sensory engagement, and teacher facilitation—are positively connected with students' motivation and interest in physics further supports these affective benefits [46,49]. Furthermore, research on laboratory standardization highlights the significance of implementation quality, showing a substantial correlation

between students' excitement and interest in laboratory learning and instructional techniques [50]. Lastly, regardless of the instructional modality used, research on inquiry-based instruction indicates that well planned, student-centered laboratory activities can increase students' interest in science [51].

4. Conclusion and Recommendations

Based on the findings of study, face-to-face laboratory experiments better enhance students' basic science process skills than the e-laboratory experiments. While their interest in learning physics remains unaffected by the type of laboratory method used. In light of these conclusions, the following recommendations are proposed: incorporate hands-on, face-to-face experiments into the physics curriculum, supplement these with e-laboratory activities to further develop students' skills and interest, and establish well-equipped laboratories to provide authentic, hands-on experiences. Regular training and workshops for teachers on conducting both types of laboratory experiments are essential to ensure sustainability and quality. Additionally, schools should develop accessible laboratory manuals, experiment guides, and online resources to support students in both face-to-face and e-laboratory experiments.

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