International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Inquiry-Based Learning and its Influence on Students' Scientific Skills Towards a Proposed Action Plan

Rosemarie Vargas
University of Perpetual Help System-DALTA, Las Piñas City, Philippines

***Abstract*— *Inquiry-based learning has been widely recognized as an effective student-centered approach in science education. Developing students' scientific skills in Biology is essential for promoting critical thinking and deeper conceptual understanding. This study aimed to determine the effectiveness of inquiry-based learning in enhancing students' scientific skills in Biology. Specifically, it examined the level of effectiveness across six scientific skill domains, the difference between pretest and post-test performance, and the relationship between perceived effectiveness and post-test scores. It utilized a quantitative one-group pretest–posttest research design. Data were collected through a validated survey questionnaire and a researcher-made scientific skills test, and analyzed using mean, standard deviation, paired-sample t-test, and Pearson correlation coefficient. Results revealed that inquiry-based learning was perceived as very effective across all six scientific skill domains. The findings indicate that inquiry-based learning significantly enhances students' scientific skills in Biology. The results support the integration of inquiry-based strategies in science instruction to improve academic performance and promote meaningful learning.*

***Keywords*— *Biology education, inquiry-based learning, pretest-posttest design, scientific skills, student performance.*

I. INTRODUCTION

In today's interconnected world, scientific literacy has become a crucial competency for making informed decisions, engaging in evidence-based reasoning, and addressing global challenges such as climate change, health crises, and technological innovations. International organizations such as the Organization for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasize that scientifically literate citizens are essential for sustainable development and active participation in society (OECD, 2024; UNESCO, 2023). Scientific literacy is not limited to content knowledge; it also involves conducting inquiry, interpreting data, and applying evidence in real-life contexts, which are increasingly emphasized in international assessments such as the Program for International Student Assessment PISA (Wu, 2025).

To meet these demands, Inquiry-Based Learning (IBL) has been recognized as a key approach to cultivating scientific literacy. Rooted in constructivist and experiential learning theories, IBL engages students in authentic practices, asking questions, experimenting, analyzing, and reflecting, linking theoretical knowledge with practical applications (Ramli & Borhan, 2024). Studies show that inquiry-based models, including Argument-Driven Inquiry, enhance students' ability to evaluate evidence and apply scientific reasoning, while integrating digital tools further supports engagement and collaboration in science learning (Instructional Science, 2024; Ramli & Borhan, 2024).

Globally, research underscores that cultural and educational contexts shape the relationship between IBL and scientific literacy. For example, incorporating ethnoscience allows learners to connect local knowledge with global scientific practices, making learning more inclusive (Mulyono et al., 2024). At the same time, international comparisons like PISA 2022 highlight that inquiry approaches are most effective when supported by adequate resources, teacher facilitation, and student dispositions such as perse0verance and curiosity (Wu, 2025). These perspectives make it timely to explore how IBL contributes to developing scientific literacy, both locally and within the broader global movement toward preparing students as critical thinkers and problem solvers in the 21st century.

In the United States, Inquiry-Based Learning (IBL) has been central to science education reform, particularly through the Next Generation Science Standards (NGSS), which emphasize authentic scientific practices such as questioning, investigating, analyzing, and constructing explanations rather than rote learning (National Research Council, 2012; NGSS Lead States, 2013). This approach fosters scientific literacy, understood as the ability to apply scientific knowledge, evaluate evidence, and make informed decisions in real-world contexts (Bybee, 2020). Research shows that American students engaged in structured inquiry tasks develop stronger skills in data interpretation, scientific reasoning, and knowledge transfer (Kang & Keinonen, 2022), while the integration of digital tools, such as simulations and data-analysis platforms, enhances engagement and accessibility, especially in diverse classrooms (Reiser et al., 2021). Thus, from an American perspective, IBL is not merely an instructional strategy but a transformative approach that cultivates critical thinking, collaboration, and evidence-based reasoning, equipping students to address both local and global challenges.

From the researcher's review of recent studies in both global and U.S. contexts, the researcher observed that Inquiry-Based Learning (IBL) plays a crucial role in developing students' scientific literacy, especially when it is supported by broader educational reforms and international programs

(Mediana, Funa, & Dio, 2025; Ramli & Borhan, 2024). IBL encourages students to actively participate in the scientific process, helping them build skills such as asking questions, forming hypotheses, conducting experiments, analyzing data, and reasoning based on evidence, all of which are essential for scientific literacy.

In Virginia, Standards of Learning are state-mandated tests that measure how well students have learned the required content in each subject aligned to Virginia's curriculum standards. Science performance from 2022-2025 shows a little increase from 40, 47, and 53, respectively. Seeing the potential of IBL, the researcher was motivated to explore how it affects students in the researcher's local context. The researcher also noticed that while IBL is sometimes used in science classrooms, its application is not always consistent, and its effectiveness can vary depending on factors such as teacher guidance, student engagement, and available resources. This led the researcher to recognize the need to examine more closely how IBL shapes scientific literacy in a real classroom setting. For this reason, the researcher designed this study to investigate the influence of IBL on the scientific literacy of Grade 9 students in a selected high school in the United States. Through this research, the researcher hopes to gain insights into both the challenges and benefits of implementing IBL in everyday teaching. Ultimately, aiming to provide recommendations that can help make IBL a more effective and consistent tool for developing students' critical thinking skills and their meaningful engagement with scientific knowledge.

Theoretical Framework

This study is grounded in Constructivist Learning Theory (Piaget, Vygotsky, & Bruner) and Kolb's Experiential Learning Theory (1984), which together provide the foundation for Inquiry-Based Learning (IBL). Constructivism views learning as an active process where students build their own understanding through exploration, questioning, and interaction with their environment, rather than simply absorbing facts. In the same way, Kolb's Experiential Learning Theory describes learning as a cycle of experiencing, reflecting, conceptualizing, and experimenting. This cycle closely mirrors the steps of scientific inquiry, making it highly relevant to how students develop both knowledge and scientific literacy.

In this study, these theories highlight how IBL enables Grade 9 students to engage in learning much like real scientists. Through inquiry activities, students not only test ideas and analyze data but also reflect on their experiences and draw conclusions based on evidence. This process helps them build important skills such as observation, hypothesis-making, experimentation, and reasoning. At the same time, it strengthens higher-order abilities like critical thinking, problem-solving, and communication, all of which are essential components of scientific literacy. In this way, constructivist and experiential perspectives show that IBL is not just a teaching method but a meaningful pathway for helping students learn science deeply and apply it to real-world situations.

Conceptual Framework

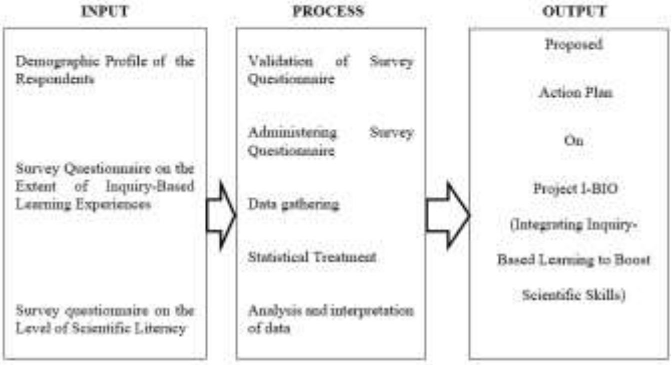


Figure 1. Conceptual Framework

The study used the Input–Process–Output (IPO) Model to establish a clear, structured research framework.

The input phase involved gathering key information, including respondents' demographic profiles, to better understand their learning context. It also involved administering two survey instruments: one that measured the Extent of inquiry-based learning experiences, exploring practices such as questioning, hypothesizing, experimenting, analyzing data, and drawing conclusions; and another that assessed the level of scientific literacy, focusing on students' scientific knowledge, scientific processes, critical thinking, and the application of concepts to real-world situations.

The process phase emphasized the systematic validation of these instruments through expert review to ensure their accuracy, clarity, and alignment with the study's objectives. Following validation, the questionnaires were distributed to Grade 9 students with clear instructions to facilitate accurate responses. Data collection was carefully managed to ensure completeness and reliability. The gathered information underwent statistical treatment using descriptive statistics to present respondents' profiles and learning experiences, and inferential statistics to examine the relationships between variables. This was followed by a comprehensive analysis and interpretation of the findings, connecting the results to the research objectives and relevant literature to deepen understanding.

The output phase culminated in the development of a proposed action plan designed to strengthen scientific literacy through enhanced inquiry-based learning practices. Through this framework, the IPO model provided a systematic pathway for transforming inputs into meaningful outcomes that informed educational improvements in scientific literacy.

Statement of the Problem

The primary goal of this study was to determine the influence of inquiry-based learning on students' scientific skills. The study sought answers to the following research inquiries.

1. What is the effectiveness of inquiry-based learning in Biology in terms of;
    1.1 Questioning;
    1.2 Hypothesizing;

1.3 Experimenting;
1.4 Analyzing Data;
1.5 Drawing conclusion; and
1.6 Reflecting?

2. What is the level of the gained scientific skills as revealed by the pretest and posttest of the respondents?
3. Is there a significant difference between the level of the gained scientific skills as revealed by their pretest and posttest?
4. Is there a significant relationship between the effectiveness of inquiry-based
learning and the gained scientific skills as revealed by their posttest?
5. Based on the findings of the study, what output may be crafted?

Hypotheses

There is no significant difference between the level of the gained scientific skills as revealed by their pretest and posttest.

There is no significant relationship between the effectiveness of inquiry-based learning and the gained scientific skills as revealed by their posttest.

Scope and Limitations of the Study

This study focused on Grade 9 students from a selected high school in the United States. All students enrolled during the academic year 2025–2026 were included in the study through total enumeration to ensure the results reflected the experiences of the entire group of learners. The research explored how Inquiry-Based Learning (IBL) was implemented in the classroom and how it influenced students' scientific skills, particularly their ability to observe, develop hypotheses, conduct experiments, analyze data, and draw conclusions based on evidence. Data were collected during the same academic year to capture authentic, current classroom practices.

However, the study was conducted in only one school, which may have had its own distinct curriculum, teaching strategies, and available resources. Because of this, the findings may not fully represent the situation in other schools or learning environments. Despite this limitation, the study still offered meaningful insights into how Inquiry-Based Learning can strengthen students' scientific skills and Support more active, student-centered science learning.

Significance of the Study

Students. They are expected to develop a stronger grasp of scientific concepts, improve their problem-solving abilities, and apply scientific reasoning effectively to real-world scenarios.

Teachers. Teachers can gain insights into effective inquiry-based strategies that enhance students' scientific literacy and inform more engaging, student-centered instruction.

Parents. They can benefit from this study by understanding how inquiry-based learning supports their children's scientific literacy, critical thinking, and problem-solving skills, enabling them to better guide and Support learning at home.

School Heads. They will benefit from the study by gaining evidence on how inquiry-based learning enhances students' scientific literacy, guiding curriculum planning, instructional strategies, and school-wide academic improvement initiatives.

Future Researchers. They will benefit from the study by gaining a foundation of data and insights on inquiry-based learning and scientific literacy, which can inform and guide further studies in science education.

Definition of Terms

The following terms were defined operationally to enhance understanding of their significance within the scope of this study.

Analyzing Data. This refers to the process in which students examine and interpret information gathered from inquiry-based learning activities, identify patterns, relationships, and trends in experimental results, compare their findings with expected outcomes, and use evidence to draw informed conclusions, as assessed through survey responses and classroom observations.

Application to Real-life Context. This refers to students' ability to apply the scientific knowledge and skills gained through inquiry-based learning to explain everyday phenomena, solve practical problems, make informed decisions, and relate classroom experiments to real-world situations, as measured through survey responses and classroom observations.

Critical thinking. This refers to students' ability to analyze, evaluate, and interpret scientific information gathered through inquiry-based learning, including questioning assumptions, assessing the reliability of evidence, identifying patterns or inconsistencies, and making reasoned judgments, as measured through survey responses and classroom observations.

Concluding. This refers to the process by which students synthesize information and evidence gathered from inquiry-based learning activities to make informed judgments, explain outcomes, and connect findings to scientific concepts or theories, as measured through survey responses and classroom observations.

Experimenting. This refers to the process by which students actively engage in hands-on scientific investigations during inquiry-based learning, including testing hypotheses, manipulating variables, observing outcomes, and following systematic procedures, as measured through survey responses and classroom observations.

Hypothesizing. This refers to the process by which students formulate testable predictions or possible explanations based on prior knowledge and observations during inquiry-based learning activities, which guide their experiments and investigations, as measured through survey responses and classroom observations.

Inquiry-based learning. This refers to a student-centered instructional approach in science that actively engages learners in questioning, investigating, experimenting, analyzing data, and reflecting to construct their own understanding of scientific concepts. It will be measured through a survey questionnaire that assesses students' experiences with inquiry-based learning practices in their science classes.

Questioning. This refers to the process by which students actively generate and pose relevant scientific questions during inquiry-based learning activities, aimed at exploring phenomena, clarifying concepts, and guiding investigations, as measured through survey responses and classroom observations.

Reflecting. This refers to the process by which students think critically about their inquiry-based learning experiences, evaluate their methods and results, consider what they have learned, and identify ways to improve future investigations, as measured through survey responses and classroom observations.

Scientific knowledge. This refers to students' understanding and comprehension of key scientific concepts, principles, and facts in subjects such as biology, chemistry, physics, and earth science, as measured through survey responses and classroom observations.

Scientific Literacy. This refers to the students' ability to understand scientific concepts, apply scientific knowledge to real-life situations, analyze and evaluate scientific information critically, and make informed decisions based on evidence. It will be measured using a survey questionnaire designed to assess scientific literacy.

Scientific processes. This refers to the set of skills and procedures that students use during inquiry-based learning to investigate scientific phenomena, including observing, classifying, measuring, experimenting, analyzing data, and interpreting results, as measured through survey responses and classroom observations.

II. REVIEW OF RELATED LITERATURE

The objective of this chapter is to explore a range of concepts and findings from previously published research, scholarly articles, and theses relevant to the study. Insights from established academic literature serve as key references, guiding the development of the present study and ensuring that it makes a meaningful contribution to the ongoing discourse in this field.

Inquiry-Based Learning

Inquiry-Based Learning (IBL) has been widely acknowledged as an effective teaching approach that positively impacts various aspects of students' learning outcomes. One of its most significant contributions is enhancing critical thinking skills, which are essential for evaluating information, making informed judgments, and solving complex problems. Arifin (2025), in a meta-analysis of 25 studies, reported that IBL substantially improves students' critical thinking abilities in science education, with a notable mean effect size of 1.27. This indicates that students engaged in IBL are more capable of analyzing, interpreting, and synthesizing information compared to their peers in traditional learning settings. The study also highlighted that IBL's effectiveness is influenced by factors such as teaching strategies, the design of inquiry activities, and assessment approaches (Eurasia Journal). This underscores the importance of carefully implementing IBL with appropriate scaffolding and instructional guidance to maximize its cognitive benefits.

Beyond fostering critical thinking, IBL also cultivates higher-order thinking skills, including problem-solving, decision-making, and analytical reasoning. Antonio (2024) emphasized that these skills are essential for students to navigate complex, dynamic, and uncertain learning environments. By engaging with authentic problems that require investigation, experimentation, and reflection, students learn to connect theoretical knowledge with practical applications, evaluate multiple solutions, and make informed decisions. This process promotes intellectual independence and adaptability; skills are increasingly vital in the 21st century (ERIC).

In addition to cognitive growth, IBL enhances student engagement and agency. According to MacKenzie (2025), IBL provides accessible entry points and allows learners to pursue personalized pathways that align with their interests, prior knowledge, and curiosity. By actively constructing knowledge, exploring ideas, and collaborating with peers, students shift from passive recipients of information to active participants in their own learning. This sense of ownership fosters intrinsic motivation, sustained engagement, and deeper involvement with learning content. The combination of cognitive gains and increased engagement illustrates that IBL not only improves academic performance but also cultivates essential skills, motivation, and attitudes for lifelong learning.

Research has identified several strategies that enhance the implementation of Inquiry-Based Learning (IBL) and ensure its effectiveness across various educational contexts. Ramaila (2024), in a systematic review of IBL studies spanning multiple disciplines and educational levels, found that careful planning, structured scaffolding, and alignment with learning objectives are essential for successful execution. The review emphasized that inquiry activities should be deliberately sequenced, with scaffolds gradually removed as students develop competence and confidence. This approach prevents learners from feeling overwhelmed by open-ended tasks while simultaneously fostering independence, critical thinking, and problem-solving skills.

Moreover, the incorporation of digital technologies has become increasingly vital in supporting effective IBL. Hinostroza et al. (2024), after analyzing 25 studies, identified seven key roles that technology plays in facilitating inquiry processes, including promoting collaboration, providing access to diverse information sources, enabling experimentation through simulations, and offering real-time feedback. These technological tools make learning more interactive, flexible, and student-centered, while also allowing teachers to monitor student progress and tailor instruction to meet individual learning needs.

In addition, teacher preparation and professional development are critical factors in the success of IBL. Bacak (2021) highlighted that pre-service teachers gain substantial benefits from experiencing the full spectrum of IBL phases during their training. Exposure to planning, guiding, and evaluating inquiry activities helps educators develop a comprehensive understanding of how to design and facilitate meaningful inquiry experiences. Well-prepared teachers are better equipped to balance guidance with autonomy, cultivate supportive learning environments, and adapt inquiry tasks to diverse learners' needs, ensuring that IBL produces effective and lasting learning outcomes.

Moreover, recent studies have identified several emerging trends and innovative applications of Inquiry-Based Learning (IBL), highlighting its increasingly important role in modern education. A prominent development is the application of learning analytics to enhance and optimize IBL processes. Chen (2025), in a synthesis of 51 studies, demonstrated that learning analytics can offer detailed insights into students' behaviors during inquiry activities. These analytics enable educators to monitor engagement, identify areas where students encounter difficulties, and adjust instructional strategies in real time. Additionally, they provide students with personalized feedback, guide their learning progress, and encourage reflective practices. By making inquiry experiences data-informed and adaptive, learning analytics significantly improves the effectiveness of IBL.

Likewise, another key trend is the integration of IBL into formal curricula. The International Baccalaureate (IB) organization examined how inquiry-based teaching is interpreted and implemented across its programs, offering guidance for curriculum design. Their findings emphasize that IBL can be systematically embedded across diverse subject areas while maintaining its core principles of student-centered learning, curiosity-driven exploration, and critical thinking. Integrating inquiry into curricular frameworks promotes coherence in learning, aligns activities with learning objectives, and encourages students to apply knowledge in meaningful, real-world contexts.

Furthermore, IBL has demonstrated considerable versatility across different subjects and educational contexts. Research on its application in fields such as science, information technology, and mathematics shows that inquiry-based approaches can be adapted to various content areas, teaching styles, and student populations. In science, for example, IBL emphasizes hands-on experimentation and hypothesis testing, while in information technology, it supports project-based problem-solving and collaborative exploration of digital tools. This adaptability highlights IBL's potential as a flexible and effective instructional approach that fosters both conceptual understanding and practical skills, regardless of discipline or learning environment. These trends indicate that IBL is not only a powerful teaching strategy but also a dynamic, evolving practice. By leveraging learning analytics, embedding inquiry into structured curricula, and adapting strategies across multiple disciplines, educators can design richer, more engaging learning experiences that cultivate students' critical thinking, problem-solving, and lifelong learning skills.

Vale (2013) strongly argues that authentic science learning "begins by asking questions," positioning inquiry as the foundation rather than the outcome of instruction. He critiques traditional science classrooms that emphasize the transmission of factual knowledge, suggesting that such approaches reduce students to passive recipients of information. According to Vale, when teaching centers primarily on memorization, students may acquire isolated facts but fail to develop the habits of mind characteristic of scientific thinkers. He emphasizes that restoring "the true spirit of science" requires allowing students to formulate and pursue their own questions, mirroring the processes used by practicing scientists. Furthermore, Vale notes that "virtually all educators agree that teaching science should involve more inquiry-based learning and less fact-based memorization," highlighting a broad professional consensus on the need for reform. This perspective is particularly relevant to the present findings, as the high ratings in student questioning suggest that when teachers intentionally create opportunities for inquiry, learners become more intellectually engaged. Vale's argument implies that questioning is not merely a classroom strategy but a defining practice of science itself-one that nurtures analytical thinking, curiosity, and sustained engagement.

Expanding on this theoretical foundation, Stehr (2025) describes inquiry-based learning as a student-centered pedagogical model that deliberately "encourages students to ask questions, think deeply, and investigate problems." Unlike teacher-dominated instruction, which often prioritizes efficiency and content coverage, Stehr emphasizes exploration, dialogue, and critical reflection as central to meaningful learning. In this framework, students are not expected to answer the teacher's questions; rather, they are guided to construct their own lines of inquiry. This shift fosters autonomy and strengthens intrinsic motivation, as learners perceive themselves as active contributors to knowledge construction. Similarly, a commentary from Studies Weekly underscores that when students learn to "wonder, ask questions, and lead their own research… amazing things happen." The commentary highlights how inquiry transforms classroom dynamics, enabling students to transition from passive listeners to active investigators. Together, these perspectives reinforce the idea that structured opportunities for questioning cultivate both cognitive engagement and a sense of ownership over learning. In relation to the present study, these theoretical insights help explain why inquiry-driven practices are associated with higher student participation and stronger perceived effectiveness in questioning behaviors.

Empirical evidence further substantiates these claims. In their study of Grade 8 biology students, Palaguyan and Abusama (2025) examined the impact of inquiry-based instruction compared to traditional teaching approaches. Their findings revealed that students exposed to inquiry methods demonstrated significantly higher levels of engagement and conceptual understanding. The researchers describe inquiry learning as an approach that "encourages students to ask questions, explore ideas, and discover answers on their own," thereby fostering curiosity and building confidence in scientific reasoning. Importantly, the inquiry group achieved markedly greater gains in both knowledge acquisition and classroom participation, suggesting that questioning enhances not only motivation but also comprehension. These results provide concrete Support for the present study's "very effective" ratings in questioning practices. They indicate that when biology instruction actively promotes student-generated inquiry, learners develop deeper conceptual understanding and become more invested in the learning process. Collectively, this body of literature affirms that inquiry-based teaching strengthens students' ability and willingness to question, an essential component of analytical thinking and sustained academic engagement.

Inquiry-based learning (IBL) is widely recognized as an instructional approach that promotes scientific thinking by engaging students in the same intellectual processes scientists use to construct knowledge. According to Pedaste et al. (2019), inquiry learning unfolds through structured phases, orientation, conceptualization, investigation, conclusion, and discussion, which collectively guide learners from curiosity to evidence-based explanation. During orientation, students are introduced to a problem or phenomenon that stimulates questioning; conceptualization then involves generating hypotheses or research questions; investigation requires systematic data collection and experimentation; conclusion centers on interpreting findings; and discussion encourages reflection and communication of results. Their synthesis of empirical studies demonstrates that when these phases are intentionally implemented, students show measurable gains in scientific reasoning, particularly in hypothesis formulation and in the justification of hypotheses using evidence. Importantly, the authors emphasize that inquiry is most effective when it balances structure and student autonomy, ensuring that learners remain cognitively challenged while supported. This structured yet flexible framework explains why IBL is associated with stronger analytical thinking and deeper conceptual understanding compared to purely lecture-based instruction.

Building on this framework, Lazonder and Harmsen (2019) highlight the critical role of guidance within inquiry-based environments. Their research demonstrates that guided inquiry, in which teachers provide scaffolding such as prompts, modeling, or feedback, leads to significantly better learning outcomes than minimally guided discovery. They found that students who receive appropriate scaffolding are more successful in generating testable hypotheses, designing controlled experiments, and interpreting results accurately. This structured Support strengthens predictive reasoning by training learners to anticipate outcomes based on prior knowledge and theoretical understanding. Furthermore, the authors argue that guidance prevents cognitive overload, allowing students to focus on higher-order thinking rather than procedural confusion. Their findings suggest that inquiry is not simply about freedom to explore; rather, it requires intentional instructional design to maximize the development of reasoning. In this way, guided inquiry fosters both conceptual clarity and the disciplined thinking habits characteristic of scientific practice.

Similarly, Zion and Mendelovici (2019) emphasize the metacognitive dimension of inquiry-based learning. They explain that inquiry environments encourage students to reflect on their own thinking processes, particularly when they are required to revise hypotheses in light of new or contradictory evidence. This iterative process of testing, evaluating, and refining ideas mirrors authentic scientific investigation and strengthens adaptability in reasoning. The authors note that when students encounter unexpected results, they must reconsider their assumptions, analyze potential sources of error, and construct alternative explanations. Such reflective engagement cultivates metacognitive Awareness, the ability to monitor and regulate one's own cognitive strategies. Over time, this practice enhances students' capacity for independent problem-solving and flexible thinking. By promoting reflection alongside experimentation, inquiry-based instruction develops not only procedural skills but also deeper cognitive resilience and intellectual autonomy.

Further empirical validation is provided by Furtak et al. (2021), who conducted a meta-analysis examining the overall impact of inquiry-based science instruction on student achievement. Their large-scale synthesis revealed a consistently positive effect of inquiry approaches, particularly in domains related to experimentation, data analysis, and scientific explanation. Students in inquiry classrooms demonstrated stronger abilities to interpret graphs, evaluate evidence, and draw justified conclusions than peers in traditional lecture-based settings. The meta-analysis also found that the effectiveness of inquiry was amplified when instruction incorporated explicit discussion of scientific concepts alongside hands-on investigation. This combination of practice and conceptual clarification led to higher achievement gains and improved transfer of knowledge to new contexts. The findings underscore that inquiry-based instruction does not merely enhance engagement but produces measurable improvements in academic performance and higher-order scientific skills.

At the global level, the Organization for Economic Co-operation and Development (OECD, 2020) reinforces these conclusions in its report on international science education outcomes. The report highlights that hands-on, inquiry-driven approaches significantly enhance students' problem-solving abilities and overall scientific literacy. By engaging learners in experimentation, collaborative discussion, and evidence-based reasoning, inquiry classrooms cultivate competencies essential for navigating complex real-world issues. The OECD emphasizes that students who frequently participate in investigative tasks are better equipped to analyze unfamiliar problems, evaluate information critically, and apply scientific principles beyond the classroom. These findings suggest that inquiry-based education contributes not only to subject mastery but also to broader 21st-century skills such as adaptability, critical thinking, and informed decision-making. Collectively, the literature demonstrates that inquiry-based learning systematically strengthens scientific reasoning, metacognitive Awareness, academic achievement, and problem-solving capacity, core indicators of effective science education.

The Role of Questioning in Inquiry-Based Learning

Questioning lies at the heart of Inquiry-Based Learning (IBL), driving active engagement with scientific concepts. Rather than simply memorizing facts, students are encouraged to explore phenomena, formulate hypotheses, and analyze outcomes. According to Alarcon et al. (2023), IBL empowers learners to generate their own questions and investigate them, enabling the construction of personalized understanding. This process strengthens scientific literacy by helping students critically assess evidence, connect ideas, and apply their knowledge to real-world contexts (Alarcon et al., 2023).

In addition, Aidoo (2024) further emphasizes that fostering questioning skills sparks curiosity and promotes deeper learning. By learning to ask meaningful, purposeful questions, students become more actively involved in their education, enhancing both conceptual understanding and analytical thinking. In this sense, inquiry-based science teaching goes beyond providing answers; it develops the cognitive abilities needed to generate questions that drive scientific exploration and discovery (Aidoo, 2024).

Moreover, the skill of asking and answering questions is closely tied to scientific literacy. Encouraging students to ask questions helps them practice essential scientific skills such as observation, reasoning, and interpretation. Kyriazis et al. (2025) found that inquiry-based laboratory activities significantly improved pre-service teachers' understanding of scientific concepts while boosting their confidence and self-efficacy. This shows that questioning does more than spark curiosity; it equips learners to engage confidently with complex scientific ideas and to apply scientific methods effectively.

Similarly, Teplá and Distler (2025) observed that sustained engagement in inquiry-based science education enhances students' motivation and knowledge acquisition. Questioning played a central role in this process, guiding learners to seek explanations, test hypotheses, and reflect critically on their results. Such continuous inquiry not only strengthens content knowledge but also fosters critical thinking habits essential to lifelong scientific literacy (Teplá & Distler, 2025).

Despite its benefits, effectively integrating questioning into IBL can be challenging. Teachers may find it difficult to fully adopt inquiry-based approaches, which can affect the depth and quality of the questions they pose in the classroom. Aidoo (2024) notes that some educators struggle with integrating questioning strategies due to limited experience, insufficient resources, or rigid curricula. This can lead to superficial questioning that fails to engage students in authentic inquiry.

In addition, Morris (2025) adds that successful IBL requires a careful balance between open-ended exploration and structured Support. Without guidance, students may feel overwhelmed by the freedom to ask questions or may pursue inquiries that lack scientific rigor. Scaffolded questioning helps ensure that students' inquiries remain meaningful, promoting deeper understanding while providing the cognitive Support needed to develop scientific literacy (Morris, 2025).

Hypothesizing

Hypothesizing is a cornerstone of scientific inquiry, serving as the essential link between careful observation and systematic experimentation. Within the framework of Inquiry-Based Learning (IBL), hypothesizing is not merely a procedural step; it serves as a dynamic tool that encourages students to actively construct knowledge and deepen their scientific understanding. Recent research underscores the importance of this skill in promoting both engagement and comprehension in science education, highlighting its central role in cultivating scientific literacy among learners.

Likewise, Harefa (2023) emphasizes that incorporating hypothesizing within a scientific inquiry approach allows students to develop critical scientific process skills alongside positive attitudes toward science. This combination enhances their ability to analyze problems and communicate scientific ideas effectively. Such an approach is closely aligned with the Merdeka curriculum, which prioritizes student-centered learning and encourages learners to explore concepts through inquiry. By formulating and testing hypotheses, students practice generating evidence-based explanations, a process that mirrors how scientists investigate and discover new phenomena.

Moreover, expanding on this, a systematic review by Urdanivia Alarcon et al. (2023) that synthesized findings from 51 studies on inquiry-based teaching and learning revealed that hypothesizing is a pivotal component in the development of research skills and the construction of scientific knowledge. Instructional strategies that emphasize hypothesizing help students conceptualize and model scientific principles and laws, thereby making abstract concepts more tangible and engaging. By actively engaging in this process, students not only acquire knowledge but also develop a deeper appreciation for the investigative nature of science.

Furthermore, the context of teacher preparation, Kyriazis et al. (2025) examined the effects of inquiry-based laboratory activities on pre-service teachers' understanding of heat concepts and their self-efficacy beliefs. The study demonstrated significant gains in both conceptual understanding and teaching confidence, suggesting that hands-on, inquiry-driven experiences that incorporate hypothesizing can effectively prepare future educators. This evidence underscores the value of integrating hypothesis-driven inquiry into teacher education programs to equip educators with the skills and mindset to foster scientific literacy in their students.

Collectively, these studies highlight the indispensable role of hypothesizing within inquiry-based learning. Engaging in hypothesis generation and testing enables students to develop key scientific competencies, critical thinking skills, and an enduring curiosity about the natural world. In doing so, students move beyond memorization to actively participating in the processes that define scientific investigation, ultimately leading to a richer and more meaningful understanding of science.

Experimentation

Kyriazis, Stylos, and Kotsis (2025) explored how pre-service primary teachers' understanding of scientific concepts could be strengthened through hands-on, inquiry-based laboratory activities. Their study involved eight intensive sessions, each lasting three hours, during which participants actively engaged in structured experiments focusing on heat concepts. By observing and manipulating real phenomena, the participants were able to connect abstract theoretical principles to tangible outcomes. The results showed significant improvements not only in their conceptual understanding but also in their confidence in applying scientific ideas. This research highlights the transformative power of experimentation in IBL, showing that direct engagement with experiments helps learners build a deeper, more enduring grasp of scientific concepts while fostering a sense of ownership over their learning (Kyriazis et al., 2025).

Furthermore, critical thinking is a cornerstone of scientific literacy, and experimentation within IBL plays a pivotal role in cultivating this skill. Arifin (2025) conducted a meta-analysis to determine how inquiry-based interventions influenced students' critical thinking across different educational levels. The analysis revealed that activities emphasizing hands-on experimentation produced moderate to large gains in critical thinking abilities. Factors such as teaching strategies, integration of ICT-based simulations, and assessment methods significantly moderate these effects. This suggests that structured experiments do more than reinforce conceptual knowledge; they also nurture analytical, evaluative, and problem-solving skills essential to scientific literacy. In other words, experimentation encourages students to think like scientists: hypothesizing, testing, and reasoning through evidence (Arifin, 2025).

On the other hand, beyond immediate learning outcomes, experimentation in IBL has long-term benefits for motivation and knowledge retention. Teplá and Distler (2025) investigated how sustained engagement in experimental inquiry affected students' intrinsic motivation and understanding of scientific concepts over time. The study found that students who regularly participated in experimental activities were more likely to internalize concepts, maintain curiosity, and retain knowledge, even across different subjects and levels of complexity. These findings indicate that repeated, hands-on experimentation not only strengthens comprehension but also nurtures a sustained, self-driven interest in science, an essential element of scientific literacy (Teplá & Distler, 2025).

Furthermore, Akmam et al. (2025) studied high school physics students using the Cognitive Conflict-Based Generative Learning Model (GLBCC) in a pretest-posttest control group design. Students engaged in laboratory experiments designed to provoke cognitive conflict, encouraging them to question assumptions, test ideas, and revise their understanding in light of experimental results. The study found that this model significantly enhanced students' scientific literacy, demonstrating how carefully structured experiments serve as a central mechanism for effective inquiry-based learning. Through active experimentation, learners not only grasp concepts more deeply but also practice the scientific method in authentic contexts (Akmam et al., 2025).

Moreover, Warkentin et al. (2025) investigated the use of augmented reality (AR) smart glasses in teaching the Lorentz force. Their study revealed that AR-supported experiments allowed students to visualize and manipulate variables in real time, creating immersive, interactive experiences. This form of experimental learning reduced cognitive load, helped students comprehend abstract phenomena, and strengthened practical inquiry skills. The findings underscore that whether through traditional lab work or technology-enhanced experiments, active engagement with experimental processes is vital to fostering scientific literacy (Warkentin et al., 2025).

The teacher's role in experimental IBL is crucial. Soomro (2025) emphasized that carefully planned experiments, guided by teacher facilitation, enable students to deeply engage with scientific processes. Structured yet flexible experiments encourage problem-solving, hypothesis testing, and critical thinking. Teachers who scaffold learning while allowing students room for exploration help ensure that experimentation becomes a meaningful and effective part of the learning process (Soomro, 2025).

Likewise, Morris (2025) highlighted the benefits of integrating digital tools into experimental inquiry. Simulations, virtual labs, and other technology-mediated platforms allow students to experiment safely, repeat procedures, and explore scenarios beyond the constraints of physical labs. This approach enhances engagement, encourages iterative learning, and broadens opportunities for data analysis and hypothesis testing. By combining traditional experimentation with technological Support, IBL can provide rich, multifaceted learning experiences that foster both understanding and scientific literacy (Morris, 2025).

Analyzing Data

Data analysis forms the backbone of Inquiry-Based Learning (IBL), as it transforms raw observations into meaningful scientific understanding. Through IBL, students are not merely passive recipients of information; they actively collect, organize, and interpret data, which cultivates their ability to think critically and draw evidence-based conclusions. Eymur (2024) investigated how inquiry-based science laboratories contribute to students' scientific literacy development. The study emphasized that hands-on engagement in data collection and analysis equips students with essential skills to evaluate information systematically, recognize patterns, and make informed decisions grounded in evidence. This process of actively interpreting data reinforces conceptual understanding and promotes deeper cognitive engagement with scientific phenomena.

Moreover, the way data is analyzed within IBL can vary depending on the instructional model employed. Lestari (2024) explored the impact of the Inquiry-Based Nature of Science Argumentation (IB-NOSA) model on students' scientific literacy. Using a pretest-posttest control-group design, the study revealed that structured argumentation within inquiry-based activities significantly enhanced students' abilities to interpret and analyze data. By incorporating clear procedures for evidence collection and reasoning, instructional models like IB-NOSA help students connect empirical observations to scientific concepts, fostering both analytical thinking and problem-solving skills.

Likewise, modern technologies have further expanded students' opportunities to engage with data in inquiry-based settings. According to Alarcon et al. (2023), integrating electronic, virtual, and remote laboratories into IBL activities enables learners to collect and manipulate data in ways previously impossible in traditional classrooms. These tools not only facilitate more complex data analysis but also encourage students to visualize and interpret information in dynamic, interactive formats. As a result, technology-supported IBL strengthens students' capacity to evaluate scientific evidence and enhances overall scientific literacy. Evaluating students' proficiency in scientific inquiry requires careful attention to how they analyze and interpret data. Vo (2025) conducted a systematic review on assessing scientific inquiry and emphasized that meaningful assessment goes beyond testing factual knowledge. Instead, it focuses on students' abilities to construct evidence-based arguments, interpret results, and draw logical conclusions from data. Incorporating such assessments ensures that students are not only learning scientific content but also mastering critical thinking and analytical skills central to scientific literacy.

Drawing Conclusion

Concluding is a fundamental skill in scientific literacy, as it empowers students to interpret data, evaluate evidence critically, and make reasoned judgments. In Inquiry-Based Learning (IBL), this skill is developed through active engagement rather than passive instruction. Students are encouraged to explore scientific phenomena, formulate meaningful questions, and navigate the reasoning process independently, which naturally cultivates their ability to draw informed conclusions. Research consistently highlights that IBL not only strengthens students' analytical skills but also enhances their overall capacity for critical thinking and evidence-based reasoning, making them more scientifically literate (Sam, 2024; Aidoo, 2024).

Likewise, at the heart of IBL is student-centered exploration, in which learners investigate, hypothesize, experiment, and draw conclusions from firsthand evidence. This approach mirrors authentic scientific practices and aligns with the goals of scientific literacy: deep understanding of concepts, logical reasoning, and connection to real-world contexts. Studies show that when properly implemented, IBL fosters creativity, curiosity, and problem-solving skills, while also improving academic performance. However, its effectiveness depends heavily on teacher Preparedness, supportive learning environments, and access to appropriate technological tools, emphasizing the need for comprehensive instructional Support (Sam, 2024).

Moreover, the process of concluding IBL is dynamic, involving careful observation, data analysis, and evidence-based interpretation. By engaging in structured inquiry, students learn to recognize patterns, evaluate findings, and make reasoned decisions, much as professional scientists do. Research by Akmam et al. (2025) demonstrates that IBL strategies, such as the Cognitive Conflict-Based Generative Learning Model, significantly enhance high school students' science literacy by strengthening their ability to translate observations into meaningful conclusions. These findings underscore the educational value of inquiry-driven learning: when students are given opportunities to explore, question, and reflect, they develop deeper understanding, critical thinking, and confidence in applying scientific knowledge beyond the classroom.

Reflection

Reflection is a fundamental element of Inquiry-Based Learning (IBL), acting as a bridge between hands-on exploration and deeper conceptual understanding. Through reflective practices, students are encouraged to pause and reflect on their own learning processes, evaluate the strategies they use to solve problems, and refine their understanding of scientific concepts. This self-examination not only nurtures greater self-awareness in learning but also supports the development of scientific literacy, enabling students to analyze, interpret, and apply information thoughtfully.

Research consistently shows that incorporating structured reflection within IBL enhances learning outcomes. For instance, Verawati et al. (2021) found that reflective-inquiry learning models significantly improve critical thinking skills, especially for pre-service teachers with field-independent cognitive styles. In a broader review, Prayogi (2025) reported that reflective interventions positively influence student learning across a variety of disciplines. Even in virtual learning environments, reflective feedback has been shown to strengthen students' scientific communication and overall scientific literacy, demonstrating the versatility of reflection in modern educational settings.

In addition, when reflection is thoughtfully integrated into IBL, it deepens the connection between inquiry and scientific understanding. Alarcon et al. (2023) highlighted that IBL encourages students to develop research skills and actively construct knowledge, while Arifin (2025) confirmed that it enhances critical thinking when paired with effective teaching and assessment strategies. Additionally, Akmam et al. (2025) demonstrated that cognitive conflict-based generative learning helps correct misconceptions and fosters a more nuanced understanding of scientific principles. Interdisciplinary approaches, as explored by Schizas et al. (2024), further demonstrate that embedding reflective elements into inquiry activities across various scientific contexts can heighten student engagement and comprehension, underscoring reflection as an essential part of inquiry-based science education.

Scientific Knowledge

Ebidor and Ikhide (2024) highlight the vital role of literature reviews in advancing scientific research, emphasizing that their purpose extends far beyond mere summary of previous studies. Literature reviews serve as essential tools for researchers, guiding them through complex and often fragmented research landscapes, pinpointing methodological gaps and identifying potential biases in earlier work. By examining different types of reviews, such as traditional reviews, systematic reviews, meta-analyses, and meta-syntheses, the authors provide a comprehensive framework for understanding the diverse strategies researchers can use depending on their investigative goals. Moreover, their study offers practical guidance for novice researchers, equipping them with techniques for conducting systematic and thorough searches, critically appraising sources, and synthesizing findings effectively. Such guidance is crucial for fostering meticulous research practices, strengthening the credibility of scientific studies, and ensuring that new contributions are built on a solid foundation of existing knowledge.

Moreover, expanding on this foundation, recent research has explored the challenges and innovations in conducting literature reviews. Chigbu (2023) notes that postgraduate students often struggle to conduct in-depth reviews, which can result in incomplete, skewed, or biased interpretations of the literature. Similarly, Mukherjee (2025) examines the limitations of conventional review methods, particularly their ability to integrate insights across multiple disciplines, and advocates for approaches that better Support cross-disciplinary knowledge synthesis. In parallel, Roy (2025) underscores the critical role of scientific literacy in early education, highlighting how understanding and applying scientific knowledge from a young age can shape future learning. Vo (2025) contributes by outlining modern approaches to assessing scientific inquiry, detailing trends, and validation strategies that strengthen research rigor. Additionally, Wang et al. (2025) demonstrate the application of literature review principles in technological contexts, introducing Science Meter as a framework to evaluate how scientific knowledge is updated in large language models. Taken together, these studies reinforce the idea that carefully conducted literature reviews are indispensable not only for building a coherent understanding of scientific knowledge but also for driving innovation, improving educational practices, and guiding the integration of emerging technologies.

Scientific Processes

Recent scholarship underscores the fundamental importance of scientific processes in fostering knowledge generation and promoting scientific literacy. Da Silva (2025) highlights that the scientific method operates through systematic, rational, and critically reflective procedures, encouraging not only disciplined individual investigation but also collaborative research practices. In a complementary vein, Cansiz and Cansiz (2024) introduce an updated framework for scientific literacy in education, emphasizing the integration of environmental Awareness and responsibility. This approach aligns with contemporary global benchmarks, such as the PISA 2025 framework, and reflects the need for education systems to equip learners with the knowledge and skills necessary to engage with complex, real-world scientific challenges. Collectively, these studies illuminate the role of structured methodologies and literacy frameworks in developing a comprehensive and nuanced understanding of science.

In addition to foundational knowledge, recent research emphasizes the assessment and enhancement of scientific inquiry skills. Vo (2025) examines strategies for evaluating students' capacity for scientific inquiry through systematic literature reviews, highlighting trends in development and the application of rigorous validation techniques. Likewise, Ebidor and Ikhide (2024) underscore the pivotal role of literature reviews in scientific research, providing a methodological compass that ensures access to relevant studies while guiding research design and decision-making. Furthermore, Zhang (2025) explores the transformative potential of artificial intelligence, particularly large language models, in supporting the scientific method. Zhang argues that AI tools can facilitate creative thinking, streamline data analysis, and enhance productivity across multiple stages of research, thereby complementing traditional scientific processes and enabling more efficient, innovative knowledge generation.

Critical Thinking

Recent research highlights the pivotal role of pedagogical strategies in cultivating critical thinking among students. Daulika et al. (2025) conducted a systematic review of 33 studies, revealing that inquiry-based learning (IBL) and project-based learning (PBL) effectively enhance student engagement and motivation. Despite these benefits, challenges such as limited teacher training, insufficient resources, and adherence to traditional teaching methods remain significant barriers. Furthermore, integrating technology into education has been shown to Support the development of critical thinking. Technology-enhanced approaches, including collaborative learning platforms, game-based learning, and AI-assisted tools, provide students with interactive, engaging opportunities to develop analytical and evaluative skills, underscoring the need for a balanced, thoughtful integration of digital tools in learning environments (Daulika et al., 2025).

Likewise, the emergence of generative AI introduces both opportunities and challenges for critical thinking. Lee et al. (2025) and Singh et al. (2025) note that while AI can streamline information retrieval, over-reliance may reduce deeper analytical engagement unless metacognitive prompts are used to stimulate reflection and evaluation. Supporting this, Kosmyna et al. (2025) found that excessive use of AI tools such as ChatGPT may reduce cognitive engagement and hinder performance on tasks requiring critical thinking. Additionally, bibliometric studies provide insight into evolving research trends, with Arthi (2025) and Hajmási et al. (2025) mapping key themes and directions in critical thinking studies, particularly within tertiary education and English language teaching. Collectively, these findings underscore the importance of pedagogical innovation, technological integration, and careful AI utilization to effectively nurture critical thinking skills.

Application of Real-Life Examples

Lindenwood University (2025) emphasizes that applied science programs equip students with essential scientific skills, including data collection, analysis, and interpretation, which are critical for solving real-world problems. By engaging in hands-on experiments, fieldwork, and project-based learning, students develop the ability to draw evidence-based conclusions and make informed decisions. These skills have direct applications across diverse real-life contexts, including monitoring environmental changes, managing public health initiatives, improving industrial processes, and supporting policy development. Furthermore, the program fosters analytical thinking and problem-solving, enabling students to translate theoretical knowledge into practical solutions to societal challenges. By bridging classroom learning with tangible, real-world scenarios, applied science education not only enhances students' competence but also prepares them to contribute meaningfully to their communities and professional fields.

Furthermore, Silverio (2024) examines scientific skills and disciplinary practices across multiple STEM fields, highlighting the importance of cultivating a core set of competencies that apply across disciplines. The study identifies key skills, including hypothesis development, experimental design, data analysis, and the critical evaluation of evidence, as essential foundations for scientific literacy and interdisciplinary problem-solving. Establishing this common skill set ensures that students gain proficiency in their own fields while also developing the versatility to apply their knowledge in real-world contexts. These skills enable learners to address environmental issues, contribute to biomedical research, innovate in engineering, and Support data-driven decision-making in technology. Silverio (2024) further emphasizes that embedding these core scientific practices into educational curricula enhances adaptability, critical thinking, and collaborative problem-solving, equipping students to tackle complex societal and professional challenges effectively.

Synthesis

Inquiry-Based Learning has proven to be an effective teaching approach that enhances students' scientific literacy, critical thinking, and higher-order cognitive skills. By engaging learners in authentic investigations, experimentation, and evidence-based reasoning, IBL strengthens their ability to analyze, interpret, and synthesize information while fostering problem-solving, decision-making, and reflective thinking. Central to IBL are the processes of questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting, which together cultivate curiosity, conceptual understanding, metacognition, and evidence-based reasoning. Effective implementation requires careful planning, scaffolding, teacher guidance, and professional development, along with the integration of technological tools such as simulations, virtual labs, augmented reality, and learning analytics to Support collaboration, personalized feedback, and adaptive learning. Embedding IBL within formal curricula ensures alignment with learning objectives, coherence across disciplines, and the systematic development of scientific competencies, while its adaptability allows application across various subjects, including science, mathematics, and information technology. By emphasizing core scientific processes, promoting critical thinking, and fostering engagement with real-world problems, IBL equips students with transferable skills such as hypothesis development, experimental design, data analysis, and critical evaluation, preparing them for lifelong learning and practical problem-solving across diverse contexts.

III. METHODOLOGY

This chapter detailed the study's research design, including the sampling methods, the profile of the respondents, and the survey instruments employed. It also described the procedures for data collection, validation, and reliability, as well as the steps in the data-gathering process. Additionally, the chapter outlined the statistical analysis techniques used and highlighted the ethical considerations upheld throughout the research.

Research Design

This study used a descriptive quantitative research design to examine students' scientific literacy levels and their connection with inquiry-based learning (IBL) experiences. Creswell and Creswell (2022) noted that descriptive quantitative research was particularly useful when the aim was to measure variables and explore their relationships without manipulating them. This design enabled the systematic collection and statistical analysis of numerical data, allowing the identification of trends and relationships among variables. By employing standardized tools such as surveys or assessments, the study objectively captured both students' scientific literacy and their IBL experiences. Overall, this approach was well-suited for understanding the current state of scientific literacy and its association with IBL, while also laying the groundwork for future experimental or longitudinal research.

Population and Sampling Technique

This study employed a total enumeration method, which included all Grade 9 students enrolled in Biology classes for the 2025–2026 school year. The participants were drawn from two sections, each comprising 30 students, for a total of 60. By involving the entire Grade 9 Biology cohort, the study ensured comprehensive coverage and effectively eliminated potential sampling bias that could arise when only a subset of participants was selected. This approach enabled more accurate and representative measurement of students' scientific literacy levels and provided a thorough understanding of how inquiry-based learning (IBL) experiences may have influenced their learning outcomes. Moreover, including all students improved data reliability and strengthened the validity of the statistical analyses used to examine the relationship between scientific literacy and IBL experiences. This comprehensive approach also allowed the findings to more accurately reflect the overall performance and learning behaviors of the entire Grade 9 Biology cohort, offering valuable insights for educators and curriculum developers in designing strategies that fostered scientific literacy through inquiry-based learning.

Respondents of the Study

The respondents in this study were all 60 students enrolled in Grade 9 Biology classes for the 2025–2026 school year, drawn from two sections of 30 students each. This inclusive approach ensured that the entire Grade 9 Biology student population was represented, providing a comprehensive perspective on the unit. The respondents exhibited a diverse range of academic abilities, learning styles, interests, and prior experiences with scientific concepts, which made the group highly representative of the student population. This diversity enabled the study to examine how variations in learning experiences, individual capabilities, and engagement levels influenced students' scientific literacy. By including all students, the research captured the full spectrum of learning behaviors, attitudes, and competencies within the classroom, minimizing potential sampling bias and increasing the reliability and validity of the results. This comprehensive participation provided a strong foundation for examining the relationship between inquiry-based learning (IBL) experiences and students' development of scientific literacy, offering meaningful insights.

Instrumentation

This study employed a researcher-developed instrument adapted from Kolb's Learning Theory and the principles of inquiry-based learning (IBL) to gather information on students' learning experiences and scientific literacy. The instrument was designed to comprehensively capture IBL experiences, including questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting. These components represented the sequential processes through which students actively engaged in scientific inquiry, fostering deeper understanding and experiential learning. At the same time, the instrument evaluated students' scientific literacy in terms of scientific knowledge, scientific processes, critical thinking, and the application of concepts to real-life situations. By connecting IBL experiences with these dimensions of scientific literacy, the instrument provided a comprehensive assessment of how active participation in inquiry-based learning supported students' conceptual understanding, problem-solving skills, and their ability to apply science in meaningful contexts. This alignment ensured that the instrument effectively captured both experiential and cognitive aspects of learning, making it appropriate for the study's objectives.

Validation and Test of Reliability of the Instrument

The researcher-developed instrument underwent a thorough validation process to ensure its accuracy, relevance, and reliability. The validation involved three experienced Science teachers from the researcher's school and one Science professor from the University of Perpetual Help System Dalta, who evaluated the instrument on content, clarity, and alignment with the principles of inquiry-based learning (IBL) and the objectives of scientific literacy. Furthermore, the instrument was pilot tested with a small group of students to assess its internal consistency and reliability. The Cronbach's alpha coefficient of 0.909 was calculated from the pilot test to assess the instrument's reliability before it was administered to the entire Grade 9 population. This process ensured the instrument was both valid and reliable, enabling the study to generate accurate and reliable data.

Data Gathering Procedure

To ensure the smooth and ethical conduct of the research, a formal letter was submitted to the principal of a junior high school in one of the states in America, the designated research site, requesting permission to conduct the study. The primary data-gathering tool was a researcher-developed survey questionnaire checklist carefully designed to collect relevant information regarding students' inquiry-based learning experiences and their level of scientific literacy. Respondents' confidentiality was strictly maintained, and an initial orientation session was conducted to clearly explain the study's purpose, provide instructions, and address any questions or concerns.

The survey was designed to be easily accessible and simple to complete so that respondents could participate conveniently and confidently. Special attention was given to obtaining informed consent, and respondents were asked to participate voluntarily and provide honest responses. After the data collection process was completed, the gathered information underwent statistical analysis and interpretation, which served as the basis for answering the research questions. Finally, based on the findings, the researcher developed a set of recommendations that reflected the study's results and provided practical insights for improving inquiry-based learning and strengthening students' scientific literacy.

Statistical Treatment of Data

The data gathered in this study were analyzed using the following statistical methods:

Frequency and Percentage were used to determine the demographic profile of the respondents.

Mean and Standard Deviation were used to assess the Extent of respondents' inquiry-based learning experiences.

The Mean and Standard Deviation were used to assess the respondents' scientific skills.

One-way Analysis of Variance (ANOVA) was used to assess the extent of inquiry-based learning experiences of the respondents, grouped by profile.

One-way Analysis of Variance (ANOVA) was used to assess the level of scientific skills among respondents, grouped by profile.

Pearson's correlation was used to determine whether there is a significant relationship between the Extent of inquiry-based learning experiences and respondents' scientific skills.

Ethical Considerations

This study adhered to ethical guidelines to protect the rights, dignity, and well-being of all respondents. Before data collection, formal approval was sought from the administration of the designated high school in the United States, which served as the research site. Participation was entirely voluntary, and informed consent was obtained from the parents or guardians of all student respondents.

During an orientation session, the respondents received a clear explanation of the study's objectives, procedures, potential risks, and anticipated benefits. They were also informed of their right to withdraw from the study at any time without penalty. Measures were taken to ensure confidentiality and anonymity throughout the research process.

IV. PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

Problem Number 1. What is the effectiveness of inquiry-based learning in Biology in terms of questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting?

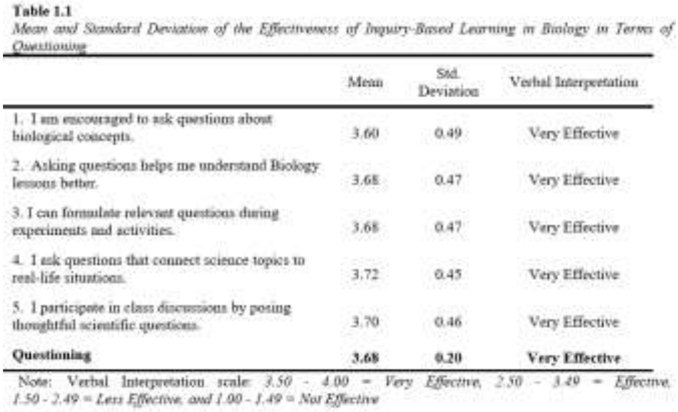


Table 1.1
Mean and Standard Deviation of the Effectiveness of Inquiry-Based Learning in Biology in Terms of Questioning

	Mean	Std. Deviation	Verbal Interpretation
1. I am encouraged to ask questions about biological concepts.	3.60	0.49	Very Effective
2. Asking questions helps me understand Biology lessons better.	3.68	0.47	Very Effective
3. I can formulate relevant questions during experiments and activities.	3.68	0.47	Very Effective
4. I ask questions that connect science topics to real-life situations.	3.72	0.45	Very Effective
5. I participate in class discussions by posing thoughtful scientific questions.	3.70	0.46	Very Effective
Questioning	**3.68**	**0.20**	**Very Effective**

Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

The data show that students rate inquiry-based learning as very effective in fostering questioning skills. All five items about questioning scored high, yielding an overall mean of 3.68 ("Very Effective"). In practical terms, this means students feel strongly that inquiry methods encourage them to ask meaningful questions about biology, urge them to wonder and inquire, see questions as aids to their understanding, and even connect science concepts to real-life situations. The very low standard deviations suggest almost all students share this positive view. In sum, the results indicate that inquiry-based biology instruction puts questioning at the center of learning. This aligns with prior findings that inquiry learning actively prompts students to formulate questions and drive their own discovery. As one source notes, inquiry-based methods "encourage students to ask questions, explore ideas, and discover answers on their own, thereby building their curiosity and confidence (Palaguyan & Abusama, 2025). In other words, when students are invited to wonder and question, they become active participants in learning (Stehr, 2025). The data with nearly all items in the "very effective" range, echo this: inquiry instruction in biology clearly empowers students to generate and use questions as part of deep, engaged learning (Vale, 2013).

The findings reveal that inquiry-based learning is perceived as very effective in developing students' hypothesizing skills in Biology. Students reported that they can make predictions before conducting experiments, propose explanations for scientific phenomena, discuss alternative hypotheses with classmates, anticipate outcomes based on prior knowledge, and revise their hypotheses when presented with new evidence.

These results suggest that inquiry-based learning strengthens students' ability to think scientifically. Hypothesizing requires learners to activate prior knowledge, make logical predictions, and remain open to modifying their ideas when confronted with new data. The high ratings across all indicators imply that students are not merely memorizing biological facts but are engaging in the cognitive processes characteristic of authentic scientific inquiry.

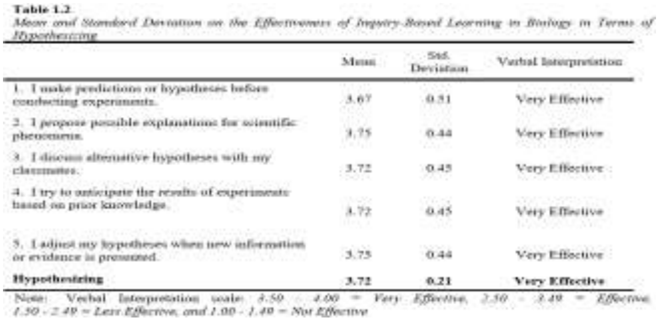


Table 1.2
Mean and Standard Deviation on the Effectiveness of Inquiry-Based Learning in Biology in Terms of Hypothesizing

	Mean	Std. Deviation	Verbal Interpretation
1. I make predictions or hypotheses before conducting experiments.	3.67	0.51	Very Effective
2. I propose possible explanations for scientific phenomena.	3.75	0.44	Very Effective
3. I discuss alternative hypotheses with my classmates.	3.72	0.45	Very Effective
4. I try to anticipate the results of experiments based on prior knowledge.	3.72	0.45	Very Effective
5. I adjust my hypotheses when new information or evidence is presented.	3.75	0.44	Very Effective
Hypothesizing	**3.72**	**0.21**	**Very Effective**

Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

This aligns with research indicating that inquiry-based instruction enhances students' scientific reasoning and predictive thinking skills (Pedaste et al., 2019; Lazonder & Harmsen, 2019). Studies have shown that when students are allowed to generate and test their own hypotheses, they demonstrate deeper conceptual understanding and improved analytical thinking. Moreover, collaborative discussion of alternative hypotheses strengthens reasoning skills and promotes cognitive flexibility (Zion & Mendelovici, 2019).

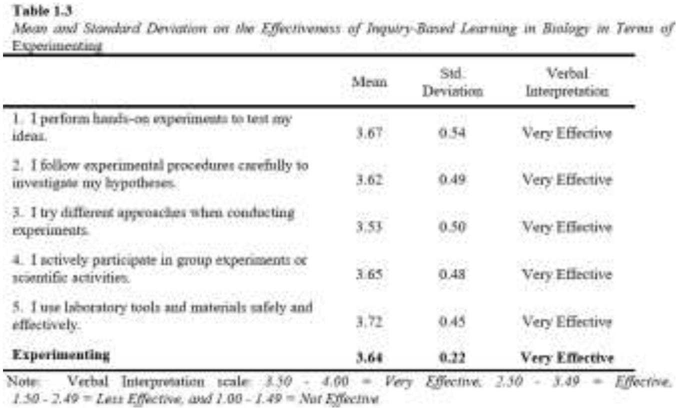


Table 1.3
Mean and Standard Deviation on the Effectiveness of Inquiry-Based Learning in Biology in Terms of Experimenting

	Mean	Std. Deviation	Verbal Interpretation
1. I perform hands-on experiments to test my ideas.	3.67	0.54	Very Effective
2. I follow experimental procedures carefully to investigate my hypotheses.	3.62	0.49	Very Effective
3. I try different approaches when conducting experiments.	3.53	0.50	Very Effective
4. I actively participate in group experiments or scientific activities.	3.65	0.48	Very Effective
5. I use laboratory tools and materials safely and effectively.	3.72	0.45	Very Effective
Experimenting	**3.64**	**0.22**	**Very Effective**

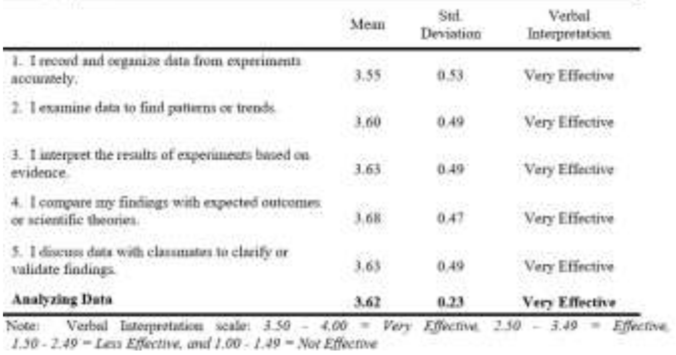
Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

The data indicate that inquiry-based learning is also very effective in enhancing students' experimenting skills. Students reported active participation in hands-on experiments, careful adherence to procedures, exploration of different approaches, collaborative engagement in group activities, and safe use of laboratory tools and materials.

These findings demonstrate that inquiry-based learning promotes experiential and active learning. Rather than passively observing demonstrations, students are directly involved in testing their ideas and validating their hypotheses through experimentation. This hands-on engagement strengthens procedural knowledge and reinforces the connection between theory and practice.

Recent studies affirm that inquiry-based approaches significantly improve students' practical laboratory skills and scientific process competencies (Furtak et al., 2021; OECD, 2020). Research also suggests that active experimentation enhances students' motivation and ownership of learning, leading to more meaningful understanding of scientific concepts (Hmelo-Silver et al., 2019).

Table 1.4
Mean and Standard Deviation on the Effectiveness of Inquiry-Based Learning in Biology in Terms of Analyzing Data



	Mean	Std. Deviation	Verbal Interpretation
1. I record and organize data from experiments accurately.	3.55	0.53	Very Effective
2. I examine data to find patterns or trends.	3.60	0.49	Very Effective
3. I interpret the results of experiments based on evidence.	3.63	0.49	Very Effective
4. I compare my findings with expected outcomes or scientific theories.	3.68	0.47	Very Effective
5. I discuss data with classmates to clarify or validate findings.	3.63	0.49	Very Effective
Analyzing Data	**3.62**	**0.23**	**Very Effective**

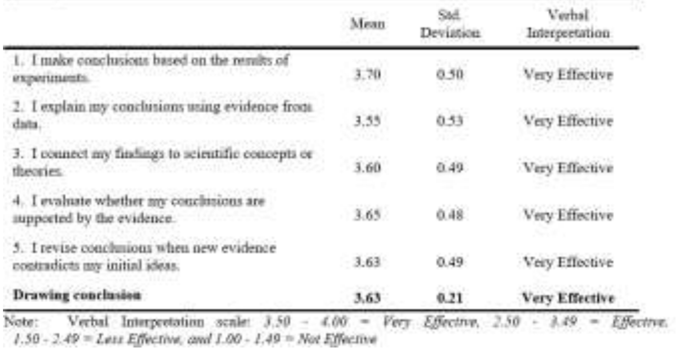
Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 – 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

The results further reveal that inquiry-based learning is very effective in strengthening students' data analysis skills. Students reported being able to accurately record and organize data, identify patterns and trends, interpret results based on evidence, compare findings with scientific theories, and discuss results collaboratively.

These outcomes indicate that inquiry-based learning fosters evidence-based reasoning. Data analysis is a critical phase of scientific inquiry that requires students to move beyond observation toward interpretation and justification. The findings suggest that students are developing the ability to make sense of evidence and construct logical explanations grounded in data.

Research supports this conclusion, noting that inquiry-based environments significantly enhance students' analytical and critical thinking skills (Pedaste et al., 2019; Zion & Mendelovici, 2019). Furthermore, collaborative data analysis has been shown to improve students' ability to justify claims with evidence, a core scientific practice (National Research Council, 2020).

Table 1.5
Mean and Standard Deviation on the Effectiveness of Inquiry-Based Learning in Biology in Terms of Drawing Conclusion



	Mean	Std. Deviation	Verbal Interpretation
1. I make conclusions based on the results of experiments.	3.70	0.50	Very Effective
2. I explain my conclusions using evidence from data.	3.55	0.53	Very Effective
3. I connect my findings to scientific concepts or theories.	3.60	0.49	Very Effective
4. I evaluate whether my conclusions are supported by the evidence.	3.65	0.48	Very Effective
5. I revise conclusions when new evidence contradicts my initial ideas.	3.63	0.49	Very Effective
Drawing conclusion	**3.63**	**0.21**	**Very Effective**

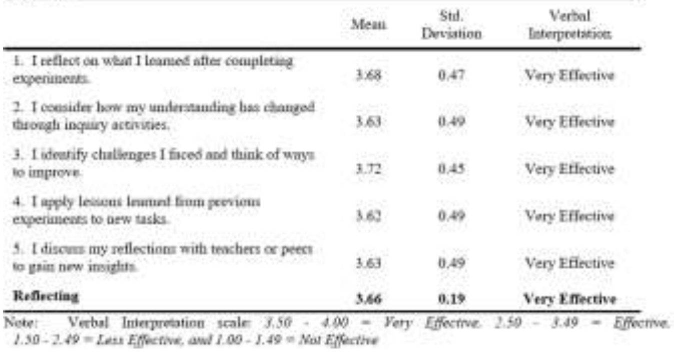
Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

The findings indicate that inquiry-based learning is very effective in developing students' ability to conclude Biology. Students affirmed that they can formulate conclusions based on experimental results, justify their claims with evidence, connect findings to scientific theories, evaluate whether conclusions are supported by data, and revise their ideas when confronted with contradictory evidence.

These results suggest that inquiry-based learning promotes evidence-based reasoning, a central component of scientific literacy. Concluding is not merely about stating results; it involves critical evaluation, logical reasoning, and the ability to connect empirical findings with established scientific concepts. The consistently high ratings imply that students are engaging in higher-order thinking processes, particularly analysis, synthesis, and evaluation.

According to Furtak et al. (2021), inquiry-based science instruction significantly enhances students' ability to construct evidence-based explanations and scientific arguments. Similarly, Pedaste et al. (2019) emphasize that the conclusion phase of the inquiry cycle requires learners to interpret results and link them to theoretical frameworks, strengthening conceptual understanding. Studies further indicate that when students are encouraged to revise conclusions in light of new evidence, they develop deeper epistemic understanding and scientific reasoning skills (Zion & Mendelovici, 2019).

Table 1.6
Mean and Standard Deviation on the Effectiveness of Inquiry-Based Learning in Biology in Terms of Reflecting



	Mean	Std. Deviation	Verbal Interpretation
1. I reflect on what I learned after completing experiments.	3.68	0.47	Very Effective
2. I consider how my understanding has changed through inquiry activities.	3.63	0.49	Very Effective
3. I identify challenges I faced and think of ways to improve.	3.72	0.45	Very Effective
4. I apply lessons learned from previous experiments to new tasks.	3.62	0.49	Very Effective
5. I discuss my reflections with teachers or peers to gain new insights.	3.63	0.49	Very Effective
Reflecting	**3.66**	**0.19**	**Very Effective**

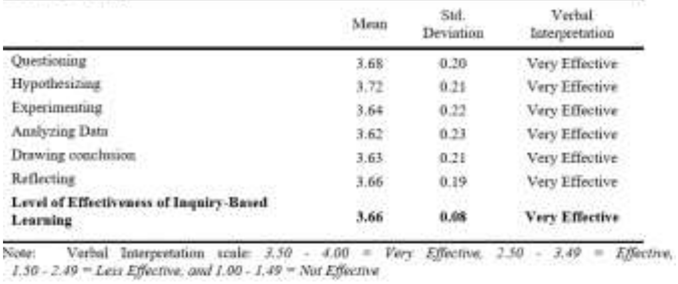
Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

The data further reveal that inquiry-based learning is very effective in fostering students' reflective skills. Students reported reflecting on their learning after experiments, recognizing changes in understanding, identifying challenges and areas for improvement, applying previous learning to new situations, and engaging in reflective discussions with peers and teachers.

Reflection is a metacognitive process that allows learners to evaluate their own thinking and learning strategies. The high ratings in this domain suggest that inquiry-based learning does not end with experimentation or conclusion but extends to self-assessment and continuous improvement. This implies that students are becoming more aware of how they learn and how their understanding evolves through inquiry activities.

Recent literature highlights that reflection is a crucial component of inquiry learning. Hmelo-Silver et al. (2019) explain that inquiry-based environments promote metacognitive Awareness by encouraging students to evaluate their reasoning and learning processes. Likewise, OECD (2020) reports emphasize that reflective practices enhance problem-solving skills and long-term retention of scientific concepts. When students engage in reflective dialogue, they deepen conceptual understanding and develop lifelong learning skills.

Table 1.7
Mean and Standard Deviation of the Composite Table on Competitive Effectiveness of Inquiry-Based Learning in Biology



	Mean	Std. Deviation	Verbal Interpretation
Questioning	3.68	0.20	Very Effective
Hypothesizing	3.72	0.21	Very Effective
Experimenting	3.64	0.22	Very Effective
Analyzing Data	3.62	0.23	Very Effective
Drawing conclusion	3.63	0.21	Very Effective
Reflecting	3.66	0.19	Very Effective
Level of Effectiveness of Inquiry-Based Learning	**3.66**	**0.08**	**Very Effective**

Note: Verbal Interpretation scale: *3.50 - 4.00 = Very Effective, 2.50 - 3.49 = Effective, 1.50 - 2.49 = Less Effective, and 1.00 - 1.49 = Not Effective*

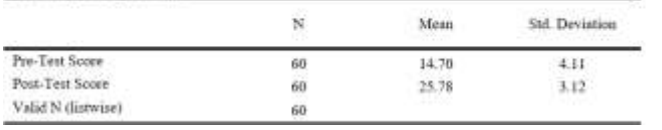
The composite results show that inquiry-based learning is very effective across all six domains: questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting. The overall mean falls within the highest interpretation category, indicating strong agreement among students regarding the effectiveness of inquiry-based strategies in enhancing their scientific skills.

Notably, all components of the scientific process received consistently high ratings, demonstrating that inquiry-based learning supports the entire inquiry cycle rather than isolated skills. This consistency suggests that students experience Biology not as fragmented tasks but as an integrated scientific process from asking questions to reflecting on outcomes.

These findings are consistent with contemporary research asserting that inquiry-based learning improves both cognitive and procedural scientific skills (Furtak et al., 2021; Pedaste et al., 2019). Furthermore, international assessments highlight that students exposed to inquiry-oriented science instruction demonstrate stronger problem-solving abilities and scientific literacy (OECD, 2020).

Problem Number 2. What is the level of the gained scientific skills as revealed by the pretest and post-test of the respondents?

Table 2
Mean and Standard Deviation on the Level of the Gained Scientific Skills as Revealed by the Pretest and Post-test of the Respondents



	N	Mean	Std. Deviation
Pre-Test Score	60	14.70	4.11
Post-Test Score	60	25.78	3.12
Valid N (listwise)	60		

Table 2 presents the level of students' scientific skills before and after the implementation of inquiry-based learning. The results show a substantial increase in the mean score from the pretest to the post-test. This indicates that students demonstrated notable improvement in their scientific skills after being exposed to inquiry-based instruction in Biology.

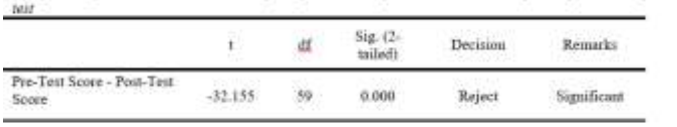
The increase in performance suggests that inquiry-based learning contributed positively to students' mastery of scientific concepts and processes. Prior to the intervention, students' skills were comparatively lower, reflecting limited initial proficiency. However, after engaging in activities involving questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting, students demonstrated a deeper understanding and application of scientific principles.

This finding is consistent with research showing that inquiry-based learning improves academic performance and scientific process skills. Furtak et al. (2021) found that students exposed to inquiry-oriented instruction achieved higher gains than those in traditional classrooms. Similarly, OECD (2020) reports that active engagement in scientific inquiry significantly strengthens students' problem-solving and reasoning abilities. Therefore, the results indicate that inquiry-based learning effectively enhances students' scientific skills, as evidenced by the marked improvement from pretest to post-test scores.

Problem Number 3. Is there a significant difference between the level of the gained scientific skills as revealed by their pretest and post-test?

Table 3 shows that there is a statistically significant difference between the pretest and post-test scores. The computed t-value and significance level indicate that the improvement in students' scientific skills is not due to chance.

Table 3
Significant difference between the level of the gained scientific skills as revealed by their pretest and post-test



	t	df	Sig. (2-tailed)	Decision	Remarks
Pre-Test Score - Post-Test Score	-32.155	59	0.000	Reject	Significant

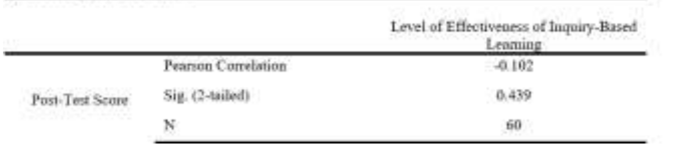
Thus, the null hypothesis is rejected.

This result confirms that inquiry-based learning had a measurable impact on students' scientific skill development. The significant improvement demonstrates that the instructional strategy was effective in strengthening students' understanding and application of scientific processes.

According to Lazonder and Harmsen (2019), guided inquiry significantly enhances learning outcomes, particularly when students are actively involved in investigation and reasoning tasks. Furtak et al. (2021) also concluded in their meta-analysis that inquiry-based science instruction leads to statistically significant gains in student achievement compared to conventional teaching approaches. The significant difference between pretest and post-test scores, therefore, provides empirical evidence that inquiry-based learning positively influences students' scientific competencies.

Problem Number 4. Is there a significant relationship between the effectiveness of inquiry-based learning and the scientific skills as revealed by the post-test?

Table 4
Pearson r Correlation Between the Effectiveness of Inquiry-Based Learning and Gained Scientific Skills as Revealed by Their Post-Test



		Level of Effectiveness of Inquiry-Based Learning
Post-Test Score	Pearson Correlation	-0.102
	Sig. (2-tailed)	0.439
	N	60

Table 4 reveals that there is no statistically significant relationship between students' perceived effectiveness of inquiry-based learning and their post-test scores. The correlation coefficient indicates a very weak relationship, and the p-value suggests it is not statistically significant.

Although students rated inquiry-based learning as highly effective in developing their scientific skills, this perception did not directly correlate with their measured post-test performance. This suggests that while students recognize the benefits of inquiry-based strategies, other factors may also influence their academic performance, such as prior knowledge, learning styles, motivation, or external Support systems.

This finding aligns with studies suggesting that perceptions of instructional effectiveness do not always directly translate into measurable academic outcomes (OECD, 2020). While inquiry-based learning fosters engagement and skill development, achievement may also depend on individual differences and contextual variables (Hmelo-Silver et al., 2019).

Nonetheless, the absence of a significant correlation does not diminish the observed improvement in post-test scores. Rather, it highlights the complexity of learning processes and suggests the need for further investigation into mediating factors that influence academic performance.

Problem Number 5. Based on the findings of the study, what output may be crafted?

Project I-BIO (Institutionalizing Inquiry-Based Learning to Boost Scientific Skills)

Introduction

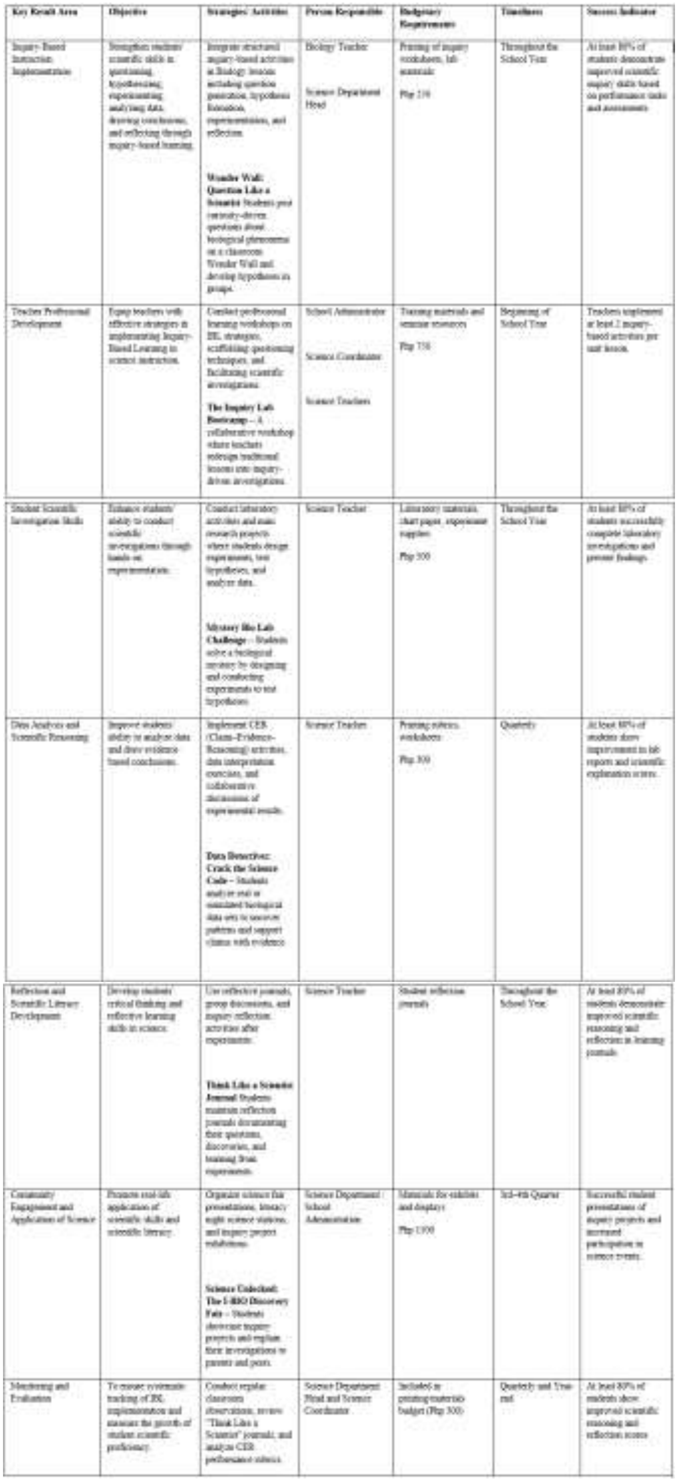
Project I-BIO (Institutionalizing Inquiry-Based Learning to Boost Scientific Skills) is an institutional initiative designed to transform science education by shifting from traditional instruction to an inquiry-driven discovery model. The program focuses on bridging the gap between student curiosity and academic competence by embedding the scientific method into the core of Biology instruction. By fostering an environment where questioning and experimentation are central, the project aims to produce scientifically literate individuals capable of navigating complex biological phenomena.

Rationale

Traditional science instruction often focuses on rote memorization, which can stifle a student's natural curiosity; Project I-BIO addresses this by institutionalizing Inquiry-Based Learning (IBL) as a standard pedagogical approach. By implementing strategies like the "Wonder Wall" and "Data Detectives," the project provides a structured framework for students to practice Claim–Evidence–Reasoning (CER) and evidence-based conclusion drawing. This approach not only targets improved lab report scores but also encourages the real-world application of science through community engagement events such as the I-BIO Discovery Fair.

Objectives

The primary objective of Project I-BIO is to strengthen students' fundamental scientific skills, specifically in questioning, hypothesizing, experimenting, and data analysis. The project seeks to ensure that at least 80% of students demonstrate significant improvement in scientific reasoning and performance tasks through structured inquiry-based activities. Additionally, it aims to empower educators through professional development, enabling them to effectively redesign lessons and facilitate hands-on scientific investigations within the classroom.



Key Result Area	**Objective**	**Strategies/ Activities**	**Person Responsible**	**Budgetary Requirements**	**Timelines**	**Success Indicator**
Inquiry-Based Instruction Implementation	Strengthen students' scientific skills in questioning, hypothesizing, experimenting, analyzing data, drawing conclusions, and reflecting through inquiry-based learning.	Integrate structured inquiry-based activities in Biology lessons including question generation, hypothesis formation, experimentation, and reflection. **Wonder Wall: Question Like a Scientist** Students post curiosity-driven questions about biological phenomena on a classroom Wonder Wall and develop hypotheses in groups.	Biology Teacher Science Department Head	Printing of inquiry worksheets, lab materials Php 250	Throughout the School Year	At least 80% of students demonstrate improved scientific inquiry skills based on performance tasks and assessments.
Teacher Professional Development	Equip teachers with effective strategies in implementing Inquiry-Based Learning in science instruction.	Conduct professional learning workshops on IBL strategies, scaffolding questioning techniques, and facilitating scientific investigations. **The Inquiry Lab Bootcamp** – A collaborative workshop where teachers redesign traditional lessons into inquiry-driven investigations.	School Administrator Science Coordinator Science Teachers	Training materials and seminar resources Php 750	Beginning of School Year	Teachers implement at least 2 inquiry-based activities per unit lesson.
Student Scientific Investigation Skills	Enhance students' ability to conduct scientific investigations through hands-on experimentation.	Conduct laboratory activities and mini research projects where students design experiments, test hypotheses, and analyze data. **Mystery Bio Lab Challenge** – Students solve a biological mystery by designing and conducting experiments to test hypotheses.	Science Teacher	Laboratory materials, chart paper, experiment supplies Php 500	Throughout the School Year	At least 80% of students successfully complete laboratory investigations and present findings.
Data Analysis and Scientific Reasoning	Improve students' ability to analyze data and draw evidence-based conclusions.	Implement CER (Claim–Evidence–Reasoning) activities, data interpretation exercises, and collaborative discussions of experimental results. **Data Detectives: Crack the Science Code** – Students analyze real or simulated biological data sets to uncover patterns and support claims with evidence	Science Teacher	Printing rubrics, worksheets Php 300	Quarterly	At least 80% of students show improvement in lab reports and scientific explanation scores.
Reflection and Scientific Literacy Development	Develop students' critical thinking and reflective learning skills in science.	Use reflective journals, group discussions, and inquiry reflection activities after experiments. **Think Like a Scientist Journal** Students maintain reflection journals documenting their questions, discoveries, and learning from experiments.	Science Teacher	Student reflection journals	Throughout the School Year	At least 80% of students demonstrate improved scientific reasoning and reflection in learning journals.
Community Engagement and Application of Science	Promote real-life application of scientific skills and scientific literacy.	Organize science fair presentations, literacy night science stations, and inquiry project exhibitions. **Science Unlocked: The I-BIO Discovery Fair** – Students showcase inquiry projects and explain their investigations to parents and peers.	Science Department / School Administration	Materials for exhibits and displays Php 1500	3rd–4th Quarter	Successful student presentations of inquiry projects and increased participation in science events.
Monitoring and Evaluation	To ensure systematic tracking of IBL implementation and measure the growth of student scientific proficiency.	Conduct regular classroom observations, review "Think Like a Scientist" journals, and analyze CER performance rubrics.	Science Department Head and Science Coordinator	Included in printing/materials budget (Php 300)	Quarterly and Year-end	At least 80% of students show improved scientific reasoning and reflection scores

Project I-BIO (Integrating Inquiry-Based Learning to Boost Scientific Skills) is a structured educational initiative that enhances students' scientific competencies by systematically integrating inquiry-based learning. Anchored in constructivist and learner-centered pedagogies, the project shifts instruction from traditional, teacher-directed methods to a more active learning environment where students take greater responsibility for constructing their own understanding. It emphasizes the exploration of scientific concepts through curiosity-driven inquiry, guided investigation, and hands-on, experiential learning. This project proposal enables learners to engage in essential scientific processes, including formulating researchable questions, developing hypotheses, conducting experiments, and collecting, analyzing, and interpreting data. These practices mirror authentic scientific work, enabling students to develop not only conceptual knowledge but also higher-order thinking skills, including critical analysis, problem-solving, and logical reasoning. Additionally, the project fosters collaboration and reflection through group activities and discourse, leading to deeper understanding, improved knowledge retention, and increased engagement. Project I-BIO cultivates scientifically literate learners who can apply their knowledge in real-life contexts and function as critical thinkers and responsible decision-makers.

V. SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusions, and recommendations organized according to the identified research problems. The study on inquiry-based learning and its influence on students' scientific skills served as the basis for crafting a proposed action plan.

Summary of Findings

Using the prescribed research methodologies, the findings are summarized as follows:

Students perceived inquiry-based learning as highly effective in developing their scientific skills, as they actively engaged in asking questions, forming hypotheses, conducting experiments, analyzing data, drawing conclusions, and reflecting on their learning.

Students showed significant improvement in their scientific skills from the pretest to the post-test, demonstrating better understanding, stronger analytical thinking, and improved ability to apply Biology concepts after experiencing inquiry-based learning.

The paired-sample t-test indicated a significant difference between the pretest and post-test results, confirming that inquiry-based learning positively contributed to the development of students' scientific skills.

Although students considered inquiry-based learning very effective, no significant relationship was found between their perceived effectiveness and their post-test scores, suggesting that other factors may also influence their academic performance.

The study suggests that inquiry-based learning (IBL) enhances students' scientific skills, critical thinking, engagement, and ability to apply knowledge through hands-on experiments and collaborative projects. It also indicates that IBL fosters positive attitudes toward science and can be systematically integrated into the curriculum to Support ongoing scientific literacy.

Conclusions

Based on the findings of the study, the following conclusions are drawn:

1. Inquiry-based learning effectively enhances multiple dimensions of students' scientific skills. The strategy strengthens students' abilities to question, hypothesize, experiment, analyze data, draw conclusions, and reflect. By engaging learners actively in the scientific process, inquiry-based learning promotes higher-order thinking and deeper conceptual understanding in Biology.
2. Inquiry-based instruction significantly improves students' academic performance in scientific skills. The substantial increase in post-test scores confirms that students benefit cognitively from structured inquiry activities. The strategy enables learners to construct knowledge actively and apply scientific reasoning more effectively than traditional teacher-centered approaches.
3. The significant difference between pretest and post-test results confirms the effectiveness of inquiry-based learning as an instructional approach. Statistical evidence supports the claim that inquiry-based learning contributes meaningfully to academic growth. The measurable improvement demonstrates that the strategy is not only perceived positively but also produces concrete learning gains.
4. Students' perception of instructional effectiveness does not necessarily predict academic achievement. The absence of a significant correlation between perceived effectiveness and post-test scores indicates that multiple interacting variables influence learning outcomes. While inquiry-based learning creates a positive learning environment, other cognitive and contextual factors may mediate performance results.
5. Inquiry-based learning effectively develops students' scientific skills, critical thinking, and engagement while promoting the practical application of knowledge. Additionally, it cultivates positive attitudes toward science and can be sustainably incorporated into the curriculum to enhance scientific literacy.

Recommendations

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

1. Institutionalize inquiry-based learning across Biology instruction to sustain the development of scientific skills. Science teachers may consistently integrate structured inquiry cycles into lesson planning, including opportunities for questioning, hypothesis formulation, experimentation, data interpretation, and reflection. Regular implementation will reinforce scientific thinking habits and maintain skill development.
2. Strengthen monitoring of student progress through formative and summative assessments aligned with inquiry processes. Teachers may design assessment tools that measure not only factual knowledge but also scientific reasoning and process skills. Continuous assessment will help track improvement and identify areas requiring additional Support.
3. Provide professional development programs focused on the effective implementation of inquiry-based strategies. School administrators may organize training sessions, workshops, and

peer mentoring activities to enhance teachers' competence in facilitating inquiry-driven instruction. Strengthening teacher expertise will ensure consistent and high-quality application of the strategy.

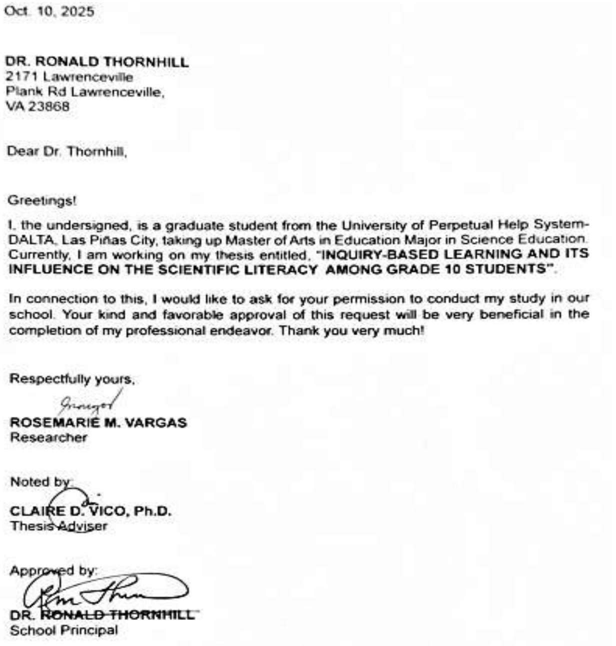
4. Conduct further studies to examine other factors influencing academic performance in inquiry-based environments. Future research may explore variables such as motivation, prior knowledge, learning styles, and classroom climate to better understand their interaction with inquiry-based instruction. Identifying these factors can help refine instructional practices and maximize student achievement.

5.Teachers may regularly implement inquiry-based learning strategies in science classes to strengthen students' skills and critical thinking. Schools can also provide training and resources to Support the systematic integration of IBL into the curriculum, fostering sustained engagement and positive attitudes toward science.

APPENDIX

APPENDIX A

PERMIT TO CONDUCT STUDY



Oct. 10, 2025

DR. RONALD THORNHILL
2171 Lawrenceville
Plank Rd Lawrenceville,
VA 23868

Dear Dr. Thornhill,

Greetings!

I, the undersigned, is a graduate student from the University of Perpetual Help System-DALTA, Las Piñas City, taking up Master of Arts in Education Major in Science Education. Currently, I am working on my thesis entitled, "**INQUIRY-BASED LEARNING AND ITS INFLUENCE ON THE SCIENTIFIC LITERACY AMONG GRADE 10 STUDENTS**".

In connection to this, I would like to ask for your permission to conduct my study in our school. Your kind and favorable approval of this request will be very beneficial in the completion of my professional endeavor. Thank you very much!

Respectfully yours,

ROSEMARIE M. VARGAS
Researcher

Noted by:

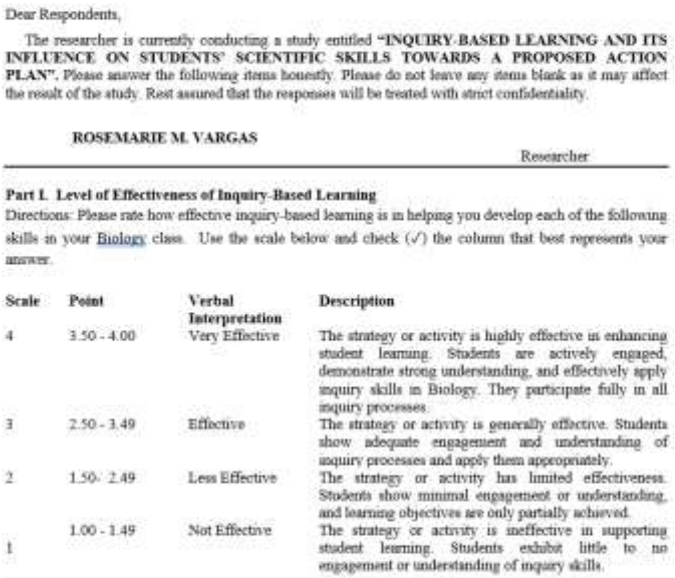
CLAIRE D. VICO, Ph.D.
Thesis Adviser

Approved by:

DR. RONALD THORNHILL
School Principal

APPENDIX B

SURVEY QUESTIONNAIRE



Dear Respondents,

The researcher is currently conducting a study entitled **"INQUIRY-BASED LEARNING AND ITS INFLUENCE ON STUDENTS' SCIENTIFIC SKILLS TOWARDS A PROPOSED ACTION PLAN"**. Please answer the following items honestly. Please do not leave any items blank as it may affect the result of the study. Rest assured that the responses will be treated with strict confidentiality.

ROSEMARIE M. VARGAS
Researcher

Part I. Level of Effectiveness of Inquiry-Based Learning

Directions: Please rate how effective inquiry-based learning is in helping you develop each of the following skills in your Biology class. Use the scale below and check (✓) the column that best represents your answer.

Scale	Point	Verbal Interpretation	Description
4	3.50 - 4.00	Very Effective	The strategy or activity is highly effective in enhancing student learning. Students are actively engaged, demonstrate strong understanding, and effectively apply inquiry skills in Biology. They participate fully in all inquiry processes.
3	2.50 - 3.49	Effective	The strategy or activity is generally effective. Students show adequate engagement and understanding of inquiry processes and apply them appropriately.
2	1.50- 2.49	Less Effective	The strategy or activity has limited effectiveness. Students show minimal engagement or understanding, and learning objectives are only partially achieved.
1	1.00 - 1.49	Not Effective	The strategy or activity is ineffective in supporting student learning. Students exhibit little to no engagement or understanding of inquiry skills.

QUESTIONING	**4**	**3**	**2**	**1**
1. I am encouraged to ask questions about biological concepts.				
2. Asking questions helps me understand Biology lessons better.				
3. I can formulate relevant questions during experiments and activities.				
4. I ask questions that connect science topics to real-life situations.				
5. I participate in class discussions by posing thoughtful scientific questions.				
HYPOTHESIZING	**4**	**3**	**2**	**1**
1. I make predictions or hypotheses before conducting experiments.				
2. I propose possible explanations for scientific phenomena.				
3. I discuss alternative hypotheses with my classmates.				
4. I try to anticipate the results of experiments based on prior knowledge.				
5. I adjust my hypotheses when new information or evidence is presented.				
EXPERIMENTING				
1. I perform hands-on experiments to test my ideas.				
2. I follow experimental procedures carefully to investigate my hypotheses.				
3. I try different approaches when conducting experiments.				
4. I actively participate in group experiments or scientific activities.				
5. I use laboratory tools and materials safely and effectively.				
ANALYZING DATA				
1. I record and organize data from experiments accurately.				
2. I examine data to find patterns or trends.				
3. I interpret the results of experiments based on evidence.				
4. I compare my findings with expected outcomes or scientific theories.				
5. I discuss data with classmates to clarify or validate findings.				
DRAWING CONCLUSIONS				
1. I make conclusions based on the results of experiments.				
2. I explain my conclusions using evidence from data.				
3. I connect my findings to scientific concepts or theories.				
4. I evaluate whether my conclusions are supported by the evidence.				
5. I revise conclusions when new evidence contradicts my initial ideas.				
REFLECTING				
1. I reflect on what I learned after completing experiments.				
2. I consider how my understanding has changed through inquiry activities.				
3. I identify challenges I faced and think of ways to improve.				
4. I apply lessons learned from previous experiments to new tasks.				
5. I discuss my reflections with teachers or peers to gain new insights.				

APPENDIX C

STATISTICIAN'S CERTIFICATION

February 19, 2026

CERTIFICATION

This is to certify that the thesis entitled "INQUIRY-BASED LEARNING AND ITS INFLUENCE ON SCIENTIFIC LITERACY TOWARDS AN PROPOSED ACTION PLAN" prepared and submitted by ROSEMARIE M. VARGAS in partial fulfillment for the degree Master of Arts in Education major in Science has been statistically reviewed by the undersigned.

OLIVER P. BALTAZAR
Statistician

APPENDIX D

CERTIFICATE OF ORIGINALITY

UNIVERSITY OF PERPETUAL HELP SYSTEM DALTA

CERTIFICATE OF ORIGINALITY

This is to certify that the research paper with the following specifics has been checked for originality using the TURNITIN platform.

Title: **INQUIRY-BASED LEARNING AND ITS INFLUENCE ON STUDENTS' SCIENTIFIC SKILLS TOWARDS A PROPOSED ACTION PLAN**

Name of Student/s: **ROSEMARIE M. VARGAS**

Program: **MASTER OF ARTS IN EDUCATION MAJOR IN SCIENCE**

Date of Submission to Turnitin: **APRIL 10, 2026**

Percentage: **10%**

This is to further certify that all pertinent sources from which ideas and other extracts have been taken were duly acknowledged and cited. As it is, the project is free from any plagiarism and may be eligible for possible publication in any reputable peer reviewed or refereed journal.

Processed by

Anabelle Tabuac
Intellectual Property Officer

Belinda T. Conde, PhD
Research Director

April 13, 2026
Date Issued

LAS PIÑAS CAMPUS

APPENDIX E

CERTIFICATE OF DATA PROCESSING

UNIVERSITY OF PERPETUAL HELP SYSTEM DALTA

CERTIFICATE OF DATA PROCESSING

Title: **INQUIRY-BASED LEARNING AND ITS INFLUENCE ON STUDENTS' SCIENTIFIC SKILLS TOWARDS A PROPOSED ACTION PLAN**

Name of Student/s: **ROSEMARIE M. VARGAS**

Program: **MASTER OF ARTS IN EDUCATION MAJOR IN SCIENCE**

This is to further certify the integrity of data which has been processed.

Belinda T. Conde, PhD
Research Director

April 13, 2026
Date Issued

LAS PIÑAS CAMPUS

APPENDIX F

LANGUAGE EDITING CERTIFICATION

UNIVERSITY OF PERPETUAL HELP SYSTEM DALTA

LANGUAGE EDITING CERTIFICATION

This is to certify that the research paper whose title appears below has been subjected to Language Editing.

Title: **INQUIRY-BASED LEARNING AND ITS INFLUENCE ON STUDENTS' SCIENTIFIC SKILLS TOWARDS A PROPOSED ACTION PLAN**

Name of Student/s: **ROSEMARIE M. VARGAS**

Program: **MASTER OF ARTS IN EDUCATION MAJOR IN SCIENCE**

Cristina D. Abaya
Research Assistant

April 13, 2026
Date Issued

LAS PIÑAS CAMPUS

ACKNOWLEDGMENT

The researcher wishes to express his deepest thanks and profound appreciation to those individuals who aided, support, and guidance throughout the study's completion.

DR. EDUARDO C. ZIALCITA, Dean, Graduate School, for allowing the researcher to conduct the study.

DR. CLAIRE D. VICO, her thesis adviser, for the suggestions given for the improvement of the study, and for her immeasurable support and untiring perseverance in extending her knowledge to finish the study.

DR. ARLENE A. JUSTO, her panel chairman, for the comments, suggestions, and recommendations for the betterment of the study.

DR. EMMA E. LINGA and PROF. GALILEO C. GERVACIO, her panel members, for their unselfish and unfailing suggestions and recommendations in this study.

To the RESPONDENTS, for their willingness to serve as subject of the study.

To the FAMILY and FRIENDS, of the researcher for their moral support and inspiring ideas and encouragement to pursue this work.

-Rosemarie

REFERENCES

[1] Abdullah, M. Y., Hussin, S., Hammad, Z. M., & Ismail, K. (2021). Exploring the effects of flipped classroom model implementation on EFL learners' self-confidence in English speaking performance. *Recent Advances in Intelligent Systems and Smart Applications*, 223–241.

[2] Ai, J., Pan, Y., & Zhong, W. (2021, November). The Role of Motivation in Second Language Acquisition: A review. In *2021 3rd International Conference on Literature, Art and Human Development (ICLAHD 2021)* (pp. 623–627). Atlantis Press.

[3] Aidoo, B. (2024). A reflective study on adopting inquiry-based science teaching. *Disciplinary and Interdisciplinary Science Education Research*, 5(1), 1–15.

[4] Akmam, A., Ahzari, S., Emiliannur, E., Anshari, R., & Setiawan, D. (2025). Enhancing science literacy through a cognitive conflict-based generative learning model: An experimental study in physics learning. *arXiv*.

[5] Alamer, A. (2022). Basic Psychological Needs, Motivational Orientations, Effort, And Vocabulary Knowledge: A Comprehensive Study.

[6] Alarcon, D. A., Talavera-Mendoza, F., Rucano Paucar, F. H., Cayani Caceres, K. S., & Machaca Viza, R. (2023). Science and inquiry-based teaching and learning: A systematic review. *Frontiers in Education*, 8, 1170487.

[7] Antonio, R. P. (2024). Effects of inquiry-based approaches on students' higher-order thinking skills in science education. *ERIC*.

[8] Arifin, Z. (2025). The effect of inquiry-based learning on students' critical thinking skills in science education: A meta-analysis. *European Journal of STEM Education*, 10(1), 15988.

[9] Arthi, M. P. (2025). Research trends and network approach of critical thinking in English language teaching. *Journal of Language Teaching and Research*, 16(2), 123–135.

[10] Bacak, J. (2021). Inquiry theory: A literature review of inquiry-based teacher preparation. *ERIC*.

[11] Bybee, R. W. (2020). Scientific literacy and the twenty-first century citizen. *Journal of Science Education and Technology*, 29(2), 177–187.

[12] Cansiz, M., & Cansiz, S. (2024). Reimagining scientific literacy: A framework for future-focused science education. *ResearchGate*.

[13] Chen, F. (2025). Learning analytics in inquiry-based learning: A systematic review. *Journal of Educational Technology & Society*.

[14] Chigbu, U. E. (2023). The science of literature reviews: Searching, identifying, and mitigating biases. *Publications*, 11(1), 2.

[15] Creswell, J. W., & Creswell, J. D. (2022). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.

[16] Daulika, A., Junus, K., Santoso, H. B., Michael, J., & Mannix, I. A. (2025). The influence of critical thinking implementation in education: A systematic literature review. *Eduvest – Journal of Universal Studies*, 5(9), 11648–11660.

[17] da Silva, J. G. C. (2025). Science and scientific method. *ResearchGate*.

[18] Ebidor, L., & Ikhide, I. G. (2024). Literature review in scientific research: An overview. *East African Journal of Education Studies*, 7(2), 211–218.

[19] Eymur, G. (2024). Investigating the role of an inquiry-based science lab on students' scientific literacy. *Instructional Science*.

[20] Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. *Review of Educational Research*, 82(3), 300–329.

[21] Hajmási, K., Tóth, Z., & Varga, L. (2025). Global research trends on the relationship between critical thinking and tertiary education. *Education Sciences*, 15(8), 296.

[22] Harefa, E. (2023). Implementation of scientific inquiry approach for enhancing scientific literacy among elementary students. *IRAONO: Journal of Elementary and Childhood Education*, 1(1), 32–38.

[23] Hinostroza, J. E., et al. (2024). Roles of digital technologies in the implementation of inquiry-based learning. *Computers & Education*.

[24] Hmelo-Silver, C. E., Chinn, C. A., Chan, C. K. K., & O'Donnell, A. M. (2019). *The international handbook of collaborative learning*. Routledge.

[25] Inquiry-based learning in Bangladesh: Insights into middle and high school students' experiences and 21st century skill development. (2025). *Disciplinary and Interdisciplinary Science Education Research*, 7(1), 1–16.

[26] Kang, J., & Keinonen, T. (2022). Inquiry-based science learning and students' scientific literacy: Evidence from U.S. classrooms. *Science Education*, 106(3), 546–567.

[27] Kosmyna, N., et al. (2025). ChatGPT may be eroding critical thinking skills. *Time*.

[28] Kyriazis, N., Stylos, G., & Kotsis, K. T. (2025). Impact of inquiry-based laboratory activities on understanding heat concepts and self-efficacy in pre-service teachers. *Journal of Pedagogical Research*, 9(1), 161–181.

[29] Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research*, 86(3), 681–718.

[30] Lee, H. P. H., Rintel, S., Banks, R., & Wilson, N. (2025). The impact of generative AI on critical thinking. *Microsoft Research*.

[31] Lestari, D. P. (2024). The effect of the inquiry-based nature of science argumentation (IB-NOSA) instructional model on scientific literacy skills. *EduLearn*, 8(2), 21024.

[32] Lindenwood University. (2025). Real-world applications of an applied science education. *Lindenwood University Online*.

[33] MacKenzie, T. (2025). From curiosity to curriculum: How inquiry-based learning boosts student engagement and agency. *The Balance*.

[34] Mediana, N., Funa, A., & Dio, R. (2025). Effectiveness of inquiry-based learning (IBL) on improving students' conceptual understanding in science and mathematics: A meta-analysis. *International Journal of Education in Mathematics, Science and Technology*, 13(2), 231–247.

[35] Mukherjee, U. (2025). The future of literature reviews: Enhancing literature reviews with multidisciplinary perspectives. *Academy of Marketing Studies Journal*, 29(3), 1–9.

[36] Mulyono, Y., Sapuadi, S., Yuliarti, Y., & Sohnui, S. (2024). A framework for building scientific literacy through an inquiry learning model using an ethnoscience approach. *International Journal of Advanced and Applied Sciences*, 11(8), 158–168.

[37] National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

[38] National Research Council. (2020). *Science and engineering for grades K–12: Investigation and design at the center*. National Academies Press.

[39] NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. National Academies Press.

[40] OECD. (2020). *PISA 2018 results (Volume I): What students know and can do*. OECD Publishing.

[41] Palaguyan, R. K., & Abusama, H. P. (2025). Inquiry-based learning: Effect on student's engagement and conceptual knowledge in biology. *Psychology and Education: A Multidisciplinary Journal*, 37(4).

[42] Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. T., & Tsourlidaki, E. (2019). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 27, 47–61.

[43] Prayogi, S. (2025). Emphasizing reflective processes in scientific inquiry and learning: A meta-analysis.

[44] Ramaila, S. R. (2024). Systematic review of inquiry-based learning: Assessing impact and best practices in education.

[45] Sam, R. (2024). Systematic review of inquiry-based learning: Assessing impact and best practices in education. *F1000Research*, 13, 1045.

[46] Schizas, D., Psillos, D., & Asimopoulos, S. (2024). Advancing scientific literacy: Integrating nature of science and nature of scientific inquiry in teaching Griffith's and Avery-MacLeod-McCarty experiments. *Interdisciplinary Journal of Environmental and Science Education*, 20(4), e2421.

[47] Silverio, D. L. (2024). A comparison of scientific skills and disciplinary practices across STEM disciplines. *Journal of Research in Science Teaching*, 61(3), 345–367.

[48] Singh, A., Guan, Z., & Rieh, S. Y. (2025). Enhancing critical thinking in generative AI search with metacognitive prompts. *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*, 1–12.

[49] Stehr, K. (2025, July 15). What is inquiry-based learning? *ACE Blog*.

[50] Studies Weekly. (2025, October 27). Empowering students through inquiry: Studies Weekly's approach. *Studies Weekly*.

[51] Vale, R. D. (2013). The value of asking questions. *Molecular Biology of the Cell*, 24(6), 680–682.

[52] Verawati, N. N. S. P., Hikmawati, H., Prayogi, S., & Bilad, M. R. (2021). Reflective practices in inquiry learning: Its effectiveness in training pre-service teachers' critical thinking viewed from cognitive styles. *Jurnal Pendidikan IPA Indonesia*, 10(4), 505–514.

[53] Vo, D. V. (2025). Assessing scientific inquiry: A systematic literature review.

[54] Waked, A. (2024). Differences that matter: Inquiry-based learning approach to academic performance and engagement. *Scientific Reports*.

[55] Wang, Y., Feng, S., Tsvetkov, Y., & Hajishirzi, H. (2025). ScienceMeter: Tracking scientific knowledge updates in language models. *arXiv*.

[56] Zhang, Y. (2025). Exploring the role of large language models in the scientific method.

[57] Zion, M., & Mendelovici, R. (2019). Moving from structured to open inquiry: Challenges and limits. *International Journal of Science Education*, 41(3), 353–373.