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Effectiveness of Phenomenon-Based Inquiry Learning in Improving the Scientific Literacy and Critical Thinking Skills of Grade 10 Learners in Science at Bunawan National High School, Division of Agusan del Sur: A Quasi-Experimental Study

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ABSTRACT

This study determined the effectiveness of Phenomenon-Based Inquiry Learning (PBIL) in improving the scientific literacy and critical thinking skills of Grade 10 learners in Science at Bunawan National High School during School Year 2025-2026. It employed a quantitative quasi-experimental, non-equivalent comparison-group pretest-posttest design involving 97 learners through complete enumeration: 49 in the experimental group and 48 in the comparison group; a separate intact section was used for pilot testing. Researcher-developed Scientific Literacy and Critical Thinking Skills Tests underwent expert content validation, pilot testing, item analysis, and reliability assessment. Means and standard deviations described learner performance, while paired-samples and independent-samples t-tests at the .05 level tested within- and between-group differences. Both groups initially demonstrated low scientific literacy and critical thinking. After instruction, the PBIL group reached high levels in scientific literacy ($M = 19.84$, $SD = 3.64$) and critical thinking ($M = 21.18$, $SD = 3.98$), whereas the comparison group reached only moderate levels. Significant pretest-posttest improvements occurred in the experimental group for scientific literacy, $t = 42.61$, $p < .001$, and critical thinking, $t = 30.80$, $p < .001$. Experimental-group posttest and mean-gain scores were also significantly higher than those of the comparison group in both outcomes. The findings support PBIL as an effective approach for authentic inquiry, evidence-based reasoning, and higher-order thinking and informed an Instructional Enhancement Plan for sustained implementation in Grade 10 Science.

Keywords: *Phenomenon-Based Inquiry Learning, scientific literacy, critical thinking skills, Grade 10 learners, inquiry-based science education, quasi-experimental study*

INTRODUCTION

Scientific literacy and critical thinking are central outcomes of contemporary science education because learners increasingly encounter environmental, health, technological, and societal problems that require interpretation of evidence and responsible decision-making. Scientific literacy extends beyond recalling scientific facts to explaining phenomena, evaluating inquiry, and interpreting data and evidence in authentic contexts (Organisation for Economic Co-operation and Development [OECD], 2023, 2025). UNESCO (2021) similarly

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emphasizes that education should prepare learners to understand complex global challenges and participate meaningfully in decisions affecting sustainable futures.

Despite these priorities, substantial learning gaps remain in Philippine science education. PISA 2022 showed that only 23% of Filipino learners reached at least the minimum proficiency level in science, indicating continuing difficulty in explaining phenomena, interpreting evidence, and applying scientific knowledge to unfamiliar situations (OECD, 2023). The K to 12 Science Curriculum therefore promotes learner-centered, inquiry-based, contextualized instruction that develops scientific understanding, investigation, problem-solving, and higher-order thinking rather than factual memorization (Department of Education [DepEd], 2016). The MATATAG agenda likewise reinforces the need to strengthen foundational and higher-order competencies through quality teaching and assessment (DepEd, 2023).

Phenomenon-Based Inquiry Learning (PBIL) responds to these instructional demands by beginning with observable, meaningful scientific phenomena and guiding learners through questioning, investigation, evidence analysis, explanation, collaboration, and reflection. Its emphasis on authentic phenomena is consistent with modern science frameworks that position investigation and design at the center of science learning (National Research Council [NRC], 2012) and with inquiry-cycle models that organize learning through orientation, conceptualization, investigation, conclusion, and discussion (Pedaste et al., 2015). A recent systematic review also identifies phenomenon-based learning and storylines as promising ways of connecting disciplinary ideas with coherent, real-world scientific sense-making (Walker & Nouri, 2025).

At Bunawan National High School, Grade 10 learners encounter science topics that can be connected directly to observable environmental and community phenomena. However, the source thesis reports classroom difficulties in explaining scientific events using scientific principles, interpreting evidence, applying concepts to real situations, and demonstrating critical reasoning. These local concerns align with research showing that structured inquiry can improve conceptual understanding and scientific reasoning when learners receive appropriate guidance and opportunities to evaluate evidence (Furtak et al., 2012; Roy et al., 2025).

Although inquiry-based science instruction has been widely investigated, the thesis identified limited empirical evidence on PBIL as a distinct approach for simultaneously improving scientific literacy and critical thinking among Grade 10 learners in Philippine public secondary schools, particularly in Agusan del Sur. The study therefore examined learners' scientific literacy and critical thinking before and after PBIL, tested significant within- and between-group differences in posttest and gain scores, and used the findings to develop an Instructional Enhancement Plan for Grade 10 Science.

Literature Review

Scientific Literacy and Inquiry-Oriented Science Education

Scientific literacy is a multidimensional competence involving scientific knowledge, inquiry, interpretation of evidence, and the capacity to apply science to personal and societal issues. Contemporary frameworks place particular emphasis on explaining phenomena scientifically, constructing and evaluating scientific inquiry, and interpreting data and evidence (OECD, 2025). Bybee (2013) likewise argues that science education should prepare learners to use scientific understanding in meaningful contexts, while Roy et al. (2025) show that current scientific-literacy research increasingly emphasizes authentic inquiry, communication, reasoning, and application rather than factual achievement alone.

Inquiry-oriented instruction provides a practical means of developing these competencies. The NRC (2012) describes science learning as participation in practices such as questioning, planning investigations, analyzing data, constructing explanations, and arguing from evidence. Pedaste et al. (2015) similarly conceptualize inquiry as a structured cycle that moves learners from orientation and question formation to investigation, conclusion, and discussion. These perspectives indicate that inquiry is most educationally productive when it is deliberately scaffolded rather than treated as unguided discovery.

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Meta-analytic evidence supports this position. Furtak et al. (2012) found that inquiry-based science teaching produced positive learning effects, particularly when inquiry included teacher guidance and conceptual support. Within the Philippine setting, this rationale is consistent with the K to 12 Science Curriculum's emphasis on inquiry, contextualization, scientific investigation, and meaningful application (DepEd, 2016). Thus, scientific literacy provides both a target outcome and a framework for evaluating whether PBIL strengthens learners' capacity to use science beyond routine recall.

Critical Thinking in Science Learning

Critical thinking involves purposeful interpretation, analysis, evaluation, inference, explanation, and self-regulation. Facione's (1990) Delphi framework identifies these interrelated cognitive skills as essential to reasoned judgment. In science learning, the same processes are required when learners compare explanations, determine whether evidence supports a claim, identify weaknesses in an investigation, infer relationships from data, and justify conclusions.

Research indicates that critical thinking improves when instruction makes reasoning explicit and gives learners sustained opportunities to analyze and defend ideas. Abrami et al. (2015), in a meta-analysis of critical-thinking interventions, reported stronger outcomes when instruction combined explicit attention to thinking with active learning approaches. Hattie (2023) similarly emphasizes the importance of learners engaging with challenging tasks, feedback, metacognition, and visible reasoning processes rather than remaining passive recipients of information.

Inquiry-based science education provides a natural context for these processes because learners must ask questions, examine evidence, evaluate alternatives, and construct defensible explanations. Arifin et al. (2025) concluded that inquiry-based learning in science generally enhances critical thinking when implementation includes meaningful problems, teacher facilitation, and structured evidence evaluation. PBIL therefore offers a plausible mechanism for integrating disciplinary content with the deliberate practice of higher-order reasoning.

Phenomenon-Based Inquiry Learning

PBIL organizes instruction around authentic scientific phenomena that are sufficiently familiar or observable to stimulate curiosity while also requiring disciplinary explanation. Rather than beginning with abstract definitions, learners encounter a phenomenon, identify what requires explanation, formulate questions, investigate evidence, and progressively refine scientific accounts. Walker and Nouri (2025) describe phenomenon-based learning and coherent storylines as approaches that can support connected sense-making across science concepts and practices.

The approach is consistent with constructivist assumptions that learners actively build knowledge by connecting new experiences with prior understanding (Piaget, 1952). It also reflects experiential learning, in which concrete experience, reflection, conceptualization, and application contribute to deeper learning (Kolb, 1984). In PBIL, these principles are realized through authentic observation, inquiry, collaborative interpretation, and evidence-based explanation rather than through lecture alone.

PBIL also requires purposeful teacher facilitation. Teachers select meaningful phenomena, provide appropriate scaffolds, maintain alignment with curriculum competencies, guide productive scientific discussion, and help learners evaluate the adequacy of evidence without directly supplying conclusions. This guided structure is consistent with evidence that inquiry benefits learners most when the cognitive demands of investigation are balanced by instructional support (Furtak et al., 2012; NRC, 2012).

Empirical Basis and Research Gap

The broader evidence base consistently favors learner-centered and inquiry-rich science instruction over approaches dominated by factual transmission. Reviews and meta-analyses show that structured inquiry can strengthen conceptual understanding, reasoning, and critical thinking (Abrami et al., 2015; Furtak et al., 2012;

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Arifin et al., 2025). Research on scientific literacy also highlights the value of authentic contexts, evidence evaluation, and participation in scientific practices (Roy et al., 2025).

However, the thesis notes that much of the existing literature examines inquiry-based learning in general rather than PBIL as a specifically phenomenon-anchored instructional approach. This distinction is important because the instructional starting point - an authentic, observable phenomenon - is intended to create a coherent reason for learners to ask questions, investigate, and connect concepts with evidence. The literature therefore supports PBIL theoretically, while leaving a need for localized experimental evidence on its effectiveness.

The research gap is particularly relevant to Grade 10 science instruction in Bunawan National High School, where authentic environmental and scientific phenomena can be used as learning anchors. By simultaneously measuring scientific literacy and critical thinking, the study tested whether PBIL could improve both disciplinary application and higher-order reasoning within an actual Philippine public-school classroom setting.

Conceptual Framework

The study conceptualized Phenomenon-Based Inquiry Learning as the independent variable and scientific literacy and critical thinking skills as the outcome variables. Scientific literacy was represented through the competencies of explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting scientific data and evidence, while critical thinking was represented through interpretation, analysis, evaluation, inference, explanation, and self-regulation. The source manuscript's schematic is retained below as closely as possible, including its displayed orientation and arrow direction.

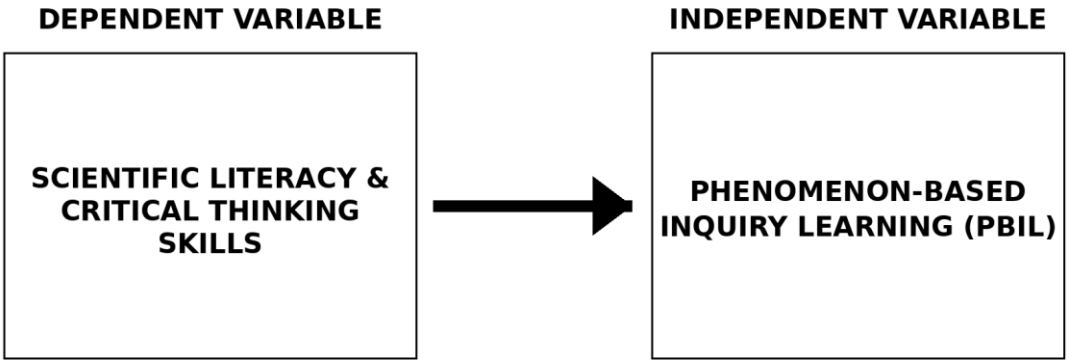


Figure 1. *Schematic Diagram of the Study*

METHODS

Research Design

The study employed a quantitative quasi-experimental, non-equivalent comparison-group pretest-posttest design. Two intact Grade 10 classes were used because individual random assignment was not practical in the school setting. Both groups completed identical pretests, the experimental group received PBIL while the comparison group received the school's existing Science instruction, and both groups then completed identical posttests. This design permitted examination of changes within the PBIL group and comparison of post-intervention performance and gain scores between groups (Campbell & Stanley, 1963; Creswell & Creswell, 2018; Fraenkel et al., 2019).

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Research Locale

The study was conducted at Bunawan National High School, Division of Agusan del Sur, in the Caraga Administrative Region of Mindanao, Philippines, during School Year 2025-2026. The local setting was relevant to PBIL because Grade 10 Science competencies can be connected to authentic phenomena involving ecosystems, biodiversity, climate, Earth processes, heredity, and chemical processes that learners encounter in their broader environment.

Participants and Sampling Technique

Complete enumeration was used for the accessible Grade 10 population included in the actual comparative study. Ninety-seven learners participated: 49 in one intact section assigned as the experimental group and 48 in another intact section assigned as the comparison group. Existing class organization was maintained throughout the study. A separate intact Grade 10 section with comparable characteristics was used only for pilot testing and validation of the instruments and was excluded from the final comparative analysis.

Research Instrument

Two researcher-developed instruments were used: the Scientific Literacy Test and the Critical Thinking Skills Test. The Scientific Literacy Test assessed learners' ability to explain scientific phenomena, evaluate and design scientific inquiry, and interpret scientific data and evidence in line with the OECD science-literacy framework. The Critical Thinking Skills Test used contextualized science situations to assess interpretation, analysis, evaluation, inference, explanation, and self-regulation based on Facione's (1990) framework. The tests consisted primarily of contextualized multiple-choice items requiring higher-order reasoning and evidence-based decision-making.

Both instruments underwent expert review by science education specialists, research experts, and experienced Grade 10 Science teachers. Content validity was established through the Content Validity Index following Polit and Beck (2006). After revision, the instruments were pilot-tested with non-participating Grade 10 learners of comparable characteristics. Internal consistency was assessed using Cronbach's alpha (Cronbach, 1951), and the thesis reports satisfactory reliability without presenting the numerical coefficients. Item analysis considered difficulty, discrimination, and distractor efficiency; items not meeting acceptable criteria were revised, replaced, or discarded before final administration.

Data Gathering Procedure

After securing permission from the school administration, the researcher coordinated the schedule and procedures with the school principal and the Grade 10 classes. Participants were informed of the study's purpose and procedures, and the finalized Scientific Literacy Test and Critical Thinking Skills Test were administered as pretests to both groups. The experimental group then received PBIL through researcher-prepared lessons aligned with Grade 10 Science competencies, using authentic phenomena, guided inquiry, collaborative investigation, scientific discussion, evidence-based reasoning, and reflection. The comparison group covered the same competencies using the school's conventional Science instruction during the same instructional period. Both groups subsequently completed the same tests as posttests.

Completed test papers were retrieved, checked, scored, coded, and verified before data were encoded in Microsoft Excel and appropriate statistical software. The resulting dataset was then analyzed in accordance with the research questions and used as the basis for the conclusions and the proposed Instructional Enhancement Plan.

Data Analysis

Means and standard deviations described scientific literacy and critical thinking before and after instruction. Paired-samples t-tests examined pretest-posttest differences within the experimental group. Independent-samples t-tests compared experimental and comparison posttest means and also compared gain

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scores, computed as posttest minus pretest. All inferential tests used a .05 level of significance, consistent with the procedures described by Field (2018).

Ethical Consideration

The study was implemented only after authorization from the school administration. Participation was voluntary, and informed consent was obtained from learners and, where required, from parents or guardians. The objectives, procedures, confidentiality protections, and participants' rights were explained before data collection. Identities were kept confidential, information was used only for academic and research purposes, and the use of intact classes avoided unnecessary disruption of the regular instructional program.

RESULTS AND DISCUSSION

Levels of Scientific Literacy and Critical Thinking Before and After PBIL

Both groups entered the study with low performance in scientific literacy and critical thinking. The experimental group's scientific-literacy mean increased from 8.96 (SD = 3.09) to 19.84 (SD = 3.64), shifting from Low to High, while the comparison group increased from 11.81 (SD = 3.80) to 14.75 (SD = 3.78), reaching only Moderate. A similar pattern appeared in critical thinking: the experimental group rose from 9.71 (SD = 3.24) to 21.18 (SD = 3.98), whereas the comparison group rose from 12.00 (SD = 2.94) to 15.21 (SD = 2.87).

Table 1. *Pretest and Posttest Levels of Scientific Literacy and Critical Thinking*

Outcome	Group	Test	Mean	SD	Interpretation
Scientific literacy	Experimental	Pretest	8.96	3.09	Low
Scientific literacy	Experimental	Posttest	19.84	3.64	High
Scientific literacy	Comparison	Pretest	11.81	3.80	Low
Scientific literacy	Comparison	Posttest	14.75	3.78	Moderate
Critical thinking	Experimental	Pretest	9.71	3.24	Low
Critical thinking	Experimental	Posttest	21.18	3.98	High
Critical thinking	Comparison	Pretest	12.00	2.94	Low
Critical thinking	Comparison	Posttest	15.21	2.87	Moderate

The larger descriptive gains in the PBIL group are consistent with the premise that authentic inquiry provides learners with repeated opportunities to connect concepts with observable situations, interpret data, and justify explanations. This pattern accords with science-education frameworks that emphasize participation in scientific practices rather than memorization (NRC, 2012; OECD, 2025) and with reviews showing that inquiry and authentic application are central to the development of scientific literacy (Roy et al., 2025).

Pretest-Posttest Differences Within the Experimental Group

Paired-samples t-tests confirmed that the experimental group's improvements were statistically significant. Scientific literacy increased by 10.88 points, $t = 42.61$, $p < .001$, while critical thinking increased by 11.47 points, $t = 30.80$, $p < .001$. Thus, the null hypotheses of no pretest-posttest difference were rejected for both outcomes.

Table 2. *Paired-Samples Tests for the Experimental Group*

Outcome	Pretest M (SD)	Posttest M (SD)	Mean Difference	t	p	Decision
Scientific literacy	8.96 (3.09)	19.84 (3.64)	10.88	42.61	< .001	Reject H0
Critical thinking	9.71 (3.24)	21.18 (3.98)	11.47	30.80	< .001	Reject H0

The statistically significant changes support the instructional logic of PBIL. Learners did not merely receive explanations; they observed phenomena, formulated questions, investigated relationships, interpreted evidence, collaborated, and reflected on explanations. Such practices closely match the cognitive operations

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emphasized in inquiry research (Pedaste et al., 2015) and critical-thinking interventions that require active analysis and justification (Abrami et al., 2015). The pattern also reflects experiential learning, in which engagement with concrete problems and reflection supports conceptual development (Kolb, 1984).

Posttest Differences Between Experimental and Comparison Groups

Independent-samples t-tests showed significant posttest advantages for learners exposed to PBIL. In scientific literacy, the experimental group ($M = 19.84$, $SD = 3.64$) exceeded the comparison group ($M = 14.75$, $SD = 3.78$) by 5.09 points, $t = 6.75$, $p < .001$. In critical thinking, the experimental group ($M = 21.18$, $SD = 3.98$) exceeded the comparison group ($M = 15.21$, $SD = 2.87$) by 5.97 points, $t = 8.47$, $p < .001$.

Table 3. *Posttest Differences Between Experimental and Comparison Groups*

Outcome	Experimental M (SD)	Comparison M (SD)	Mean Difference	t	p	Decision
Scientific literacy	19.84 (3.64)	14.75 (3.78)	5.09	6.75	< .001	Reject H0
Critical thinking	21.18 (3.98)	15.21 (2.87)	5.97	8.47	< .001	Reject H0

The between-group findings indicate that improvement was not limited to the passage of instructional time; the PBIL learning environment was associated with substantially stronger end-of-intervention performance. This result is consistent with evidence that guided inquiry improves scientific reasoning and conceptual understanding (Furtak et al., 2012) and that inquiry-based instruction can strengthen critical thinking when learners evaluate evidence and defend conclusions (Arifin et al., 2025). It also supports the constructivist assumption that learners develop deeper understanding when they actively organize and revise knowledge through meaningful experience (Piaget, 1952).

Differences in Mean Gain Scores

Gain-score comparisons further demonstrated the magnitude of the difference in improvement. For scientific literacy, the experimental group gained 10.88 points ($SD = 1.79$), compared with 2.94 points ($SD = 1.10$) in the comparison group; the 7.94-point difference was significant, $t = 26.29$, $p < .001$. For critical thinking, the experimental group gained 11.47 points ($SD = 2.61$), compared with 3.21 points ($SD = 1.37$) in the comparison group; the 8.26-point difference was also significant, $t = 19.48$, $p < .001$.

Table 4. *Mean Gain Score Differences Between Groups*

Outcome	Experimental Gain M (SD)	Comparison Gain M (SD)	Mean Difference	t	p	Decision
Scientific literacy	10.88 (1.79)	2.94 (1.10)	7.94	26.29	< .001	Reject H0
Critical thinking	11.47 (2.61)	3.21 (1.37)	8.26	19.48	< .001	Reject H0

These gain patterns strengthen the interpretation that PBIL offered an instructional advantage over the conventional approach used during the study. The findings align with the broader evidence that scientific reasoning develops through appropriately scaffolded inquiry and with contemporary calls for phenomenon-centered, coherent science learning experiences (Walker & Nouri, 2025). They also reinforce Facione's (1990) view that critical thinking is best understood through active cognitive processes such as analysis, evaluation, inference, explanation, and self-regulation rather than through factual recall alone.

Instructional Enhancement Plan

Based on the statistical findings, the thesis proposed an Instructional Enhancement Plan to sustain and strengthen PBIL. The plan combines classroom-level inquiry practices with teacher development, contextualized resources, assessment alignment, and school-level institutional support.

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Table 5. *Condensed Instructional Enhancement Plan for PBIL*

Area	Key Activities/Strategies	Responsible / Time Frame	Success Indicator
Scientific Literacy	Use authentic local/global phenomena, multimedia, current events, and environmental issues as lesson anchors.	Science Teachers, Department Head / Throughout school year	At least 85% of learners proficient in explaining scientific phenomena.
Scientific Inquiry	Conduct inquiry-based laboratory investigations, mini research, and guided investigations emphasizing hypotheses, design, and data collection.	Science Teachers / Every grading period	Improved performance in inquiry-based assessment tasks.
Interpretation of Scientific Evidence	Use data interpretation, claim-evidence-reasoning, graph analysis, and evidence-evaluation tasks.	Science Teachers / Weekly	At least 80% accuracy in interpreting and justifying scientific evidence.
Critical Thinking Skills	Use problem-based learning, collaborative discussion, argumentation, reflective journals, and scientific debates.	Science Teachers / Throughout each quarter	Improved critical-thinking assessment scores.
Teacher Competence	Conduct LAC sessions, in-service training, peer mentoring, demonstration teaching, and collaborative lesson planning on PBIL.	School Head, Science Coordinator, Science Teachers / Quarterly	Consistent PBIL implementation with fidelity.
Instructional Materials	Develop localized lesson exemplars, phenomenon banks, inquiry worksheets, performance tasks, and digital resources.	Science Department / Whole school year	Validated PBIL materials available for Grade 10 Science lessons.
Assessment Practices	Develop higher-order and performance-based tasks, authentic investigations, portfolios, and rubric-based evaluation.	Science Teachers / Every grading period	Assessment results reflect improved higher-order thinking and scientific reasoning.
Sustainability of PBIL	Include PBIL in the Science Improvement Plan, collaborative lesson study, classroom observations, and recognition of effective practice.	School Administration, Department Head / Annually	Sustained PBIL implementation across Grade 10 Science classes.

The plan is consistent with the study's central implication: PBIL effectiveness depends not only on individual lessons but also on coherent instructional design, teacher facilitation, authentic assessment, and sustained organizational support. These priorities are consistent with evidence on visible learning and instructional quality (Hattie, 2023) and with national expectations for inquiry-oriented and contextualized Science instruction (DepEd, 2016, 2023).

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CONCLUSION

The study demonstrated that Grade 10 learners began with limited scientific literacy and critical thinking but improved substantially after instruction. Learners exposed to Phenomenon-Based Inquiry Learning achieved high posttest levels in both outcomes, whereas learners receiving conventional Science instruction reached only moderate levels. The experimental group's pretest-posttest gains were statistically significant for scientific literacy and critical thinking, and its posttest and gain scores were significantly higher than those of the comparison group.

These results indicate that PBIL was an effective instructional approach within the conditions of the study. Anchoring instruction on authentic scientific phenomena and engaging learners in questioning, investigation, evidence analysis, scientific explanation, collaboration, and reflection supported both the application of scientific knowledge and the development of higher-order reasoning. The study therefore contributes localized quasi-experimental evidence for phenomenon-centered inquiry in Philippine Grade 10 Science.

The resulting Instructional Enhancement Plan translates the findings into a practical school-based framework by linking authentic phenomena, inquiry, evidence interpretation, critical thinking, teacher capability development, contextualized materials, aligned assessment, and implementation monitoring. The findings are limited to the participating intact classes and the instructional period covered by the study; long-term retention and other learner or contextual variables were not measured.

Recommendation

School administrators should support wider and sustained implementation of PBIL through instructional supervision, adequate learning resources, classroom monitoring, and professional-development opportunities that strengthen inquiry facilitation. Science teachers should integrate authentic phenomena, collaborative investigation, evidence-based reasoning, and reflective learning into regular Grade 10 Science instruction while aligning these activities with curriculum competencies and assessment expectations.

The Department of Education and school-based professional learning structures may consider incorporating PBIL into Learning Action Cell sessions, in-service training, curriculum enrichment, lesson development, and assessment design. Curriculum and resource developers should continue producing localized phenomenon banks, inquiry worksheets, performance tasks, and rubric-based assessments that measure scientific literacy and critical thinking rather than factual recall alone.

Future research should replicate the study in other schools, grade levels, and science contexts using larger samples and longer intervention periods. Studies may also examine retention and additional outcomes identified in the thesis, including scientific process skills, problem-solving, creativity, collaboration, environmental literacy, and academic achievement.

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