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Inquiry-Based Laboratory Instruction and Scientific Literacy of STEM Students in the First Congressional District of Batangas

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Abstract

Scientific literacy remains a key goal in STEM education, particularly in the Philippines where students perform below global standards in international assessments. This study examined the relationship between inquiry-based laboratory instruction and the scientific literacy of STEM students in the First Congressional District of Batangas. A quantitative descriptive-correlational design was used, involving 104 STEM teachers selected through stratified random sampling. Data were collected using a validated questionnaire and analyzed using weighted mean and Pearson's r at a 0.01 level of significance. Results showed that both inquiry-based laboratory instruction and scientific literacy were at above-average levels across all domains. However, no statistically significant relationship was found between the variables ($p > 0.01$). Challenges included limited laboratory resources, time constraints, and insufficient instructional support. The findings suggest that other factors may influence scientific literacy and highlight the need for improved instructional design and resource provision.

Keywords: *Inquiry-Based Instruction, Scientific Literacy, STEM education, Laboratory learning*

Introduction

Scientific literacy is a central goal of modern education, particularly in Science, Technology, Engineering, and Mathematics. In an increasingly complex and technology-driven society, students are expected not only to acquire scientific knowledge but also to evaluate information critically, formulate evidence-based conclusions, and apply scientific principles to real-world situations. These competencies are essential for informed decision-making and meaningful participation in societal and global issues (Wahyudi et al., 2024).

Despite its importance, scientific literacy remains a persistent challenge in the Philippines. International large-scale assessments such as the Programme for International Student Assessment have consistently reported that Filipino students perform below global standards. In PISA 2018, Filipino students scored significantly below the OECD average, and similar results were observed in 2022, indicating systemic issues in science education (OECD, 2022). These findings suggest gaps in instructional strategies, limited opportunities for practical engagement, and insufficient development of higher-order thinking skills (Calleja et al., 2023; Bernardo, 2023). Such conditions highlight the urgent need for effective and innovative teaching approaches.

One approach that has gained considerable attention is inquiry-based laboratory instruction. Rooted in Constructivism, this pedagogical strategy emphasizes active learning through questioning, experimentation, and evidence-based reasoning (Hajie & Amos, 2024). Unlike traditional lecture-based methods, inquiry-based instruction engages students in the processes of the Scientific Method, allowing them to develop essential skills such as hypothesis formulation, data analysis, and problem-solving (de Jong, 2023). Through hands-on laboratory experiences, students construct knowledge and deepen conceptual understanding (Alarcon, 2023).

The rationale of this study is grounded in the premise that structured inquiry-based laboratory instruction can significantly enhance students' scientific literacy. By promoting active engagement and critical thinking, this approach addresses the limitations of passive learning and fosters the development of essential scientific competencies (Mulyono et al., 2024). However, there remains a need to examine its effectiveness within specific local contexts, particularly among STEM students in the First Congressional District of Batangas.

Existing literature underscores the effectiveness of inquiry-based approaches in improving scientific literacy. Inquiry-based science teaching promotes active student engagement by encouraging learners to formulate questions, design experiments, analyze data, and draw conclusions (Kotsis, 2024). These processes reflect the core principles of scientific inquiry and are essential for developing a deeper understanding of scientific concepts.

Research indicates that students exposed to inquiry-based learning demonstrate higher levels of academic achievement, critical thinking, and scientific interest compared to those taught through traditional methods (Gormally et al., 2021). These students exhibit improved abilities in evaluating scientific information, comprehending complex concepts, and applying knowledge in meaningful contexts (Fidelino & Chua, 2021). Such competencies are integral components of scientific literacy.

Furthermore, the integration of technology, including virtual laboratory environments, has expanded the scope of inquiry-based learning. Virtual labs enable students to explore scientific phenomena and engage with abstract concepts in interactive ways, thereby improving their ability to analyze and interpret data (Ahmad et al., 2021; Putri et al., 2021). This approach is particularly beneficial in addressing resource limitations while maintaining meaningful learning experiences.

The literature also emphasizes the importance of scaffolding in inquiry-based instruction. Guided support from teachers helps students develop skills in hypothesis formulation, experimental design, and data interpretation (de Jong, 2023). Without proper scaffolding, students may struggle to engage effectively in inquiry tasks, highlighting the need for structured instructional support.

In addition, inquiry-based laboratory instruction contributes to the development of essential scientific skills, including technical and manipulative skills, experimental skills, and problem-solving abilities (Ismail & Matore, 2024; Hajie & Amos, 2024). Through hands-on activities, students gain practical experience in conducting experiments and solving real-world scientific problems, which strengthens their scientific literacy.

Despite these advantages, several challenges in implementing inquiry-based instruction have been identified. These include limited laboratory resources, time constraints, and insufficient teacher training (Arifin et al., 2025; Waked et al., 2024). Such constraints may hinder the effective integration of inquiry-based approaches in classroom settings.

Notably, while numerous studies have explored the general benefits of inquiry-based learning, limited research has specifically examined its relationship with distinct dimensions of scientific literacy—such as information evaluation and comprehension, hypothesis development and testing, and data analysis and interpretation—within localized educational contexts (Tiongco et al., 2024; Lu-ong, 2023). This gap is particularly evident in studies focusing on STEM students in specific regions of the Philippines, such as the First Congressional District of Batangas.

This study aims to examine the relationship between inquiry-based laboratory instruction and the scientific literacy of STEM students in the First Congressional District of Batangas during the school year 2024–2025.

Specifically, it seeks to answer the following questions:

1 What is the extent of utilization of Inquiry-based laboratory instruction as assessed by the teachers themselves in terms of:
    1.1 technical and manipulative skills;
    1.2 experimental skills; and
    1.3 problem solving skills?

2 How may the STEM students level of Scientific Literacy be assessed by the teacher- respondents in relation to:
    2.1 information evaluation and comprehension;

    2.2 hypothesis development and testing; and
    2.3 data analysis and interpretation?
3 Is there any significant relationship between the assessments on the extent of utilization of Inquiry-based laboratory instruction and on the STEM students level of Scientific Literacy?
4 What are the challenges faced by the Science teachers in laboratory instruction among STEM students?
5 Based on the analysis of the study, what enrichment inquiry-based laboratory instruction activities may be proposed?

Methodology

Research Design

This study utilized a **quantitative descriptive-correlational research** design to investigate the relationship between inquiry-based laboratory instruction and the scientific literacy of STEM students. The design involved the systematic collection and statistical analysis of numerical data to describe variables and determine the relationships between them. A structured, research-made Likert-scale questionnaire served as the primary data-gathering instrument, complemented by an interview to enrich and validate the findings. This approach enabled the researcher to objectively measure the extent of inquiry-based laboratory instruction and its influence on students' scientific literacy (McLeod, 2019).

Participants of the Study

The respondents of the study were STEM teachers from Senior High Schools in the First Congressional District of Batangas. From a total population of 143 teachers, 104 respondents were selected using the Raosoft sample size calculator with a 5% margin of error. Stratified random sampling was employed to ensure proportional representation across schools, as shown in the distribution table of participants.

Research Instruments

The primary instrument used in this study was a researcher-made questionnaire designed to measure STEM teachers' assessment of inquiry-based laboratory instruction and its influence on students' scientific literacy. The questionnaire covered three domains: technical and manipulative skills, experimental skills, and problem-solving skills, as well as components of scientific literacy such as information evaluation, hypothesis development, and data interpretation.

The instrument underwent validation through expert review (face validity) and pilot testing with 15 teachers from a non-participating school to ensure clarity, reliability, and appropriateness. In addition, semi-structured interviews were conducted with selected Science teachers to gather qualitative insights that supported and enriched the quantitative data.

Data Gathering Procedure

The researcher secured permission from the Public Schools District Supervisors and school principals before data collection. Upon approval, questionnaires were distributed electronically to the selected STEM teacher-respondents through an online survey platform.

Participants were informed about the purpose of the study and provided informed consent prior to participation, ensuring voluntary involvement and confidentiality. Data collection was conducted over a two-week period, with follow-up reminders sent to non-respondents. Completed responses were retrieved digitally, ensuring data accuracy, security, and confidentiality. The researcher also conducted interviews with selected teachers to further support the quantitative findings.

Data Analysis

The data collected were analyzed using appropriate statistical tools to answer the research questions.

1. Weighted Mean was used to determine the level of inquiry-based laboratory instruction and scientific literacy among STEM students as perceived by teachers.
2. Ranking was applied to identify the relative importance of each indicator based on computed means.
3. Pearson’s r correlation coefficient was used to determine the significant relationship between inquiry-based laboratory instruction and students’ scientific literacy.
4. A 0.01 level of significance (2-tailed test) was used as the basis for accepting or rejecting the null hypothesis.

All statistical computations were used to provide objective and evidence-based interpretations of the data.

Results

This section presents the findings of the study on the extent of utilization of inquiry-based laboratory instruction, the level of scientific literacy of STEM students, the relationship between the variables, and the challenges encountered by teachers.

Section 1: Extent of Utilization of Inquiry-Based Laboratory Instruction

Table 1.1 Technical and Manipulative Skills

1.1. technical and manipulative skills; The learners…	**Weighted Mean**	**Verbal Interpretation**	**Rank**
1. display increased ability to handle laboratory equipment safely	3.1346	Above Average	5
2. show confidence when attempting to set up laboratory apparatus independently	3.0865	Above Average	7
3. demonstrate proficiency in using laboratory instruments after inquiry-based instruction	3.1058	Above Average	6
4. reveal their skill in troubleshooting equipment during experiments	3.0769	Above Average	8
5. exhibit their capacity to measure and record data accurately	3.2404	Above Average	3
6. consistently follow safety protocols during laboratory activities	3.2308	Above Average	4
7. effectively calibrate laboratory instruments before use	3.4615	Above Average	1
8. show skill in maintaining and cleaning laboratory equipment properly	3.2788	Above Average	2
9. demonstrate dexterity in handling delicate or sensitive lab materials	3.0288	Above Average	9
10. accurately prepare chemical solutions or samples as required by the experiment	2.9808	Above Average	10
Composite Mean	**3.1625**	**Above Average**	

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Table 1.1 shows an above-average extent of utilization of inquiry-based lab instruction in technical and manipulative skills (Composite Mean = 3.1625). Calibrating laboratory instruments ranks highest (WM = 3.4615), while preparing chemical solutions ranks lowest (WM = 2.9808).

Table 1.2. Experimental Skills

1.2. experimental skills; and The learners…	**Weighted Mean**	**Verbal Interpretation**	**Rank**
1. display ability to identify appropriate methods for data collection	3.3365	Above Average	3
2. show confidence when attempting to modify experimental procedures when necessary	3.1151	Above Average	10
3. demonstrate proficiency in replicating experiments to verify results	3.2404	Above Average	5
4. reveal their skill in selecting suitable materials for experiments	3.2019	Above Average	6
5. exhibit their capacity to design their own experiments	3.1923	Above Average	7
6. effectively record observations systematically during experiments	3.3558	Above Average	1
7. analyze experimental data to identify trends and anomalies	3.2885	Above Average	4
8. adjust experimental variables thoughtfully to test hypotheses	3.1538	Above Average	9
9. use appropriate controls to ensure validity of experiments	3.1827	Above Average	8
10. interpret experimental results to draw logical conclusions	3.3462	Above Average	2
Composite Mean	**3.2413**	**Above Average**	

Table 1.2 suggests an above-average extent of utilization of inquiry-based lab instruction in experimental skills (Composite Mean = 3.2413). Recording observations systematically ranks highest (WM = 3.3558), whereas modifying experimental procedures ranks lowest (WM = 3.1151).

Table1.3. Problem Solving Skills

1.3 problem solving skills. The learners…	**Weighted Mean**	**Interpretation**	**Rank**
1.identify problems during experiments and find solutions	3.2481	Above Average	8
2. show confidence in attempting to solve scientific problems	3.2019	Above Average	10
3. demonstrate proficiency in applying scientific concepts to real-world problems	3.3365	Above Average	5
4. reveal their skill in proposing proposing multiple solutions to a problem.	3.3654	Above Average	2
5. exhibit their capacity to work collaboratively in solving lab challenges.	3.3173	Above Average	7
6. apply critical thinking to troubleshoot unexpected results.	3.3558	Above Average	3
7. evaluate the effectiveness of different approaches to solving a problem.	3.3750	Above Average	1
8. use evidence to support or revise hypotheses.	3.3462	Above Average	4
9. communicate problem-solving strategies clearly to peers.	3.3212	Above Average	6
10. reflect on mistakes made during experiments to improve future performance.	3.2212	Above Average	9
Composite Mean	**3.3038**	**Above Average**	

. Table 1.3 shows that students demonstrate an above-average level of problem-solving skills (Composite Mean = 3.3038) under inquiry-based laboratory instruction. The highest-rated skill is evaluating different problem-solving approaches (WM = 3.3750), followed by proposing multiple solutions (WM = 3.3654) and critical thinking in troubleshooting (WM = 3.3558).

Lower-ranked skills include confidence in solving problems (WM = 3.2019) and reflection on mistakes (WM = 3.2212), though still above average. Overall, the results indicate strong analytical and critical thinking skills, with slight room for improvement in self-confidence and reflective practices.

Section 2: Level of Scientific Literacy of STEM Students

Table 2.1 Information Evaluation and Comprehension

2.1. information evaluation and comprehension; The learners…	**Weighted Mean**	**Verbal Interpretation**	**Rank**
1. display ability in distinguishing between credible and non-credible scientific sources	3.2500	Above Average	3
2. show confidence when attempting to interpret scientific graphs and tables	3.1923	Above Average	5
3. demonstrate persistence and resilience in connecting new information to prior scientific knowledge	3.2404	Above Average	4
4. reveal their skill in summarizing key concepts from scientific texts accurately	3.2692	Above Average	2
5. exhibit their capacity to evaluate the reliability of data presented in class	3.2788	Above Average	1
6. critically assess the credibility of scientific claims encountered in media or online sources	3.1442	Above Average	6.5
7. effectively distinguish between facts, opinions, and hypotheses in scientific discussions	3.1058	Above Average	8
8. demonstrate ability to synthesize information from multiple scientific texts	3.1442	Above Average	6.5
9. apply scientific vocabulary correctly when explaining concepts	3.0673	Above Average	10
10. recognize bias or misinformation in scientific reports or articles	3.0769	Above Average	9
Composite Mean	**3.1769**	**Above Average**	

Table 2.1 presents that students have an above-average level of scientific literacy (Composite Mean = 3.1769). The highest-ranked skill is evaluating the reliability of data (WM = 3.2788)**,** followed by summarizing key concepts (WM = 3.2692) and distinguishing credible sources (WM = 3.2500)**.**

Lower-ranked skills include applying scientific vocabulary (WM = 3.0673**)** and **recognizing** bias or misinformation (WM = 3.0769). Overall, students demonstrate strong evaluation and comprehension skills, with minor areas for improvement in communication and critical analysis.

Table 2.2 Hypothesis and Development and Testing

2.2. hypothesis development and testing; The learners…	**Weighted Mean**	**Verbal Interpretation**	**Rank**
1. display ability in formulating testable hypotheses during laboratory activities.	3.2019	Above average	6.5
2. show confidence when attempting to identify variables in an experiment.	3.2019	Above average	6.5
3. demonstrate persistence and resilience in revising their hypotheses based on experimental results.	3.1992	Above average	9
4. reveal their skill in justifying their hypotheses using scientific reasoning.	3.1731	Above average	8
5. exhibit their capacity to design experiments to test their hypotheses.	3.1058	Above average	10
6. identify dependent and independent variables accurately in experimental setups.	3.2115	Above average	4.5
7. modify hypotheses logically based on preliminary observations.	3.2115	Above average	4.5
8. explain the rationale behind their experimental design choices.	3.2404	Above average	1.5
9. predict possible outcomes based on their hypotheses before testing.	3.212	Above average	3
10. evaluate the strengths and limitations of their hypotheses after experimentation.	3.2404	Above average	1.5
Composite Mean	**3.1952**	**Above average**	

Table 2.2 indicates an above-average level of scientific literacy in hypothesis development and testing (Composite Mean = 3.1952). Top skills include explaining experimental design rationale and evaluating hypotheses (WM = 3.2404), while designing experiments ranks lowest (WM = 3.1058).

Table 2.3 Data analysis and interpretation

2.3. data analysis and interpretation; The learners…	**Weighted Mean**	**Verbal Interpretation**	**Rank**
1. display ability in identifying patterns in experimental data.	3.2481	Above average	4
2. show confidence when attempting to record data accurately during laboratory experiments.	3.3942	Above average	1
3. demonstrate persistence and resilience in drawing valid conclusions from data analysis.	3.3846	Above average	2
4. reveal their skill in interpreting the meaning of results from experiments.	3.2596	Above average	6
5. exhibit their capacity to use graphs and charts to present their findings.	3.1157	Above average	10
6. use statistical tools or methods to analyze experimental data appropriately.	3.2212	Above average	7
7. compare their data with expected results and explain discrepancies.	3.2788	Above average	5
8. draw connections between experimental data and scientific theories.	3.2308	Above average	8
9. draw connections between experimental data and scientific theories.	3.2019	Above average	9
10. reflect on data collection methods to improve accuracy in future experiments.	3.3365	Above average	3
Composite Mean	**3.2721**	**Above average**	

Table 2.3 shows an above-average level of scientific literacy in data analysis and interpretation (Composite Mean = 3.2721). Accurate data recording (WM = 3.3942) and drawing valid conclusions (WM = 3.3846) rank highest, whereas using graphs and charts ranks lowest (WM = 3.115

Section 3 Relationship between the assessment on extent of utilization of Inquiry based laboratory Instruction and on the level of Scientific Literacy of STEM students

Variables	Information evaluation and comprehension	Hypothesis development and testing	Data analysis and interpretation
	p-value verbal int.	r-value	p-value verbal int.
Technical manipulative skills	0.269** HS	0.000	0.724** HS
Experimental Skills	0.866** HS	0.000	0.844** HS
Problem solving skills	0.782** HS	0.000	0.790** HS

Note: 0.01 level of significance (2-tailed test)

Table 3 suggests a highly significant positive relationship between inquiry-based laboratory instruction and students’ scientific literacy (p = 0.000). Experimental skills exhibit the strongest correlations (r = 0.866, 0.844, 0.835), followed by problem-solving skills (r = 0.782–0.738), while technical manipulative skills show relatively lower but still significant relationships (r = 0.269–0.730).

Section 4. Challenges Encountered by the Science Teachers in Laboratory Instruction among STEM students

Table 4.1 Challenges Encountered by Science Teachers

Challenges	Weighted Mean	Verbal Interpretation	Rank
1. I notice a lack of laboratory resources that limits the effectiveness of inquiry-based instruction.	3.2788	Agree	4
2. I struggle to maintain students' interest due to large class sizes making it difficult to manage inquiry-based lab activities.	3.0865	Agree	1
3. I witness the students' lack of prior lab experience bringing challenges during inquiry-based activities.	3.2212	Agree	2
4. I observe that limited access to updated laboratory equipment affects lab instruction.	3.3269	Agree	6
5. I notice that time constraints hinder the implementation of inquiry-based labs.	3.2981	Agree	10
6. I find it hard to provide individualized support to students during hands-on inquiry activities.	3.0769	Agree	7
7. I face challenges in integrating technology effectively during inquiry-based laboratory sessions.	3.7596	Agree	5
8. I observe that safety concerns restrict the scope of experiments I can perform in the lab.	3.1157	Agree	8
9. I observe that inconsistent student attendance disrupts the continuity of inquiry-based lab instruction.	3.1346	Agree	9
10. I notice that insufficient training on inquiry-based methods limits my confidence in conducting lab instruction.	3.1635	Agree	3
Composite Mean	**3.3038**		

Table 4 presents that challenges in inquiry-based laboratory instruction are generally agreed upon (Composite Mean = 3.3038). Difficulty in integrating technology ranks highest (WM = 3.7596), followed by limited access to updated equipment (WM = 3.3269) and time constraints (WM = 3.2981), whereas providing individualized support ranks lowest (WM = 3.0769).

Table 4.2 Thematic Analysis on Teachers' Challenges Encountered in Lab Instruction

Challenges	Themes	Description
Lack of laboratory resources that limits the effectiveness of inquiry-based instruction	Resource Limitations and Equipment Scarcity	Challenges related to insufficient, damaged, or lack of laboratory resources and equipment.
Maintain students' interest due to large class sizes	Class Size and Classroom Management	Difficulties managing large classes, organizing groups, and maintaining safety and engagement.
Lack of prior lab experience bringing challenges during inquiry-based activities	Safety Protocols and Safety Concerns	Balancing safety measures with the need for open-ended, exploratory activities.
Insufficient training on inquiry-based methods limits my confidence in conducting lab instruction	Teacher Preparedness and Professional Development	Need for training, skill development, and confidence in facilitating inquiry-based labs.
Time constraints hinder the implementation of inquiry-based labs	Time Constraints and Curriculum Pressure	Limited time for conducting thorough inquiry activities within the curriculum schedule.
Challenges in integrating technology effectively during inquiry-based laboratory sessions	Infrastructure and Laboratory Facilities	Inadequate laboratory spaces and facilities that restrict inquiry-based activities.
Limited access to updated laboratory equipment affects lab instruction	Support and Administrative Backing	Lack of institutional support, resources, and policy backing for inquiry practices.
Inconsistent student attendance disrupts the continuity of inquiry-based lab instruction	Student-Related Challenges	Variability in student motivation, attitude, and behavior affecting implementation.

The summary of challenges indicates that issues are mainly rooted in resource limitations, teacher preparedness, time constraints, and student-related factors. These challenges highlight the need for improved facilities, training, and institutional support to effectively implement inquiry-based laboratory instruction.

Section 5. Proposed Enrichment Activities for Inquiry-Based Laboratory Instruction.

To further enhance the effectiveness of inquiry-based laboratory instruction, this study proposes enrichment activities designed to strengthen STEM students' scientific skills and higher-order thinking. These activities aim to provide opportunities for independent experimentation, critical analysis, and real-world application, addressing challenges such as limited laboratory experience, resource constraints, and time limitations. By incorporating guided experiments, open-ended investigations, and collaborative tasks, students are expected to develop deeper comprehension, problem-solving abilities, and confidence in conducting scientific inquiry.

These activities were developed to address the challenges identified in the study, such as limited prior laboratory experience, insufficient exposure to independent experimentation, and constraints in resources and time. Each activity targets specific skills and competencies, promoting a more engaging, hands-on, and reflective learning environment.

Overall, these enrichment activities aim to provide a balanced combination of guided instruction and independent inquiry, developing both foundational laboratory skills and higher-order thinking abilities. By implementing these activities, the teacher-researcher seeks to enhance students' engagement, scientific literacy, and competence in inquiry-based learning.

Discussion

This study examined the role of inquiry-based laboratory instruction in the scientific literacy of STEM students. The discussion integrates the empirical findings with existing literature, highlighting convergences, contextual distinctions, implications, and constraints in interpretation.

The findings indicate that inquiry-based laboratory instruction is consistently implemented across technical and manipulative skills ($M = 3.1625$), experimental skills ($M = 3.2413$), and problem-solving skills ($M = 3.3038$), with the highest mean observed in problem-solving.

These results align with the conceptualization of inquiry-based science education as an active learning approach that engages students in questioning, experimentation, and evidence-based reasoning (Kotsis, 2024). The observed emphasis on problem-solving further supports prior findings that inquiry environments foster higher-order cognitive engagement by requiring learners to apply procedural and conceptual knowledge in structured investigative tasks (Ismail & Matore, 2024; Hajie & Amos, 2024).

From a pedagogical perspective, the relatively balanced distribution across skill domains suggests that inquiry activities are not isolated procedural exercises but are embedded as structured learning experiences that simultaneously develop multiple scientific competencies.

The results demonstrate above-average scientific literacy across all domains: information evaluation and comprehension ($M = 3.1769$), hypothesis development and testing ($M = 3.1952$), and data analysis and interpretation (M = 3.2721), with the highest performance observed in data analysis and interpretation.

This pattern is consistent with empirical evidence indicating that inquiry-based learning environments enhance learners' capacity to interpret scientific information and apply conceptual understanding in authentic contexts (Gormally et al., 2021; Fidelino & Chua, 2021). The prominence of data analysis and interpretation further corresponds with findings by Ahmad et al. (2021) and Putri et al. (2021), who emphasized that structured inquiry and technology-supported experimentation strengthen learners' ability to process and represent empirical data.

The relative strength in analytical domains suggests that repeated exposure to laboratory-based investigation may reinforce procedural familiarity with data handling, while conceptual domains such as hypothesis formulation remain comparatively less pronounced, though still within above-average levels.

The statistical findings reveal no significant associations between inquiry-based laboratory instruction and all dimensions of scientific literacy. Across technical and manipulative skills, experimental skills, and problem-solving skills, relationships with scientific literacy indicators yielded significant p-values at the 0.01 level.

These results are consistent with de Jong (2023), who emphasized that scaffolding in inquiry-based environments is essential for supporting learners in hypothesis generation, experimental structuring, and interpretation of evidence. The findings also extend prior research by Gormally et al. (2021), which established general gains in scientific reasoning, by providing more granular evidence linking specific laboratory skill domains with discrete components of scientific literacy.

Importantly, the uniformity of statistical significance across all skill-literacy pairings suggests that inquiry-based laboratory instruction functions as an integrated pedagogical system rather than a single-skill intervention. However, while no statistical significance indicates association, it does not establish causal direction; thus, results should be interpreted as relational rather than determinative.

The study identified three primary constraints: limited laboratory equipment, time constraints, and insufficient laboratory resources. These findings are consistent with broader international and regional literature highlighting structural barriers to inquiry-based science implementation (Arifin et al., 2025; Waked et al., 2024).

Resource limitations may restrict the complexity and frequency of inquiry tasks, thereby constraining opportunities for iterative experimentation and extended investigation. Similarly, time constraints reduce instructional flexibility, limiting the extent to which inquiry cycles—questioning, hypothesizing, testing, and revising—can be fully enacted within classroom periods.

These constraints highlight a persistent implementation gap between inquiry-based pedagogical theory and classroom realities, particularly in resource-dependent laboratory environments.

The findings have several pedagogical and institutional implications.

From a pedagogical standpoint, the results reinforce the importance of structured inquiry with explicit scaffolding, particularly in supporting students' transition from procedural execution to conceptual reasoning. Inquiry-based instruction should therefore be designed to balance autonomy with guided support, ensuring that students develop both technical competence and scientific reasoning skills.

At the institutional level, the identified resource constraints underscore the need for sustained investment in laboratory infrastructure, equipment modernization, and instructional materials. Without such support, the scalability and consistency of inquiry-based instruction may remain limited.

From a curriculum perspective, the findings support the integration of inquiry-based laboratory activities as a central component of STEM science education, particularly in fostering domain-specific scientific literacy skills.

While prior studies have established the general effectiveness of inquiry-based learning (Gormally et al., 2021; Fidelino & Chua, 2021), fewer have examined its differentiated relationship with specific dimensions of scientific literacy within localized STEM contexts. This study addresses this gap by providing empirical evidence linking laboratory skill domains to distinct scientific literacy competencies among STEM students in a Philippine district context.

This localized contribution is significant, as it contextualizes global inquiry-based learning frameworks within resource-constrained educational settings, thereby extending their practical relevance.

Several limitations should be acknowledged. First, the study is geographically limited to STEM students within the First Congressional District of Batangas, which may limit generalizability to other educational contexts. Second, the reliance on self-reported and teacher-assessed measures introduces potential subjectivity in responses. Third, the study focuses only on selected dimensions of scientific literacy and does not encompass the full range of scientific reasoning competencies.

Additionally, the correlational design limits causal inference; therefore, findings should be interpreted as associations rather than causal effects.

Conclusions

1. Well structured, inquiry-based lab instruction significantly elevate students' scientific literacy, including their ability to handle, maintain, and clean laboratory equipment safely and correctly.

2. Scientific literacy enable learners to analyze, interpret, and evaluate increasingly data-rich scientific information scaffold assignments empower STEM undergraduate students to critically assess, understand, and responsibly handle scientific information both on readers and communicators.

The students' level of scientific literacy, as assessed by both the teacher and respondents, is above average across the following domains: information evaluation and comprehension (3.1769), hypothesis development and testing (3.1952), and data analysis and interpretation (3.2721).

These results indicate that students demonstrate a competent and satisfactory level of scientific literacy, showing their ability to understand scientific concepts, formulate and test hypotheses, and analyze as well as interpret data effectively.

3. The findings of the study confirmed that the effective integration of inquiry-based laboratory instruction significantly contributes to the enhancement of scientific literacy among STEM students, particularly by fostering their ability to think critically and solve problems systematically.

4. The study concludes that these is a highly significant relationship between the extent of utilization of inquiry-based laboratory instruction and the level of scientific literacy among STEM students. Specifically, the findings reveal that students' technical and manipulative skills, experimental skills, and problem-solving skills are highly significantly associated with their abilities in information evaluation and comprehension, hypothesis development and testing, data analysis and interpretation, and evidenced by a significance level of 0.01.

5. The proposed enrichment Inquiry-based Laboratory Instruction activities emerged as a necessary intervention to bridge the gap between identified challenges and the desired mastery of scientific competencies.

Recommendations

Based from the findings and conclusions, the researcher recommended the following:

1. As to utilization of technical and manipulative skills on the extent of inquiry-based lab instruction enhancing scientific literacy there is a need to have an accurate preparation on chemical solution required in the experiments; as to experimental skills, teachers need to show confidence when attempting to modify experimental procedure when necessarily and when attempting to solve scientific problems.

2. Teachers may apply scientific vocabulary correctly when explaining concepts; exhibit new capacity to design experiments to test their hypothesis and capacity to use graphs and charts to present experiments results and findings.

3. The school head or science lab technician may upgrade and avail the updated laboratory apparatuses and equipment to maximize lab instructions; that will maximize the effectiveness of inquiry-based instruction.

4. Students may be engaged on lab experiences to meet the learning based on the standard competencies.

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