

Flip-Lab in Action: Empowering Physics Learners' Science Process Skills

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ABSTRACT

Mastering science process skills (SPS) in subjects like Physics presents a significant challenge for students, particularly in applying theoretical knowledge to real-world scenarios. This study investigated the flip-lab approach to enhance integrated science process skills (ISPS) in physics learning, focusing on Gas Laws topics. Using a quasi-experimental design, two (2) Grade 10 sections from Mayha National High School were randomly assigned to either the flip-lab or traditional instruction group. The Flip-Lab intervention incorporated pre-class instructional materials, take-home lab kits, customized lab manuals, and guided questions designed to strengthen students' scientific reasoning and inquiry skills. Pretest-posttest ISPS outcomes were compared using ANCOVA, while independent t-tests confirmed baseline

comparability. Results indicated that the developed lab manual for flip-lab was overall very satisfactory across content, format, presentation, and organization, as well as accuracy and up-to-dateness of information. Furthermore, its implementation led to a significant improvement in students' ISPS scores ($p = 0.006$; $F = 8.336$) scores compared to traditional instruction. This demonstrates the effectiveness of the flip-lab approach in developing essential scientific skills, particularly in ISPS, offering a scalable model for improving physics education and preparing students for complex, real-world problem-solving.

Keywords: *Academic Performance, Flip-Lab Approach, Student-Centered Learning, Science Process Skills (SPS), Take-Home Materials*

INTRODUCTION

The state of science education in the Philippines presents significant challenges, as evidenced by the performance of Filipino students in international assessments like PISA (Acido & Caballes, 2024). Physics, in particular, poses considerable difficulty due to its inherent problem-solving demands and complex topics, often leading to students struggling to apply theoretical knowledge. This perception of Physics as the most challenging among core science subjects is widespread, with students frequently associating it with rote memorization and a constant need for external support (Sarabi & Abdul, 2018).

The perception of Physics as a difficult subject contributes to poor student performance. Many students adopt various learning strategies, such as studying independently or with classmates, while some prepare answer notes. They rely on internal motivation and seek external reinforcement, such as rewards from parents (Camarao & Nava, 2017). A crucial element in addressing these difficulties is the enhancement of science process skills (SPS), which are central to simplifying learning, fostering student responsibility, and ensuring lasting scientific understanding. However, while students often express a highly positive attitude towards science, their science process skills are not well-developed, suggesting a critical barrier to effective learning and meaningful educational

experiences (Mirana, V. P., 2019). Compounding this issue is the common observation that students often arrive at laboratory sessions with limited prior understanding or appreciation of what they are about to learn in the laboratory, necessitating extensive initial explanations that can overwhelm them. The disconnect between theory and practice can be addressed by "flipping the laboratory" to integrate online, interactive pre-laboratory activities into the curriculum. (Loveys & Riggs, 2019).

This study investigates how the "Flip-Lab" approach can address these aforementioned challenges by integrating science process skills into the curriculum through flipped learning materials and assessments. By "flipping the laboratory," which involves interactive pre-laboratory activities, this approach aims to bridge the gap between theoretical knowledge and practical application, thereby enhancing students' skills in the science process. Furthermore, this pedagogical approach enables teachers to utilize class time more efficiently for explaining complex topics and fostering deeper engagement in lessons. Previous research supports the effectiveness of flipped learning in science education; for instance, Çelik et al. (2021) found that the flipped classroom model significantly enhanced laboratory self-efficacy and attitudes among physics students. Similarly, the study by Çakiroğlu, Güven, and Saylan (2020) indicates that integrating flipped learning into the experimentation process has a positive influence on students, particularly in identifying and stating hypotheses and operationally defining science process skills.

Ultimately, the findings of this study will also serve to aid curriculum planners in developing more flexible curricula that can be easily adjusted to meet the diverse needs of students. By shifting instructional content delivery outside of class time, the Flip-Lab approach is designed to free up in-class time for hands-on, inquiry-based learning activities, thereby promoting active learning and a deeper engagement with scientific concepts.

Research Questions and Objectives

Science education at the secondary level is critical for developing students' understanding of scientific concepts, particularly in physics. However, many students struggle to grasp these concepts, primarily due to insufficient development of Science Process Skills (SPS). This lack of proficiency in SPS hinders their ability to analyze data, conduct experiments, and apply theoretical knowledge, ultimately affecting their academic performance and interest in pursuing further studies in the field of science. This study aimed to investigate whether integrating science process skills into take-home instructional materials can improve students' achievement in physics. Specifically, it answered the following questions:

1. What is the validity level of the lab manuals in terms of:
 - a. content
 - b. format
 - c. presentation and organization
 - d. accuracy and up-to-datedness of information?
2. What is the participants' level of science process skills (Basic or Integrated) before the intervention?
3. Is there a significant difference in the pre-test scores between the experimental and control groups?
4. Is there a significant difference in the post-test scores between students exposed to Flip-Lab and those using traditional methods?

METHODS

Design

This study employed a quasi-experimental, pretest-posttest non-equivalent groups design to investigate the effect of the Flip-Lab approach on enhancing science process skills (SPS). Due to logistical constraints, intact classes were used, resulting in non-equivalent groups. The Flip-Lab approach, a pedagogical strategy involving pre-class video lectures and in-class active learning activities, served as the intervention. Science process skills (SPS) were the dependent variable, measured by the ISPS test. The pretest served as a baseline to determine the

comparability of the two sections in terms of SPS prior to the intervention. A quantitative approach was used to statistically analyze the data and identify any significant differences resulting from the Flip-Lab intervention.

Population and Sample

The population for this study comprised all Grade 10 students enrolled at Mayha National High School. From this population, a purposive sample of 42 students was selected from two Grade 10 sections (21 students per section). Purposive sampling was employed because the students must be enrolled in physics during the implementation, and the Grade 10 students have higher autonomy compared to other grade levels. The sample consisted of [Male: 7, Female: 14] students in the Flip-Lab Intervention group with an average age of 15.53 years, and [Male: 11, Female: 10] students in the Traditional Classroom group with an average age of 15.71 years. Individual ages ranged from 15 to 16 years old. Inclusion criteria required that students were officially enrolled in Grade 10 and regularly attending school throughout the data collection period. Informed consent was obtained from all participants (and their parents/guardians) prior to their participation.

Instrumentation

The research utilized the Integrated Science Process Skills Test (ISPST), a 30-item instrument developed by the researcher to assess students' science inquiry skills. This test was also adapted to serve as an Achievement Test in Gas Laws. The development process involved aligning test items with integrated science process skills, Bloom's taxonomy levels, and learning competencies in Gas Law topics. Initial item development yielded a 40-item test, which was subsequently reduced to 30 items following rigorous validation and pilot testing. Tables of Specification were provided to detail the distribution and placement of items across different skills and topics, ensuring the test comprehensively measured the intended constructs and reflected student learning in Gas Laws.

To ensure the instrument's validity, three experts in science and educational assessment evaluated the test items for content validity, confirming their alignment with the intended domain. The Content Validity Index (CVI) was calculated, and all 40 items met the required CVI values for both average and universal agreement among experts. A pilot study was conducted with Grade 11 students to assess reliability, and feedback from participants informed necessary adjustments. Item quality was further evaluated by computing the Index of Difficulty and Index of Discrimination, leading to the discard of 10 items.

The remaining 30 items were subjected to a two-factor ANOVA without replication, yielding a Cronbach's alpha coefficient of 0.74, indicating the test's reliability and acceptability. Additionally, the lab manuals used in the study underwent independent validation by science curriculum and content experts, ensuring their effectiveness as instructional materials.

Data Gathering Procedure

The researchers sought the approval of the head teacher to allow the researchers to administer the pre-test, post-test and the intervention. This research examined the effectiveness of the Flip-Lab approach in improving students' science process skills and understanding of Physics, specifically on Gas Laws during laboratory activities. Pre-tests and post-tests were administered to both control and experimental groups to assess baseline knowledge and learning gains. The pre-test data were analyzed using a t-test, while both pre-test and post-test results were analyzed using ANCOVA to measure improvement and the impact of the intervention.

Data Analysis

To analyze the effectiveness of the Flip-Lab intervention, the researcher used a t-test for independent samples on pre-test scores to identify any significant differences between the control and experimental groups before the intervention. This ensured the groups were comparable. The pre-test results were also interpreted using Arikunto's Score Interpretation Criteria, which classified students' science process skills (SPS) levels as Basic or Integrated. These criteria provided a framework for evaluating students' understanding of SPS through specific score ranges, from Very Bad (0–20) to Very Good (81–100), assessing abilities such as observation, hypothesis formation, and data analysis.

Post-test results were subjected to ANCOVA analysis to measure the effectiveness of the Flip-Lab approach while adjusting for pre-test differences. The post-test mean scores were again interpreted using Arikunto's criteria to determine improvements in SPS. Students who scored in higher ranges demonstrated stronger proficiency and integration of scientific reasoning and skills, while those in lower ranges needed more support and practice. Additionally, the lab manuals used in the Flip-Lab activities were evaluated by three expert validators to ensure their quality and relevance for educational purposes. Using the Learning Resource and Managed Development System (LDRMS) guidelines, the manuals were rated on a scale from "Very Satisfactory" (4.00–3.25) to "Not Satisfactory" (1.74–1.00).

This validation ensured that the materials met instructional standards, with high-rated manuals showing strong quality and no major errors, while lower-rated ones required significant revisions or were deemed ineffective.

Implementation Plan

Design and Development Phase: To lay the foundation for the study, the researchers designed and conceptualized the lab manuals and lab kits to be used. They also developed a research instrument, which along with the lab materials, was subjected to a validation process to ensure accuracy and effectiveness.

Implementation: After securing the necessary permits, the researchers administered a pre-test to assess students' baseline knowledge. They then implemented the intervention, which compared the Flip-Lab approach with the Traditional Classroom model - primarily differing in pre-class and in-class activities.

In the Flip-Lab model, students received lab kits and manuals in advance, containing key concepts, detailed experiment procedures, and science process skill (SPS) questions. This preparatory phase allowed for self-paced learning prior to formal instruction, fostering readiness and engagement.

In contrast, the Traditional Classroom model lacked this pre-class preparation, relying solely on teacher-led instruction during class time.

During in-class sessions, both approaches addressed the same content standards related to gas behavior. However, the Flip-Lab model incorporated interactive tasks that promoted higher-order thinking. Students were encouraged to share observations from their at-home experiments, linking hands-on experiences to theoretical concepts. This strategy deepened understanding and maximized the limited 45-minute class period for meaningful exploration.

Evaluation: Following implementation, a post-test was administered to evaluate any improvements in students' science process skills, providing a measure of the intervention's effectiveness

RESULTS

The study evaluated the effectiveness of the Flip-Lab approach in enhancing science process skills (SPS) among Grade 10 students at Mayha National High School. Researchers collected pretest and posttest scores from two groups, Diamond and Pearl, and analyzed them using a quasi-experimental design with a pretest-posttest approach. Before conducting the experiment, they validated the lab manual to ensure its suitability for classroom instruction.

Presentation of validator's rating on manuals' validity

The lab manual's validity was assessed by curriculum and content experts using the Department of Education's LRMS Assessment and Evaluation guidelines.

Table 1. Tabular representation of validator's rating on manual validity

Factors	Overall Mean	SD	Interpretation
A. Content	3.95	0.081	VS
B. Format	3.92	0.029	VS
C. Presentation & Organization	3.93	0.115	VS
D. Accuracy and up-to-datedness of information	4.00	0.000	NP

Legend:

Overall Mean	Interpretation
3.25 - 4.00	Very Satisfactory (VS)/Not Present (NP)
2.50 - 3.24	Satisfactory (S)
1.75 - 2.49	Poor (P)/ Present and Requires Major Redevelopment)
1.00 - 1.74	Unsatisfactory (US)

Table 1 summarizes the results of the assessment validation. The mean scores for Content, Format, and Presentation and Organization were 3.95, 3.92, and 3.93 respectively, all interpreted as "Very Satisfactory." Standard deviations for these factors were 0.081, 0.029, and 0.115, respectively. The Accuracy and Up-to-Datedness of Information received a mean score of 4.00 with a standard deviation of 0.000, interpreted as "Not Present" (indicating no major errors were found).

The results of the validation assessment indicate that the lab manual meets high standards for quality and is suitable for classroom instruction. The mean scores for all factors (Content, Format, Presentation and Organization) exceeded the Department of Education's LRMS Assessment and Evaluation threshold of 3.00, demonstrating that the manual is strong in terms of clarity, structure, and educational value. The low standard deviations, particularly for Format and Content, suggest a strong consensus among validators, reinforcing the reliability of these ratings. This high level of agreement indicates that the manual is consistently perceived as relevant, engaging, and professionally designed.

The perfect score of 4.00 for Accuracy and Up-to-Datedness of Information further confirms the manual's quality and alignment with current standards. While this validation provides strong evidence of the manual's quality, future research could involve further validation and assessment to ensure that the manual's content stays relevant to the current information. Overall, the findings suggest that the lab manual is a valuable resource that can enhance students' learning experiences and improve science education outcomes.

T-test analysis on students' pre-test scores between the Flip-Lab Group and the Control Group

An independent sample t-test was conducted on the pretest scores to determine whether the Flip-Lab and Control groups were statistically comparable prior to the implementation of the instructional intervention. This analysis was intended to establish baseline equivalence between the two groups.

In Table 2 below, the Flip-Lab group ($M = 45.24$, $SD = 10.09$) and the control group ($M = 41.11$, $SD = 7.91$) both consist of 21 participants. The computed *t-value* was 1.47, which was less than the critical *t-value* of 2.02 at 38 degrees of freedom, and the associated *p-value* was 0.15.

Table 2. Tabular representation of *t*-test analysis on students' pre-test scores between the Flip-Lab Group and the Control Group

Groups	Sample Size	Mean	SD	df	<i>p</i> -value
Flip-Lab	21	45.24	10.09	38	0.15
Control	21	41.11	7.91		

Given the *p*-value exceeds the alpha level of 0.05, the result is not statistically significant. This indicates that the two groups were statistically comparable, making them suitable participants for the study.

The mean rating of pretest scores was also interpreted using Arikunto's score interpretation criteria, Table 7, which was also used in Inayah et. al. (2020) study about Analysis of Science Process Skills in Senior High School Students. The mean rating of the scores in the Integrated Science Process Skills test of the Flip-Lab group (M = 45.24) and the control group (M = 41.11) was considered at a sufficient level based on Arikunto's score interpretation criteria. This means that the students already demonstrate basic competency in science process skills but need further enhancement to master the integrated level.

ANCOVA for means of scores between Flip-Lab and Control Group

As reflected in **Table 3**, the study found that the treatment had a statistically significant effect on students' post-test scores, even after controlling for pre-test scores, as indicated by a *p*-value of 0.006 and an F-value of 8.336. Pre-test scores were also a significant predictor of student outcomes ($p < 0.001$), highlighting the importance of considering baseline knowledge. The Flip-Lab group showed statistically significant improvement with a mean post-test score of 66.51 compared to the control group. However, the intervention exhibited a small effect size (0.176), which may be attributed to factors such as student motivation and engagement with take-home experiments, as some students might have lacked consistent support or a conducive home environment.

Table 3. Tabular representation of ANCOVA for means of scores between the Flip-Lab and the Control Group

Source of Variation	Sum of squares	df	Mean Square	F value	P value	Effect Size
Treatment	50.73	10	50.73	8.34	.006	0.176
Pre-Test Score	264.86	10	264.86	43.55	<.001	
Error	237.34	39	6.09	-	-	
Total	552.92	41	-	-	-	

Several factors contributed to the small effect size, including student resistance to the Flip-Lab model due to their familiarity with traditional lecture methods. Researchers also observed insufficient time to achieve desired educational goals and discuss topics in-depth. These time constraints, coupled with the short implementation period focused on a single topic, likely hindered students' ability to internalize and apply integrated science process skills fully.

DISCUSSION

The findings of this study demonstrated that the Flip-Lab approach significantly improved the science process skills (SPS) of Grade 10 students at Mayha National High School. The validation of the lab manual by experts further confirms the quality and reliability of the instructional material, achieving “Very Satisfactory” ratings in all evaluation criteria. This indicates that the design and content of the Flip-Lab materials were appropriate, relevant, and aligned with DepEd standards, which contributed to the effectiveness of the intervention.

The comparable pretest scores between the Flip-Lab and control groups established a fair baseline, confirming that both groups had similar levels of SPS prior to the intervention. This lends credibility to the observed improvements, attributing them to the Flip-Lab approach rather than pre-existing differences. The ANCOVA results showed a statistically significant difference in post-test scores between the experimental group (Flip-Lab) and the control group, with a p-value of 0.006, indicating that the Flip-Lab approach had a positive effect on enhancing students’ ISPS and mastery of physics concepts. However, despite the statistically significant improvement, the observed effect size (0.176) was small. This suggests that while the Flip-Lab Approach did enhance ISPS, other influencing factors may have limited its full impact. One key issue was student motivation and engagement with the take-home tasks and pre-class materials. Some students lacked a supportive or conducive home learning environment, which may have negatively affected their performance. Additionally, resistance to the unfamiliar instructional format may have contributed to this limitation, especially since students were accustomed to traditional teacher-led methods.

Time constraints also emerged as a significant challenge. The MATATAG curriculum limits instruction time to 45 minutes per session, making it challenging to conduct in-depth discussions and reinforce students’ home-based activities. The short implementation period—restricted to one grading period and one topic (Gas Laws)—further limited the scope of improvement in SPS. Despite these limitations, the integration of pre-class materials and home-based experiments helped bridge the gap between theory and practice. Future research may explore extended implementation periods, broader topic coverage, and more strategies for increasing student engagement with pre-class materials.

Limitations

This study had several limitations that may affect the generalizability of its findings. The small sample size of 42 Grade 10 students from a single school limits the representativeness of the results. Also, several factors likely contributed to this outcome, particularly student motivation and engagement with take-home experiments and pre-class materials. Some students may have lacked consistent support or a conducive home environment, affecting their ability to participate in Flip-Lab activities fully. Additionally, the limited duration of the intervention and the 45-minute time constraint per session imposed by the MATATAG curriculum presented difficulties.

Researchers observed challenges in covering all lessons while fostering deeper connections between theoretical knowledge and practical skills acquired outside of the classroom. With five science process skills to enhance and only 3 hours and 45 minutes per week allocated for each gas law topic, the time was insufficient to achieve the desired educational goals and reinforce what they’d learned at home through in-depth discussion of the topics. The short implementation period, confined to one grading period (4th grading), may have limited students’ ability to fully internalize and apply integrated science process skills (ISPS). Despite the positive trend observed, these factors collectively contributed to the small effect size of the intervention.

CONCLUSION

This study concludes that the Flip-Lab approach is an effective instructional strategy for improving integrated science process skills among Grade 10 students, supported by an expert-validated lab manual and significantly improved posttest scores. While the effect size (.176) indicates a relatively small practical significance, and posttest scores (mean=66.51) did not reach the DepEd’s passing threshold of 75%, the findings demonstrate the

potential of Flip-Lab to enhance science process skills. Factors hindering the full potential have been identified; however, there remains a need for further enhancement to ensure students achieve the proficiency levels required by educational authorities. Future iterations of the Flip-Lab approach should prioritize consistent implementation across all physics topics throughout the academic year, leverage digital platforms and interactive simulations to enhance pre-class engagement (ensuring equitable access to technology), and engage parents in supporting their children's learning at home. Future research should explore the long-term effects of Flip-Lab and its applicability to other subjects, alongside continuous validation of instructional materials, to bridge this gap and promote greater student mastery and science proficiency.

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