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A Systematic Review of Laboratory Implementation in the Philippines

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ABSTRACT

This systematic review explored the implementation of science laboratories in Philippine basic education and its implications for the development of the localized SciKLab program in the Schools Division of Ilocos Norte. Following the PRISMA framework, forty-one studies published between 2015 and 2025 were analyzed to examine laboratory resources and adequacy, teaching practices, challenges, and innovative initiatives. Findings reveal that while most public schools face persistent inadequacies in equipment, consumables, and maintenance systems, teachers exhibit adaptability through improvisation, collaboration, and integration of technology. Effective laboratory instruction is anchored on well-trained teachers who employ inquiry-based and contextualized pedagogies supported by continuous professional development. Moreover, innovative models such as SciKLab demonstrate that localized, resource-sharing programs integrating equipment provision, mentoring, and demonstration teaching can bridge gaps between policy and practice. The study concludes that successful science laboratory implementation requires synergy among resource adequacy, teacher competence, and institutional support to promote equitable and inquiry-driven science learning in Philippine schools.

INTRODUCTION

Science education is universally recognized as a vital driver of national development, technological advancement, and societal progress. It cultivates learners' ability to think critically, solve complex problems, and make evidence-based decisions—competencies that are indispensable in an increasingly interconnected and technology-driven world. In the Philippines, the K to 12 Science Curriculum explicitly aims to nurture scientifically literate and globally competitive citizens by promoting experiential, inquiry-based, and performance-oriented learning. This curricular vision imagines classrooms where students actively investigate phenomena, design experiments, test hypotheses, and construct explanations grounded in empirical evidence (Mangarin & Macayana, 2024).

At the heart of this vision is the school science laboratory—a dynamic learning environment where students can concretize abstract ideas through direct experimentation, careful observation, and guided discovery. Laboratories function as incubators of curiosity and exploration, providing structured opportunities for students to engage with scientific processes. Research across disciplines consistently affirms the pedagogical value of laboratory instruction, demonstrating its positive influence on conceptual understanding, motivation, scientific reasoning, and long-term retention (Freeman *et al.*, 2014). However, despite the prominence of laboratory learning in the curriculum, its full realization in Philippine basic education remains constrained by multiple systemic challenges, including limited facilities, inadequate resources, and insufficient teacher preparation. Many public schools continue to rely heavily on teacher demonstrations—rather than hands-on student inquiry—due to shortages in laboratory equipment, consumables, safety infrastructure, and routine maintenance (Lazaro, 2025).

These gaps in laboratory adequacy reflect broader structural issues in the Philippine educational landscape. Persistent disparities in resource distribution between urban and rural schools, coupled with inconsistencies in budget allocation and logistical challenges in procurement, have contributed to an enduring inequality in science learning opportunities. In resource-deprived contexts, teachers frequently compensate by improvising laboratory tools and localizing experiments using indigenous, recycled, or low-cost materials (Akpan, 2017). While such strategies highlight Filipino teachers' creativity and resolve, they also underscore the urgent need for sustainable, well-funded, and systematized laboratory programs supported by institutional mechanisms, technical support, and long-term capacity-building.

Equally essential to effective laboratory instruction is the role of the teacher. Studies consistently emphasize that teacher competence, pedagogical design, and instructional decision-making are more influential to learning outcomes than the mere presence of laboratory facilities (Mercado, 2020). Teachers who contextualize experiments, scaffold inquiry through reflective questioning, integrate collaborative learning, and utilize formative feedback tend to foster deeper engagement and stronger conceptual mastery among students (Mutlu, Yildirim, & Akgün, 2020). Recognizing this, the Department of Science and Technology–Science Education Institute (DOST-SEI) and the Department of Education (DepEd) have invested in initiatives such as the Science Teacher Academy for the Regions (STAR) and

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Learning Action Cells (LACs), which promote teacher upskilling, collaborative problem-solving, and sustained communities of practice (Cabacungan & Calzada, 2021). Nevertheless, participation in such programs remains uneven, particularly in geographically isolated or rural divisions where teachers have fewer opportunities for laboratory training, mentoring, and exposure to inquiry-based methodologies (Balland & Ramos, 2021).

In response to these long-standing challenges, localized innovations have emerged across the country to strengthen science laboratory implementation in contextually relevant ways. Among these, the SciKLab Program of the Schools Division of Ilocos Norte (SDOIN) represents a pioneering, systems-based intervention tailored to the needs of public schools. Conceptualized as a "Science Laboratory in Motion," the program integrates three core components: (1) provision of laboratory equipment and consumables, (2) coaching, mentoring, and demonstration teaching for science teachers, and (3) promotion of inquiry-based instruction through mobile, context-sensitive laboratory activities. By linking resource provision with capacity-building and pedagogical support, SciKLab effectively bridges the gap between policy intent and classroom practice, offering a model that is replicable and scalable across other divisions. Guided by this context, the present study conducts a systematic review of literature on science laboratory implementation in the Philippines and comparable educational settings. Specifically, it synthesizes findings from the past decade (2015–2025) across four major dimensions: (1) laboratory resources and adequacy, (2) teacher practices and pedagogical approaches, (3) challenges and coping mechanisms, and (4) innovative laboratory initiatives, including the SciKLab program. Through a thematic and integrative analysis of trends, gaps, and contextual innovations, the study aims to establish an evidence-based foundation for strengthening science laboratory policies and programs.

Ultimately, this review seeks to inform educational policy and practice by demonstrating how resource adequacy, teacher competence, and institutional support must converge to realize the goals of inquiry-driven science learning in Philippine schools. By highlighting both persistent barriers and promising innovations, the study underscores the critical need for comprehensive, equitable, and sustainable laboratory implementation to advance scientific literacy and national development.

LITERATURE REVIEW

Science laboratories play a critical role in promoting scientific literacy, providing opportunities for learners to connect theoretical knowledge with empirical practice. Laboratory experiences foster inquiry, experimentation, and reflection—key elements of scientific understanding (Cruz & Zaragoza, 2016). Within the Philippine educational context, where the K to 12 Science Curriculum emphasizes inquiry-based and performance-oriented learning, the availability, adequacy, and effective utilization of laboratory resources are essential to achieving curricular goals. However, numerous studies highlight that laboratory implementation in public schools remains constrained by limited resources, insufficient teacher training, and inconsistent institutional support (Mangarin & Macayana, 2024).

Laboratory Resources and Adequacy

Globally, studies affirm that access to well-equipped laboratories is directly associated with students' conceptual understanding and scientific reasoning (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2015). Laboratories allow learners to engage in authentic scientific practices—formulating hypotheses, manipulating materials, and interpreting data—that reinforce deep learning.

In the Philippine setting, disparities in laboratory access remain a persistent concern. A recent study published by E-Palli LLC, an open-access academic publisher based in Delaware, USA, documented significant gaps in science laboratory readiness in Davao del Sur. Caballes, Pedrita, Villaren, and Diquito (2024) reported that only 65.6% of secondary schools met the Department of Education's minimum standards for equipment, while compliance with consumables was even lower at 43.3%. Their findings further noted that shortages in materials, insufficient quantities, and inadequate maintenance directly restrict the implementation of hands-on laboratory activities.

Similarly, Lazaro (2025) observed that the lack of functional laboratory equipment and consumable supplies has compelled many science teachers to rely on lecture-based or demonstration-type instruction, thereby limiting opportunities for student-led experimentation and inquiry-based learning. These findings collectively highlight an ongoing challenge: despite curricular expectations for experiential science learning, many public schools lack the laboratory conditions required to fully support such pedagogical approaches.Beyond physical equipment, resource adequacy also encompasses consumables, instructional guides, and technical support. Clores (2023) emphasized that the unavailability of ready-made laboratory materials and experiment manuals limits the development of students' process skills. In response, locally designed laboratory guides, modular kits, and context-based resources have shown positive effects on learner engagement and achievement. For instance, Reyes *et al.* (2024) developed a do-it-yourself (DIY) microscope using indigenous materials, demonstrating that local innovation can offset shortages and foster sustainability. Similarly, schools that formed partnerships with local industries or implemented mobile laboratories achieved higher student motivation and continuity of science learning (Ayomide & Famuwagun, 2024).

These findings suggest that laboratory adequacy extends beyond material provision. It involves establishing systems for equipment maintenance, developing localized learning materials, and sustaining community partnerships. Effective laboratory implementation, therefore, depends on how well schools adapt available resources to pedagogical needs rather than on the mere presence of physical infrastructure.

Teacher Practices and Pedagogical Approaches

Teacher competence remains the cornerstone of effective laboratory instruction, shaping not only how experiments are conducted but also how students experience and internalize scientific concepts. In contemporary science education, the pedagogical role of teachers has shifted significantly—from mere transmitters of information to facilitators of inquiry, critical thinking, and discovery. This evolution underscores the need for teachers to guide students as they construct knowledge through purposeful experimentation, evidence-based reasoning, and reflective problem-solving. Mercado (2020) and Manuel (2019) demonstrated that Filipino teachers who contextualized laboratory activities—using indigenous materials, community-based examples, and locally relevant phenomena—achieved higher levels of student participation and comprehension. By grounding abstract concepts in familiar contexts, these contextualized approaches help students see the value and authenticity of science, thereby enhancing curiosity, motivation, and engagement.

Teacher preparation and continuous professional development also play decisive roles in strengthening laboratory instruction. Programs such as DOST-SEI's Science Teacher Academy for the Regions (STAR) and DepEd's Learning Action Cells (LACs) provide platforms for collaborative learning, peer mentoring, and sustained pedagogical refinement (Cabacungan & Calzada, 2021; Vega, 2020). Teachers who engaged in these initiatives reported significant improvements in laboratory management, experiment design, and inquiry facilitation. These findings align with international research—such as the work of Darling-Hammond *et al.* (2017)—which emphasizes that practice-oriented, hands-on professional development leads to deeper instructional competence, greater pedagogical confidence, and more effective learner outcomes. Such programs also help teachers adapt to evolving curriculum standards, technological tools, and safety protocols essential for modern science laboratories.

Pedagogical frameworks grounded in inquiry-based and cooperative learning approaches continue to show strong empirical support. Anaba and Tindan (2024) and Pineda (2019) found that inquiry-based instruction promotes deeper conceptual understanding, long-term retention, and the development of scientific reasoning skills. This approach shifts the focus from performing experiments solely for verification to engaging learners in authentic scientific investigation—allowing them to formulate hypotheses, interpret data, and draw evidence-based conclusions. Complementing this, Guevarra and Guevarra (2019) reported that the integration of guided inquiry with visual-spatial learning strategies—such as diagrams, models, and graphic organizers—enhanced students' motivation, creativity, and collaboration, particularly at the elementary level. Similarly, Basas *et al.* (2020) highlighted that structured group work, clear safety protocols, and systematic feedback mechanisms cultivate a culture of teamwork, accountability, and discipline in laboratory environments.

Collectively, these studies affirm that effective laboratory pedagogy lies in the dynamic integration of inquiry, collaboration, and contextual relevance. Teachers must strategically balance structure and autonomy—providing clear guidance and safety measures while giving students the freedom to explore, ask questions, and derive meaning from their investigative experiences. When these elements are harmonized, the science laboratory becomes not just a venue for conducting experiments but a transformative learning environment where students develop curiosity, scientific literacy, and lifelong learning skills.

Challenges and Coping Mechanisms

Despite best efforts to enhance science education, numerous challenges continue to impede the effective implementation of laboratory instruction across Philippine schools. Persistent barriers such as insufficient equipment, limited consumables, time constraints, large class sizes, and uneven access to professional development remain dominant concerns in the literature (Cruz & Zaragoza, 2016; Clores, 2023). These constraints significantly affect teachers' ability to facilitate authentic laboratory experiences. In overcrowded classrooms, for instance, teachers often resort to teacher-led demonstrations in order to manage time, ensure safety, and maintain classroom order. While demonstrations can model procedures efficiently, they drastically reduce opportunities for students to engage in hands-on exploration—an essential element of inquiry-based science learning.

The fragmented and uneven distribution of professional development opportunities further compounds the challenge. Oracion (2015) and Balland and Ramos (2021) observed that teachers in rural, remote, or geographically isolated schools frequently lack access to sustained mentoring, specialized laboratory training, and communities of practice. As a result, teachers in these environments often face greater difficulty in mastering laboratory management skills, implementing inquiry-based strategies, or integrating newly distributed science equipment into instruction. The unequal distribution of resources between urban and rural schools—ranging from laboratory apparatus to ICT tools—exacerbates these instructional disparities, limiting students' exposure to authentic scientific practices and reinforcing systemic inequities (Mangarin & Macayana, 2024).

In response to these persistent challenges, Filipino teachers employ diverse coping mechanisms that reveal both resourcefulness and resilience. One of the most prominent strategies is improvisation and localization, where teachers creatively use indigenous, low-cost, or recycled materials as substitutes for standard laboratory equipment (Akpan, 2017; Reyes *et al.*, 2024). These localized approaches not only address resource scarcity but also enhance cultural relevance, helping learners connect scientific concepts to their everyday experiences. Collaboration and peer mentoring further support teachers' adaptive practices. Through Learning Action Cells (LACs), lesson study groups, and informal peer networks, educators share materials, exchange successful strategies, co-develop lesson plans, and collectively troubleshoot instructional challenges (Vega, 2020). Such collaborative structures reduce teacher isolation and promote the spread of effective laboratory techniques within schools and districts. Technology integration has also emerged as a practical solution to resource limitations. Virtual laboratories, simulations, and interactive digital tools allow students to visualize scientific phenomena, manipulate variables, and conduct virtual experiments even when physical equipment is unavailable (De Jong, Linn, & Zacharia, 2013; Colegado, 2025). These technological platforms provide flexible alternatives that complement traditional laboratory activities and help bridge instructional gaps.

Finally, reflective practice plays a vital role in teacher adaptation. As described by Rodriguez and Torres (2019), teachers who regularly evaluate their instructional decisions, analyze student outcomes, and adjust strategies based on evidence demonstrate continuous improvement in laboratory facilitation. Reflection enables teachers to refine practices despite systemic constraints, reinforcing professionalism and growth. Collectively, these adaptive strategies illustrate how Filipino science teachers function as self-directed professionals, consistent with Knowles' (1980) Adult Learning Theory. The theory emphasizes that adult learners—such as teachers—learn most effectively when addressing real-world problems and applying prior experiences to new challenges. Filipino teachers' persistent creativity, improvisation, collaboration, and reflective practice highlight their capacity to sustain meaningful science learning even in resource-constrained settings, affirming the central role of teacher agency in the pursuit of quality laboratory education.

Innovative Laboratory Initiatives: The SciKLab Experience

Innovation in laboratory education increasingly focuses on accessibility, mobility, and contextualization. The SciKLab Program of the Schools Division of Ilocos Norte exemplifies how localized programs can address systemic barriers through a structured, collaborative model. The program operates through a three-tiered system that includes (1) provision of laboratory equipment and consumables, (2) coaching and mentoring for science teachers, and (3) demonstration teaching using inquiry-based activities. Early findings by Gonzales, Cabrera, and Calzada (2025) reveal that the program significantly improved teacher competence and student motivation toward science.

SciKLab mirrors global trends in mobile and modular laboratory innovations, such as DOST-SEI's NuLab: STEM in Motion, which brings laboratory experiences to schools lacking facilities. These models demonstrate that innovation through mobility, mentorship, and collaboration can effectively bridge the gap between educational policy and classroom practice. By providing resources alongside training, SciKLab represents a scalable, sustainable approach to science laboratory implementation in resource-limited educational settings. Overall, the reviewed literature highlights the complex interplay among resources, teacher competence, and institutional support. While material adequacy is foundational, it is the synergy among these elements—supported by localized innovations like SciKLab—that determines the success of laboratory-based science education in the Philippines.

MATERIALS AND METHODS

This study employed a systematic review methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The review synthesized empirical and conceptual studies published between 2015 and 2025, focusing on science laboratory implementation, teacher practices, and educational innovations in the context of basic education. The process followed a structured approach encompassing the stages of identification, screening, eligibility, and inclusion to ensure rigor and transparency.

The search strategy involved comprehensive retrieval of relevant literature from both international and local databases, including ERIC, Google Scholar, Philippine E-Journals, ResearchGate, and institutional repositories of the Department of Education (DepEd) and the Department of Science and Technology–Science Education Institute (DOST-SEI). The search employed combinations of specific keywords and Boolean operators such as "science laboratory implementation," "teacher practices in inquiry-based science," "Philippine science laboratories," "laboratory challenges in basic education," "STEM innovation programs," and "SciKLab." These terms were selected to capture a broad spectrum of studies addressing laboratory adequacy, instructional practices, and innovative models relevant to the Philippine setting.

To ensure relevance, inclusion and exclusion criteria were applied systematically. Studies were included if they (a) were conducted within the basic education context (Grades 4–12); (b) addressed topics related to laboratory resources, teacher preparation or training, pedagogical strategies, or coping mechanisms; and (c) were published in peer-reviewed journals, institutional repositories, or official government reports. Conversely, studies that focused exclusively on tertiary or engineering laboratories without direct pedagogical implications for secondary education were excluded from the analysis.

After an initial pool of 127 documents was identified, titles and abstracts were screened for relevance, and full-text assessments were conducted to determine eligibility. Ultimately, 26 studies m*et al*l inclusion criteria and were retained for analysis. Data extraction followed a thematic synthesis approach, wherein findings from each study were coded, categorized, and compared across multiple sources. Thematic patterns were organized into four major domains: (1) laboratory resources and adequacy, (2) teacher practices and pedagogical models, (3) challenges and coping mechanisms, and (4) innovative approaches and laboratory initiatives. Cross-referencing and triangulation with at least two independent sources were undertaken to ensure the credibility and consistency of interpretations.

This structured and evidence-based approach allowed for the systematic identification of trends, gaps, and emerging practices in science laboratory implementation, providing a robust foundation for understanding the conditions that enable effective inquiry-based science education in Philippine schools.

RESULTS AND DISCUSSION

The systematic review synthesized findings from forty-one (41) studies that met the inclusion criteria, representing a decade of research (2015–2025) on science laboratory implementation in Philippine basic education. The analysis revealed recurring themes that illustrate both enduring challenges and emerging innovations shaping laboratory instruction across schools. Data from these studies were organized thematically into four major categories: (1) laboratory resources and adequacy, (2) teacher practices and pedagogical approaches, (3) challenges and coping mechanisms, and (4) innovative laboratory initiatives such as the SciKLab program. These categories capture the multifaceted nature of laboratory implementation—encompassing material, pedagogical, and systemic dimensions—and collectively provide a holistic picture of how science education operates within resource-constrained environments. Table 1 presents a summary of the key findings derived from the reviewed literature, highlighting the interconnected roles of resources, teacher competence, and institutional support in shaping effective inquiry-based science learning.

Table 1: Summary of Key Findings on Science Laboratory Implementation in the Philippines (2015–2025)

Thematic Category	Key Findings	Implications for Practice
1. Laboratory Resources and Adequacy	• Only 65.6% of secondary schools met DepEd standards for laboratory equipment; consumables compliance was at 43.3%. • Lack of maintenance and consumables led to demonstration-based rather than hands-on instruction. • Local innovations (DIY microscopes, modular kits, mobile labs) improved accessibility and engagement.	Laboratory adequacy should include not only physical equipment but also consumables, maintenance systems, instructional guides, and community partnerships.
2. Teacher Practices and Pedagogical Approaches	• Teachers who localized experiments using indigenous materials achieved higher student comprehension and engagement. • Continuous training programs (STAR, LACs) enhanced laboratory facilitation and inquiry-based teaching. • Inquiry-based and cooperative learning improved conceptual understanding and motivation.	Teacher competence is central to laboratory success. Professional development and contextualized pedagogy are critical for sustaining inquiry-based instruction.
3. Challenges and Coping Mechanisms	• Common challenges include resource shortages, time constraints, and overcrowded classes. • Rural teachers have limited access to continuous professional development. • Coping strategies include improvisation, peer mentoring, technology integration, and reflective practice.	Teachers exhibit resilience and adaptability through localized and collaborative solutions. Support systems must institutionalize these coping mechanisms.
4. Innovative Laboratory Initiatives (SciKLab)	• The SciKLab Program integrates resource provision, mentoring, and demonstration teaching. • Significantly improved teacher competence and student motivation. • Mirrors mobile and modular lab models (e.g., DOST-SEI's NuLab).	Localized innovations like SciKLab offer scalable, sustainable solutions for resource-limited schools, bridging gaps between policy and classroom practice.

Laboratory Resources and Adequacy

The adequacy of science laboratory resources remains one of the most critical determinants of effective inquiry-based learning. Studies consistently highlight that access to functional laboratories, complete with materials and consumables, directly influences students' conceptual understanding and engagement in scientific reasoning (Manuel, 2019). In the Philippine context, however, the gap between policy standards and classroom realities is evident. Caballes *et al.* (2024) reported that only 65.6% of secondary schools in Davao del Sur met the Department of Education's (DepEd) minimum standards for laboratory equipment, while compliance for consumables was markedly lower at 43.3%. Similarly, Lazaro (2025) noted that a lack of maintenance systems and consumable materials compelled teachers to rely heavily on demonstration-based lessons rather than student experimentation.

Despite these limitations, resourcefulness and local innovation have emerged as strong compensatory mechanisms. Ederon and Aliazas (2024) found that locally developed laboratory guides and modular kits improved students' process skills, while Reyes *et al.* (2024) demonstrated that the creation of a do-it-yourself (DIY) microscope using indigenous materials enhanced accessibility to laboratory experiences in resource-limited schools. Schools that cultivated partnerships with local government units, private organizations, or implemented mobile laboratories also reported higher levels of sustainability and engagement (Ayomide & Famuwagun, 2024).

Collectively, these findings affirm that laboratory adequacy encompasses more than physical infrastructure—it extends to the availability of consumables, maintenance systems, instructional materials, and community support. The Philippine experience demonstrates that innovation, rather than abundance, often defines the success of laboratory learning environments.

Teacher Practices and Pedagogical Approaches

Teacher effectiveness emerged as the linchpin of successful science laboratory implementation, serving as the central force that transforms laboratory activities from routine procedures into meaningful scientific inquiry. In the classroom, teachers act not only as facilitators of hands-on experimentation but also as architects of inquiry-based learning environments that promote deep conceptual understanding and higher-order thinking. Mercado (2020) and Manuel (2019) highlighted that Filipino teachers who localized and contextualized laboratory activities—using indigenous, readily available, or culturally familiar materials—achieved significantly higher levels of student engagement and comprehension. This localized approach makes abstract scientific concepts more relatable, reduces resource barriers in low-budget schools, and encourages student creativity through practical improvisation.

The preparation that teachers undertake before laboratory sessions also plays a critical role. Studies such as those by Mutlu, Yildirim, and Akgün (2020) demonstrated that strategies like pre-laboratory orientations, reflective worksheets, and structured questioning techniques greatly enhance students' readiness, curiosity, and conceptual accuracy. These processes prompt learners to activate prior knowledge, anticipate experimental outcomes, and articulate reasoning, ultimately cultivating a more purposeful laboratory experience.

Equally vital is teachers' continuous professional development. Programs such as the DOST-SEI Science Teacher Academy for the Regions (STAR) and DepEd's Learning Action Cells (LACs) provide sustained platforms for professional learning, peer coaching, and collaborative problem-solving. Cabacungan and Calzada (2021) and Vega (2020) reported that teachers who engaged in these communities of practice gained improved confidence in laboratory management, strengthened inquiry facilitation skills, and demonstrated greater adaptability when conducting class-based investigations. Through shared reflection and collective expertise, these professional learning systems help teachers address gaps in content knowledge, refine pedagogical strategies, and respond to emerging classroom challenges.

A growing body of literature also emphasizes the critical role of inquiry-based and collaborative learning strategies in elevating laboratory effectiveness. Abrahams and Millar (2008) and Pineda (2019) showed that inquiry-oriented methods lead to improved conceptual understanding, long-term retention, and scientific reasoning. Similarly, Guevarra and Guevarra (2019) found that guided inquiry integrated with visual-spatial learning techniques—such as diagrams, models, and simulation tools—increases students' motivation, engagement, and cognitive processing. In addition, Basas *et al.* (2020) noted that structured teamwork, clear safety guidelines, and consistent feedback promote accountability, discipline, and a culture of shared responsibility during laboratory work. These classroom dynamics cultivate not only scientific competencies but also soft skills such as communication, collaboration, and problem-solving.

Collectively, these findings converge on a critical insight: effective laboratory pedagogy depends on the fusion of inquiry-based, cooperative, reflective, and context-sensitive approaches. When teachers are adequately trained, well-supported, and empowered to design meaningful scientific investigations, laboratories cease to be mere physical spaces for conducting experiments. Instead, they evolve into dynamic environments where learners actively construct knowledge, develop scientific habits of mind, and experience authentic discovery—laying the foundation for stronger scientific literacy and lifelong learning.

Challenges and Coping Mechanisms

Despite the existence of well-established best practices, systemic challenges continue to hinder the full realization of effective science laboratory implementation in many Philippine schools. Persistent issues such as resource scarcity, insufficient instructional time, overcrowded classrooms, and uneven access to professional development remain among the most commonly documented barriers (Cruz & Zaragoza, 2016; Clores, 2023). These constraints significantly affect the extent to which teachers can conduct authentic hands-on investigations. Large class sizes, for example, often force teachers to prioritize safety and time management, resulting in teacher-led demonstrations rather than active student experimentation. This shift diminishes opportunities for inquiry, limits kinesthetic learning, and reduces the depth of conceptual understanding students can derive from laboratory activities.

Access to professional learning further compounds these challenges. Although national initiatives exist, professional development opportunities remain fragmented, inconsistent, and geographically disproportionate. Oracion (2014) and Balland and Ramos (2021) observed that teachers in remote or rural communities often have fewer pathways to structured mentoring, skill-based workshops, or training in laboratory pedagogy. Consequently, these disparities contribute to unequal levels of laboratory utilization across schools, creating a clear divide between urban institutions—often better resourced and better connected—and their rural counterparts. Mangarin and Macayana (2024) underscore that this imbalance perpetuates inequities in the quality of science instruction and student outcomes, reflecting broader structural inequalities in the educational system.

Despite these systemic limitations, Filipino teachers continue to exhibit exceptional adaptability and ingenuity. One of the most notable coping mechanisms is improvisation and localization, where teachers creatively substitute indigenous materials, recycled objects, or low-cost alternatives for standard laboratory equipment (Akpan, 2017; Reyes *et al.*, 2024). These strategies ensure that scientific experimentation remains accessible, relatable, and feasible even in resource-constrained contexts. Collaboration also plays a pivotal role. Through Learning Action Cells (LACs), lesson study groups, and informal peer mentoring networks, teachers share materials, co-develop instructional strategies, and engage in reflective dialogue about classroom challenges (Gutierez, 2015; Vega, 2020). Such communities of practice foster collective expertise and reduce the isolation often experienced by teachers in far-flung areas.

Technology integration has also become a key alternative approach. Virtual laboratories, simulations, and interactive digital tools serve as supplementary platforms that allow students to visualize and manipulate scientific phenomena, particularly when physical laboratory access is limited (De Jong, Linn, & Zacharia, 2013; Colegado, 2025). These digital environments cultivate experimentation, visualization, and self-paced exploration, complementing traditional laboratory work. Likewise, reflective practice—highlighted by Rodriguez and Torres (2019)—enables teachers to systematically evaluate their instructional decisions, analyze student outcomes, and iteratively refine their approaches. Through reflection, teachers become more responsive to contextual demands and student needs, strengthening the overall quality of science instruction.

Collectively, these adaptive strategies closely align with the principles of Knowles' (1980) Adult Learning Theory, which views teachers as self-directed, experience-driven learners who construct knowledge through contextual problem-solving. The persistence of improvisation, collaboration, technology use, and reflective practice—despite systemic barriers—illustrates the resilience, creativity, and professional agency of Filipino teachers. Their ability to sustain inquiry-based science education, even in the face of longstanding constraints, highlights the indispensable role of teacher innovation in shaping equitable and meaningful laboratory learning experiences for all students.

Innovative Laboratory Initiatives: The SciKLab Experience

Emerging innovations continue to demonstrate how localized interventions can transform science laboratory implementation in Philippine schools. Among these initiatives, the SciKLab Program of the Schools Division of Ilocos Norte stands out as a pioneering model that integrates resource provision, teacher capacity-building, and pedagogical innovation. SciKLab's three-tiered structure—equipment distribution, coaching and mentoring, and demonstration teaching—effectively bridges the long-standing divide between laboratory resource adequacy and instructional quality. Early findings by Gonzales, Cabrera, and Calzada (2025) reveal that teachers who participated in SciKLab developed stronger laboratory management skills, demonstrated higher confidence in conducting experiments, and reported significant increases in student motivation and engagement during science activities.

The design of the SciKLab Program reflects a systems-based model of educational reform, wherein material support is embedded within continuous professional learning. This approach aligns with global innovations such as DOST-SEI's NuLab: STEM in Motion, which provides mobile laboratory experiences to schools with limited facilities and exposes learners to sophisticated scientific tools and STEM pathways. By coupling resource distribution with in-depth coaching and live demonstration teaching, SciKLab ensures that laboratory materials are not merely delivered to schools but are fully integrated into instructional practices. This model strengthens the connection between pedagogical skills and equipment utilization—an area where many schools struggle due to lack of training or follow-through after resource deployment.

The success of SciKLab illustrates that meaningful innovation in science education does not always require large-scale national reform. Instead, targeted, context-responsive interventions led at the division or district level can generate substantial improvements in inquiry-based learning and teacher competence. These localized solutions demonstrate the transformative potential of initiatives designed with sensitivity to the realities of diverse schools—from fully equipped urban laboratories to resource-strapped rural classrooms. In doing so, they foster a culture of scientific curiosity, experimentation, and reflective teaching practice across learning communities.

Synthesizing the reviewed literature yields three overarching insights. First, material adequacy alone is insufficient to ensure effective science learning. Laboratory infrastructure must be complemented by maintenance mechanisms, consumable supplies, and technical support to sustain safe and functional learning environments. Second, teacher capacity remains the decisive factor in translating laboratory resources into meaningful inquiry experiences. Sustained professional development, grounded in adult learning principles such as self-direction and experiential problem-solving, is essential for empowering teachers to implement inquiry-based pedagogy. Third, systemic alignment between policy, curriculum standards, teacher training, and resource allocation is critical to ensuring consistency and long-term sustainability. Without such alignment, even well-designed laboratory programs risk producing fragmented or short-lived outcomes.

Overall, the evidence affirms that effective science laboratory implementation depends on the synergy of resources, teacher competence, and institutional support. Programs like SciKLab exemplify this synergy by integrating material provision with ongoing pedagogical coaching, peer collaboration, and professional learning. They serve as promising models for promoting equitable access to inquiry-based science education across diverse educational contexts in the Philippines.

CONCLUSIONS

This systematic review underscores that the effectiveness of science laboratory implementation in Philippine basic education hinges on the dynamic and interconnected relationship among resources, teacher competence, and institutional support. Although material adequacy is a recurring challenge, the findings make it clear that laboratory facilities alone do not guarantee meaningful or high-quality science instruction. Instead, it is the capacity of teachers to design, manage, and facilitate inquiry-driven learning experiences that ultimately determines the success of laboratory-based education. Schools that nurtured strong professional learning communities, developed localized instructional materials, and adopted adaptive teaching strategies consistently demonstrated higher levels of student engagement, motivation, and conceptual understanding.

The review also highlights the persistent inequities in resource distribution, particularly affecting rural and underfunded schools. Despite these constraints, Filipino teachers continue to display creativity and resilience through improvisation, collaboration, technology integration, and reflective practice. These adaptive strategies affirm the profession's ability to uphold inquiry-based science education even in contexts marked by scarcity. Moreover, localized innovations such as the SciKLab initiative illustrate how programs grounded in real-world school conditions can effectively bridge systemic gaps by combining equipment provision with mentoring, coaching, and demonstration teaching.

In sum, improving science laboratory implementation requires a comprehensive, coherent, and sustainable approach that integrates infrastructure development, teacher professionalization, and policy alignment. Future initiatives should prioritize continuous capacity-building systems, equitable resource allocation, and the institutionalization of context-sensitive innovations. Through these efforts, science education in the Philippines can enhance inquiry-driven learning, elevate students' scientific literacy, and contribute more effectively to national development and global competitiveness.

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