

Simulation-Based Instruction in Improving Integrated Science Process Skills

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Abstract— This study examined the effectiveness of simulation-based instruction in improving the Integrated Science Process Skills (ISPS) of Grade 10 students in a rural secondary school in the Philippines. Using a pre-experimental one-group pretest-posttest design, 187 students from five intact sections were assessed through a validated ISPS Test before and after a six-week instructional intervention covering fourth-quarter Chemistry topics. Prior to the intervention, students performed at the Proficient level, indicating foundational competency in scientific inquiry. Following the intervention, students' performance improved to the Advanced level, demonstrating substantial gains in higher-order science process skills. Statistical analysis confirmed a significant difference between pretest and posttest scores, affirming that simulation-based instruction effectively developed students' scientific reasoning and critical thinking abilities. The findings suggest that simulation-based instruction is a viable and effective pedagogical approach for educators in resource-limited settings seeking to foster inquiry skills among learners. Science teachers are encouraged to integrate simulation tools into regular instruction and to engage in professional development activities that deepen their understanding of technology-enhanced pedagogy. Future research should investigate the applicability of this approach across diverse educational contexts and assess its capacity to produce long-term learning outcomes.

Keywords— integrated science process skills, science process skills performance, simulation-based instruction, simulation-based teaching.

I. INTRODUCTION

Philippine science education has undergone significant reforms through the implementation of the K-12 Curriculum, which emphasizes the development of 21st-century skills among learners. Central to this reform is the enhancement of Integrated Science Process Skills (ISPS), which include higher-order competencies such as hypothesis formulation, variable control, experimental design, and data interpretation. Despite these curriculum reforms, many Filipino classrooms, particularly those in rural settings, continue to experience challenges in providing learners with sufficient opportunities to develop these scientific skills (Ignacio & Yabut, 2025; Tejero, 2025).

The problem is more evident in rural public schools where limited resources, inadequate laboratory facilities, and insufficient teacher preparation restrict the implementation of inquiry-based instruction. Studies revealed that students in resource-constrained schools demonstrate lower levels of science process skills achievement compared to students exposed to well-equipped learning environments. Nevertheless, many science classrooms

still rely heavily on teacher-centered instruction with limited laboratory activities, thereby restricting authentic scientific inquiry experiences among learners (Diquito, 2025; Ederon & Aliazas, 2024).

Integrated Science Process Skills are considered essential for scientific literacy and higher-order thinking. These skills involve advanced scientific competencies such as identifying and controlling variables, formulating hypotheses, operationally defining variables, interpreting data, and conducting experiments. However, international and national assessments continue to reveal the weak performance of Filipino learners in science. According to the Programme for International Student Assessment (PISA), the Philippines ranked 78th out of 79 participating countries in science literacy, with only 1% of Filipino students demonstrating proficiency in higher-order science process skills (Organisation for Economic Cooperation and Development [OECD], 2019). Similarly, the Trends in International Mathematics and Science Study (TIMSS) showed that Filipino learners performed poorly in scientific inquiry and investigation skills (International Association for the Evaluation of Educational Achievement [IEA], 2020). National Achievement Test results likewise revealed low student performance in competencies related to ISPS (Department of Education [DepEd], 2023).

Chemistry instruction presents additional challenges in developing integrated science process skills because students are required to transition among macroscopic, submicroscopic, and symbolic representations of scientific concepts (Johnstone, 1991). Grade 10 fourth-quarter Chemistry topics such as gas laws, conservation of mass, chemical reactions, and reaction rates inherently require learners to apply advanced inquiry skills including hypothesis testing, variable manipulation, and data interpretation. However, many Filipino students struggle to master these competencies due to the limited use of inquiry-based and interactive instructional approaches in science classrooms (Jardinico & Linaugo, 2023).

Several interventions have previously been introduced to improve science education in the Philippines. Programs such as the Science and Technology Academic and Research-Based Openly Operated Kiosks (STARBOOKS), the DepEd Science Equipment and Science Laboratory Package, and inquiry-based reforms under the K-12 Curriculum aimed to strengthen science instruction and laboratory experiences. However, these initiatives encountered implementation challenges such as inadequate teacher training, limited technological infrastructure, lack of functional laboratory facilities, and insufficient professional development opportunities for science teachers (DOST, 2018; DOST-SEI, 2021; Seva et al., 2019; Talisayon, 2018). Studies further revealed that many science teachers received limited training in inquiry-based teaching and faced time constraints in implementing laboratory and investigative activities (Bernardo et al., 2021; Ganal & Guiab, 2021).

Recent technological advancements have introduced simulation-based instruction as a promising strategy for improving science education and developing ISPS. Simulation-based learning provides interactive and virtual environments where learners can safely manipulate variables, conduct repeated experiments, and observe scientific phenomena that may otherwise be difficult, costly, or hazardous to perform in physical laboratories. Simulations are especially beneficial in Chemistry topics such as gas laws, conservation of mass, and reaction rates because they allow students to visualize molecular behavior, observe chemical interactions, and investigate factors

affecting reactions in a controlled environment (Banda & Nzabahimana, 2021; Isidro et al., 2024; Tuyizere & Rutegwa, 2024).

International and local studies consistently support the effectiveness of simulation-based learning in improving students' conceptual understanding, critical thinking, and scientific inquiry skills. Meta-analytic findings indicated that simulation-based instruction significantly enhances students' academic performance and problem-solving abilities across various educational contexts (Chernikova et al., 2020). In the Philippine setting, Ederon and Aliazas (2024) found that students demonstrated increased engagement and improved conceptual understanding when exposed to simulation-based Chemistry instruction. Furthermore, the MATATAG Curriculum of the Department of Education emphasizes learner-centered and inquiry-based science instruction, making simulation-based learning highly aligned with the current educational direction in the Philippines (DepEd, 2024; Diquito Jr., 2024).

Despite the growing recognition of simulation-based instruction, limited studies have systematically examined its effectiveness in enhancing the integrated science process skills of Grade 10 students in rural Philippine schools, particularly within the fourth-quarter Chemistry curriculum. Thus, this study aimed to determine the effectiveness of simulation-based instruction in improving the integrated science process skills of Grade 10 students by examining their pretest and posttest performance levels and identifying whether significant differences exist after the implementation of the intervention.

II. OBJECTIVES OF THE STUDY

This study aimed to determine the effectiveness of simulation-based instruction on the Integrated Science Process Skills of Grade 10 students in Chemistry within a rural Philippine school setting during the fourth quarter. Specifically, the study sought to: (1) determine the pretest performance level of students on Integrated Science Process Skills prior to the implementation of simulation-based instruction; (2) determine the posttest performance level of students on Integrated Science Process Skills after the implementation of simulation-based instruction; and (3) determine whether a significant difference exists between students' pretest and posttest performance on Integrated Science Process Skills. The findings of the study are intended to inform the development of technology-enhanced instructional strategies that can more effectively support science education within the Philippine basic education context.

III. METHODOLOGY

Research Design. This study employed a pre-experimental one-group pretest-posttest design to assess the effectiveness of simulation-based instruction in improving the Integrated Science Process Skills (ISPS) of Grade 10 students in Chemistry. Under this design, a pretest was administered to establish the baseline performance level of the students, followed by a six-week simulation-based instructional intervention, and subsequently a posttest to measure changes in performance. The lessons centered on fourth-quarter Chemistry topics, specifically gas laws and kinetic molecular theory, conservation of mass in chemical reactions, and factors influencing reaction rates. This research design was deemed appropriate for classroom-based research given the practical and ethical constraints that precluded random assignment and the use of a control group.

Participants. The participants consisted of 187 Grade 10 students enrolled at Elias A. Salvador National High School during School Year 2025–2026. Participants were selected through intact group sampling, wherein the existing class sections were utilized to preserve the natural classroom environment. Inclusion criteria required that students be officially enrolled in Grade 10 Chemistry, have an attendance rate of at least 80%, and have submitted the required parental and student consent forms. The study was conducted in a rural school setting where limited laboratory resources necessitated the use of simulation-based instruction as a viable substitute for hands-on inquiry activities.

Instruments. The main research instruments were a researcher-developed simulation-based instructional material, the Integrated Science Process Skills Test (ISPST), and Daily Lesson Logs (DLLs). The ISPST served as the primary quantitative measurement tool, capturing key ISPS domains including identifying and controlling variables, formulating hypotheses, conducting experiments, interpreting data, and making inferences. The instrument underwent expert validation, pilot testing, and item analysis to ensure content validity, reliability, and alignment with the Grade 10 Chemistry curriculum. The internal consistency of the ISPST was verified prior to full implementation. [Note to author: Insert the computed reliability coefficient, e.g., Cronbach's alpha or KR-20, here.]

Data Collection Procedure. Data collection followed a structured sequence, beginning with the procurement of necessary approvals from the relevant school and division authorities. [Note to author: Specify the ethics review or division clearance obtained here.] Upon approval, the pretest was administered to all participants. The six-week simulation-based instructional intervention was then implemented, with implementation fidelity monitored through the DLLs. The instructional approach incorporated guided simulations, inquiry-based activities, and structured tasks designed to develop students' science process skills. Following the intervention period, the posttest was administered using the same validated ISPST.

Data Analysis. Descriptive statistics, including the mean, frequency distribution, and standard deviation, were used to summarize and interpret students' pretest and posttest performance levels. The ISPS performance scale shown in Table 1 was applied to classify student scores from Beginning to Advanced levels. Inferential analysis using the paired-samples t-test was employed to determine whether a statistically significant difference existed between pretest and posttest scores. The level of significance was set at $\alpha = .05$.

Table 1. ISPS Performance Scale

Score Range	Interpretation
29-36	Advanced
22-28	Proficient
15-21	Approaching Proficiency
8-14	Developing
0-7	Beginning

IV. RESULTS AND DISCUSSION

Pre-Test for Level of Integrated Science Process Skills

Table 2 presents the pretest results of the respondents on the level of Integrated Science Process Skills prior to the implementation of simulation-based instruction. The results reveal that Grade 10 students demonstrated a Proficient level of ISPS, as indicated by a computed mean score of 24.0 (SD = 6.31). The majority of students obtained scores within the Proficient range (49.30%), while 21.80% reached the Advanced level and smaller proportions fell within the Approaching Proficiency, Developing, and Beginning levels.

These findings indicate that the respondents already possessed foundational competencies in scientific inquiry and reasoning; however, considerable room for improvement remained, particularly with respect to higher-order science process skills. It was also observed that students displayed uncertainty and difficulty in responding to standardized multiple-choice assessment formats, likely due to greater familiarity with classroom assessments that award partial credit. This observation is consistent with the findings of Ignacio and Yabut (2025), who reported that Filipino learners commonly exhibit moderate levels of integrated science process skills prior to exposure to targeted instructional interventions. Similarly, Ganal and Guiab (2021) emphasized that traditional teacher-centered instruction and limited inquiry-based learning opportunities restrict the development of higher-order thinking skills in science. Diquito Jr. (2025) further highlighted that contextual factors such as limited resources, insufficient laboratory experiences, and varying learner readiness contribute to differences in science skill development in Philippine schools.

Table 2. Integrated Science Process Skills Pre-Test Frequency Distribution

Score Range	Frequency	Percentage	Level
29-36	41	21.80	Advanced
22-28	92	49.30	Proficient
15-21	37	19.80	Approach Proficiency
8-14	15	8.00	Developing
0-7	2	1.10	Beginning
Overall	187	100.0	

Post-Test for Level of Integrated Science Process Skills

Table 3 presents the posttest results of the respondents following the six-week simulation-based instructional intervention. The results reveal that Grade 10 students achieved an Advanced level of Integrated Science Process Skills, as indicated by a computed mean score of 29.4 (SD = 4.53).

The majority of students obtained scores within the Advanced range (64.30%), followed by those in the Proficient level (30.40%), while only a very small proportion remained in the Approaching Proficiency level (4.80%) and Developing level (0.50%). No student was classified under the Beginning level, indicating a substantial improvement in science process skills following exposure to the intervention.

The findings suggest that simulation-based instruction effectively enhanced students' higher-order thinking skills, scientific reasoning, and ability to apply scientific processes in Chemistry learning activities. During the posttest, students demonstrated greater confidence and independence in using simulations to observe, analyze, and interpret scientific data. Increased engagement in inquiry-based activities was observed through individual and peer-assisted tasks facilitated via simulation platforms. The use of mobile devices, collaborative group work, television screen projection, QR codes, and shared internet access further supported continuous participation and accessibility throughout the intervention, even amid intermittent connectivity.

These results are consistent with the findings of Ederon and Aliazas (2024), who reported that simulation-based instruction significantly improves student engagement and conceptual understanding in science education. Similarly, Isidro et al. (2024) emphasized that simulations provide interactive opportunities for learners to practice scientific inquiry skills, resulting in improved performance outcomes. Rutten et al. (2021) further explained that computer simulations enhance learning by enabling students to visualize abstract concepts and manipulate variables in controlled environments. Lee et al. (2024) found that simulation-based approaches are more effective than traditional instructional methods in developing deeper scientific understanding, while Garcia and Reyes (2024) highlighted that repeated exposure to simulation activities contributes to the cumulative development of higher-order science process skills.

Table 3. ISPS Post-Test Frequency Distribution

Score Range	Frequency	Percentage	Level
29-36	120	64.30	Advanced
22-28	57	30.40	Proficient
15-21	9	4.80	Approach Proficiency
8-14	1	0.50	Developing
0-7	0	0	Beginning
Overall	187	100.0	

Significant Difference on Level of Integrated Science Process Skills

Table 4 presents the results of the paired-samples t-test comparing students' pretest and posttest performance on Integrated Science Process Skills. The results reveal a statistically significant improvement in ISPS following exposure to simulation-based instruction. The pretest mean score of 24.0 increased to 29.4 in the posttest, yielding a mean difference of -5.35 . The paired-samples t-test produced a t-value of -11.6 with 186 degrees of freedom and a p-value of $< .001$, indicating a statistically significant difference between pretest and posttest scores at the .05 level of significance.

These findings demonstrate that simulation-based instruction positively influenced students' science process skills performance. Through simulation activities, students were able to conduct laboratory-like investigations without the constraints of actual laboratory equipment and preparation time. The intervention enabled learners to visualize abstract scientific concepts such as gas particle movement, pressure-volume relationships, and

chemical interactions, which are difficult to demonstrate through conventional instructional approaches. The structured inquiry tasks further allowed students to manipulate variables, analyze results, and actively engage in scientific investigation, thereby strengthening their higher-order thinking and problem-solving skills.

Table 4. Significant Difference on Pre-Test and Post-Test

	Mean	Statistic	df	p	Mean diff	SE diff
Pre-Test	24.0	-20.0	62.0	<.001	-11.4	0.570
Post-Test	29.4					

If $p \leq .001$ (Significant)

The results are supported by Banda and Nzabahimana (2021), who demonstrated that simulations improve conceptual understanding in science topics such as gas laws and molecular theory. Chernikova et al. (2020) similarly emphasized that simulation-based learning promotes deeper engagement and greater mastery of scientific skills compared to traditional instructional methods. Isidro et al. (2024) further explained that repeated interactive simulation experiences strengthen integrated science process skills among learners. Moreover, Lee et al. (2024) highlighted that simulations encourage critical thinking by allowing students to manipulate variables and observe outcomes, while Martinez and Garcia (2024) found that continuous exposure to simulation-based activities significantly improves higher-order cognitive skills in science education.

V. CONCLUSION

The study concluded that simulation-based instruction effectively enhanced the Integrated Science Process Skills of Grade 10 students in Chemistry at Elias A. Salvador National High School. Prior to the intervention, most students demonstrated moderate levels of ISPS, indicating that they possessed only foundational competencies in scientific inquiry and higher-order thinking. Following the six-week simulation-based intervention, students showed marked improvement in performance, with the majority achieving Advanced levels in the posttest assessment.

The statistically significant difference between the pretest and posttest scores confirms that simulation-based instruction positively influenced students' ability to formulate hypotheses, identify and control variables, conduct experiments, interpret data, and draw scientific inferences. Furthermore, the intervention provided learners with engaging and interactive opportunities to visualize abstract Chemistry concepts, manipulate variables, and actively participate in inquiry-based learning activities, which collectively contributed to improvements in scientific reasoning and problem-solving skills.

Despite the positive outcomes, this study acknowledges several limitations. The pre-experimental one-group pretest-posttest design, while appropriate for the given school context, does not allow for causal inferences due to the absence of a control group. Observed improvements may be attributable in part to maturation, repeated testing, or other extraneous variables that cannot be controlled without a comparison group. Additionally, the

study was conducted in a single rural school, which limits the generalizability of the findings to other contexts and populations.

Recommendations

Based on the findings and conclusions of this study, the following recommendations are offered:

1. Science teachers are encouraged to integrate simulation-based activities into their regular instructional repertoire, particularly for Chemistry topics that require visualization of abstract or microscopic phenomena. Tools such as PhET Interactive Simulations and similar platforms can serve as effective supplements or alternatives to physical laboratory activities in resource-limited settings.
2. School administrators and curriculum planners should provide sustained professional development opportunities focused on technology-enhanced pedagogy, enabling teachers to maximize the educational potential of simulation platforms.
3. Future research should adopt quasi-experimental or true experimental designs that include a control group to allow for stronger causal conclusions regarding the effectiveness of simulation-based instruction on ISPS.
4. Subsequent studies should examine the long-term retention of ISPS gains following simulation-based instruction, and replicate this study across different grade levels, subject areas, and school contexts — including urban schools and those with relatively greater access to resources — to determine the broader applicability of this instructional approach.

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