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BIOLOGY LABORATORY MANAGEMENT IN SENIOR HIGH SCHOOLS : AN ANALYSIS OF PLANNING, IMPLEMENTATION, AND RESOURCE UTILIZATION

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ABSTRACT

This descriptive qualitative study analysed biology laboratory management across two senior high schools in Gamping District during the 2018/2019 academic year. Informants selected through purposive sampling comprised two heads of laboratory, one laboratory technician, and two biology teachers, alongside descriptive questionnaire data from 627 students across 21 study groups. Data collected via semi-structured interviews, direct observations, document reviews, and questionnaires were analysed using Miles and Huberman's qualitative framework (comprising data reduction, data display, and conclusion drawing). Results revealed three principal findings: First, operational capacity diverged sharply, as High School A maintained routine practical sessions using a dedicated technician, whereas High School B faced physical constraints, technician shortages, and multi-purpose room usage. Second, field observations and student surveys identified persistent sanitation infrastructure deficits across both institutions, including irregular running water access and unsegregated chemical waste. Third, both schools exhibited an administrative omission in evaluative governance, maintaining basic activity logs while completely omitting formal staff performance appraisals and post-evaluation action plans. To ensure sustainable laboratory operations, institutional management must prioritise technical staffing, sanitation infrastructure upgrades, and formalised performance evaluation frameworks.

INTRODUCTION

Biology education is not limited to the transmission of conceptual knowledge; it also involves the development of scientific reasoning through direct experience, observation, inquiry, and evidence-based argumentation (Antonio & Prudente, 2021; Morris, 2025; National Research Council, 2000; Osborne, 2017). In this regard, laboratory-based practical work has long been regarded as a distinctive and central component of science education because it allows students to engage with empirical phenomena, manipulate materials, collect and interpret data, and connect scientific ideas with observable evidence (de Winter & Millar, 2023; Lunetta et al., 2007; National Research Council, 2006; Oliveira & Bonito, 2023). A substantial body of scholarship further indicates that well-designed practical work can support students' interest in science, scientific reasoning, inquiry skills, and understanding of subject matter when it is meaningfully integrated with classroom instruction rather than treated as an isolated hands-on activity (Furtak et al., 2012; Gericke et al., 2022; Minner et al., 2009; National Research Council, 2006; Nicol, 2021; Rahman et al., 2025).

However, the educational value of laboratory activities does not arise automatically from the mere presence of laboratory facilities or from students' participation in hands-on tasks. Research has shown that practical work is often less effective when students are only occupied with procedural completion and are not guided to link observations with underlying scientific concepts (Abrahams & Millar, 2008). Similarly, prior reviews have emphasised that laboratory learning outcomes depend not only on access to a laboratory but also on the quality of instructional design, teacher guidance, task structure, and the integration of practical activities into broader learning sequences (Gericke et al., 2022; Haugen & Sundby, 2020; National Research Council, 2006). In other words, laboratory effectiveness is inseparable from how the laboratory is organised, managed, and pedagogically used.

From an educational management perspective, a school laboratory should be understood not merely as a physical room containing equipment, but as a structured learning environment that requires planning, implementation, maintenance, safety regulation, scheduling, and instructional alignment. The literature on science laboratory education consistently suggests that effective laboratory experiences require coherent goals, adequate resources, trained personnel, and systematic integration with the curriculum (Hakim & Hamidah, 2025; Hunsche & Goi, 2019; National Research Council, 2006; Suseno et al., 2022). When these conditions are weak, the laboratory may become underutilised, disconnected from the intended curriculum, or reduced to routine procedural activity with limited impact on students' understanding of science.

Practical science instruction relies heavily on laboratory-based learning to enhance scientific literacy and process skills. While existing literature extensively documents the pedagogical benefits of laboratory activities (Hester et al., 2018; Law Hui et al., 2022), Recent empirical inquiries in secondary education reveal persistent structural challenges in operational management (Asmarany et al., 2024; Memiasih et al., 2024). Studies assessing laboratory management in Indonesian high schools demonstrate that practical execution is frequently constrained by unstandardized equipment maintenance, irregular administrative tracking, and suboptimal supervision (Fitriani et al., 2026; Sartika et al., 2024). However, most current evaluations focus primarily on isolated managerial competencies (such as basic inventory compliance or broad facility readiness) using single-dimension cross-sectional surveys (Rahmawati et al., 2025; Sartika et al., 2024). Consequently, existing research offers limited insight into how operational planning dynamically interacts with day-to-day practical implementation and facility utilisation within contrasting institutional environments.

Addressing this managerial divide is vital because biology instruction involves unique logistical demands, including biosafety management, perishable material handling, and intensive interactive practical sessions. Prior studies often group biology facilities under general science management, obscuring the specific administrative controls required for biological experimentation. This study fills this empirical gap by evaluating how institutional resource structures govern the operational continuity across planning, implementation, utilisation, and supervisory evaluation. Rather than relying on broad regional assumptions, this research provides a comparative analysis of how high schools navigate administrative constraints to maintain practical biology education.

To establish the empirical rationale for this inquiry, initial exploratory observations were conducted across secondary institutions in Gamping District, Sleman Regency. These preliminary observations identified pronounced operational variations between sites, prompting the selection of two specific schools as comparative study sites. To distinguish this preliminary contextualization from formal research outcomes, the two participating institutions were chosen based on contrasting operational parameters: High School A operates as a public school equipped with a dedicated laboratory technician and allocated operational funds, whereas High School B operates as a private school lacking specialised technical support and relying on multi-purpose facility usage. Accordingly, the scope of this study is intentionally delimited to an in-depth comparative investigation of these two contrasting case sites rather than a district-wide generalisation.

To provide a systematic evaluation of laboratory operations across these contrasting environments, this study addresses four specific research questions:

1. How do secondary schools structure and execute operational planning for biology laboratory management?
2. In what ways is practical biology instruction implemented across differing technical staffing and facility conditions?
3. What patterns of facility utilisation emerge under contrasting institutional and spatial resources?
4. How are administrative supervision and quality monitoring mechanisms conducted to sustain laboratory management quality?

MATERIALS AND METHODS

Research Design and Context

This study employed a qualitative comparative case study design to evaluate and compare the management of biology laboratories across public and private senior high schools in Gamping District, Sleman Regency, Special Region of Yogyakarta, Indonesia. The unit of analysis was the laboratory management system, which encompasses four operational aspects: planning, utilisation rules, supervision, and evaluation. Data collection was carried out over eight months from May to December 2019. The research settings comprised two distinct institutional contexts: School A (a public school) and School B (a private school). Formal access to the research sites was granted through official institutional permission, and informed consent was obtained from all participants before data collection. Participant anonymity and confidentiality were strictly preserved by anonymising individual identities and institutional labels.

Participants and Sampling Procedures

The target population comprised all senior high schools in Gamping District (N=2). Both schools were included to contrast laboratory management practices between public and private educational settings. Participants were selected using a combination of purposive and probability sampling techniques tailored to the specific participant groups: 1) Laboratory Personnel and Teachers (Purposive Sampling): Key informants directly responsible for laboratory administration were selected based on professional qualification criteria. This group included laboratory heads (n=2, one per school), biology teachers (n=2, one per school), and a laboratory technician (n=1, present only at School A). 2) Students (Proportionate Stratified Random Sampling): To evaluate student perspectives on laboratory utilisation, a proportionate stratified random sampling technique was employed. This ensured proportional representation across three academic grade levels (Grades X, XI, and XII) spanning six intact classes per school. A total of 120 students (n=60 per school) were selected to complete the evaluation questionnaire.

Data Collection Procedures

Data were collected sequentially using four complementary techniques to ensure comprehensive coverage: 1) Semi-Structured Interviews: Conducted individually with laboratory heads, laboratory technicians, and biology teachers using an interview guide. Interviews focused on annual planning, scheduling, supervision, and evaluation. Each session lasted approximately 30 to 45 minutes and was audio-recorded and transcribed. 2) Direct Observations: Conducted during active biology practical activities (specifically photosynthesis experiments and food test practicals) to observe facility preparation, safety protocol enforcement, tool/material storage, and spatial layout. 3) Document Analysis: Included physical and administrative records such as laboratory rule boards, usage schedules, equipment inventory logs, annual management plans, and organisational structures. 4) Questionnaires: Administered to the 120 student respondents using a 4-point Likert scale (ranging from 1 = Strongly Disagree to 4 = Strongly Agree) to quantify student perceptions of laboratory usability and management effectiveness.

Instrument Validation and Qualitative Data Trustworthiness

All research instruments were developed based on an operational blueprint aligned with national laboratory standards (Permendikbudristek No. 22 of 2023) (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2023). Content and construct validity were established through an expert judgment procedure involving senior biology education faculty members who reviewed indicator coverage, item clarity, and alignment with research objectives. Revisions were made based on expert recommendations prior to field deployment. For the quantitative questionnaire, structural item refinement and pilot testing were conducted to confirm item clarity and construct validity.

To establish the trustworthiness of qualitative findings, four criteria were implemented: 1) Credibility: Achieved through source triangulation (cross-verifying data across laboratory heads, technicians, teachers, and students) and method triangulation (comparing interview transcripts with observation field notes and document evidence). 2) Dependability and Confirmability: Secured through a systematic audit trail. The primary researcher conducted continuous audit consultations with academic supervisors to review raw transcripts, coding frameworks, and analytical interpretations. 3) Transferability: Facilitated by providing thick, detailed descriptions of the institutional settings, sampling profiles, and operational contexts.

Data Analysis and Triangulation

Data analysis combined qualitative thematic analysis with descriptive quantitative summarisation. Qualitative Data Analysis included Interview transcripts, observation field notes, and document records, which were analysed using the interactive model proposed by Miles et al. (2014), describe three stages: data reduction (condensing raw field notes into thematic codes), data display (organising data into comparative matrices), and conclusion drawing/verification. Thematic coding was performed independently by the researcher, with cross-case comparison conducted between the public and private school settings.

Quantitative Data Analysis for student questionnaire responses was scored, tabulated, and analysed using descriptive statistics to calculate percentage scores and mean categories (e.g., Very Poor, Poor, Good, Very Good). Data integration: Quantitative questionnaire scores were integrated with qualitative interview and observation findings to cross-validate results regarding laboratory utilisation and service quality. The integrated operational matrix linking research questions, indicators, data collection tools, participant groups, and analytical strategies is detailed in Table 1.

Table 1. Alignment Matrix of Research Aspects, Indicators, Data Sources, Instruments, Evidence, and Analysis Method

Research Aspect	Operational Indicators	Data Source/ Participants	Instrument	Evidence Generated	Data Analysis Method
Laboratory Management Planning	1) Annual program planning 2) Supervision & performance evaluation planning 3) Facility & material procurement planning 4) Guideline/ manual planning	a) Lab Head b) Lab Technician c) Biology Teacher	a) Semi-structured Interview Guide b) Document Checklist	a) Interview transcripts on planning mechanisms b) Annual work plan documents & procurement budgets	Interactive Qualitative Analysis (Miles & Huberman)
Laboratory Implementation & Regulation	1) Work schedule & coordination meetings 2) Lab rules & Permendiknas No. 24/2007 spatial standardization 3) Tool/material storage, maintenance, & safety procedures 4) Execution of practical work (photosynthesis & food tests)	a) Lab Head b) Lab Technician c) Biology Teacher d) Students $(n = 120)$	a) Semi-structured Interview Guide b) Observation Sheet c) Document Checklist d) Student Questionnaire	a) Interview transcripts on operational routines b) Observation logs on spatial layout & safety compliance c) Lab schedule & rule boards d) Student perception scores	a) Qualitative Analysis (Interviews, Observations, Documents) b) Descriptive Quantitative Analysis (Questionnaire percentages) c) Data Triangulation
Supervision, Evaluation, & Utilization	1) Annual reporting & practical monitoring 2) Staff performance review & recommendations 3) Identification of management obstacles 4) Effectiveness of lab utilization in biology learning	a) Lab Head b) Lab Technician c) Biology Teacher d) Students $(n = 120)$	a) Semi-structured Interview Guide b) Document Checklist c) Student Questionnaire	a) Interview transcripts on evaluation routines & barriers b) Monitoring reports & organizational charts c) Student utilization evaluation scores	a) Qualitative Analysis (Interviews & Documents) b) Descriptive Quantitative Analysis (Questionnaire percentages) c) Cross-case Synthesis

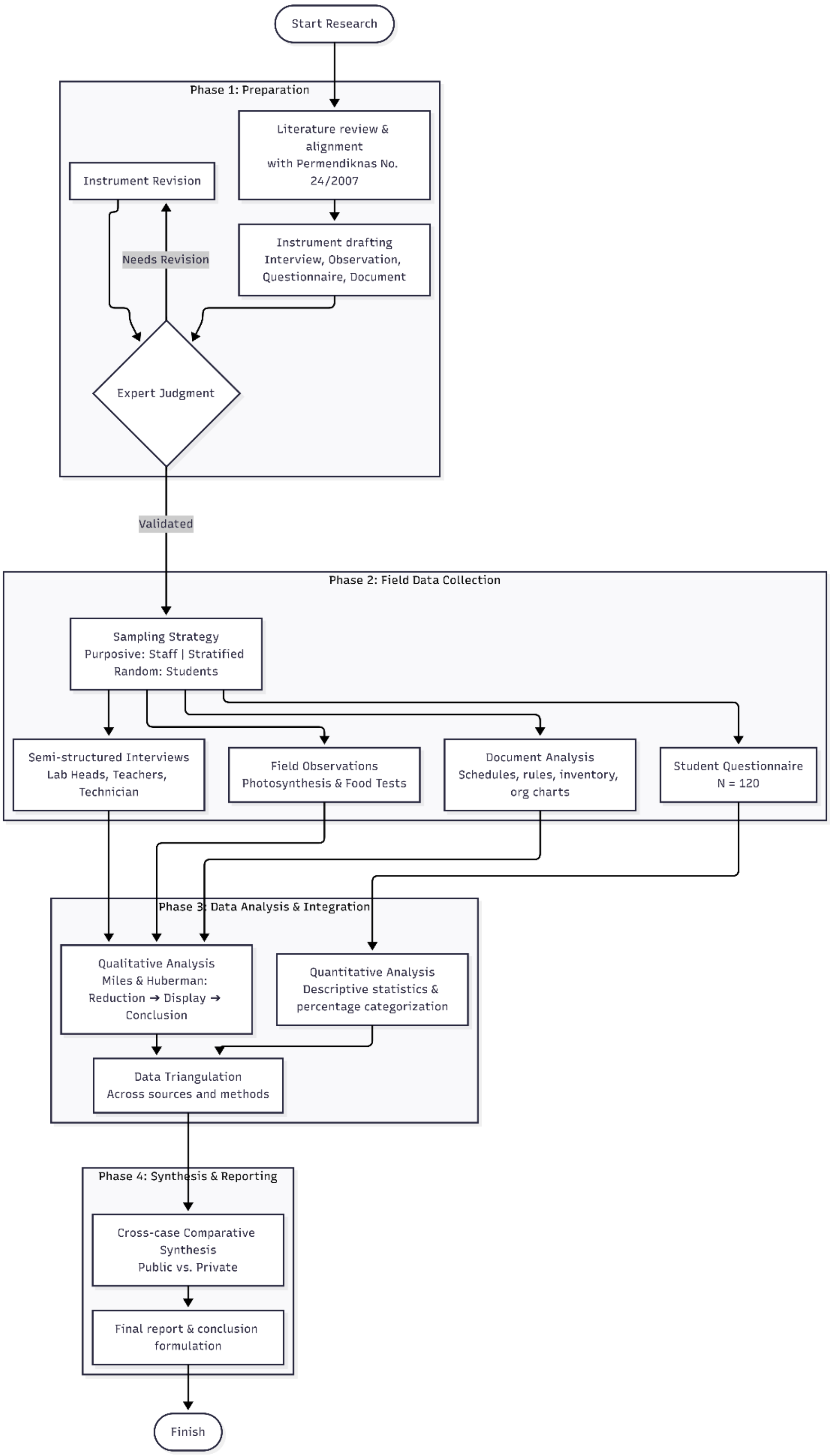

Figure 1. Research Procedure Flowchart

RESULTS AND DISCUSSION

Overview of Comparative Laboratory Management Findings

The evaluation of biology laboratory management across the two senior high schools in Gamping District revealed structural and operational disparities. School A catered to 389 students and was organised into 12 study groups, supported by 27 teaching staff and 14 administrative personnel. School B served 238 students across 9 study groups with 23 teachers and 6 administrative staff. While School A operated separate, dedicated laboratories for biology, chemistry, and physics managed by one full-time laboratory technician across the three science units, School B possessed physical laboratory space but lacked a dedicated biology laboratory setup and employed no laboratory technician. Consequently, biology teachers at School B directly executed administrative, preparation, and maintenance duties alongside their teaching responsibilities.

Evidentiary Analysis by Management Theme

Planning Practices

Data derived from informant interviews and document audits (Table 2) indicated that School A fulfilled 4 out of 5 operational planning indicators. Annual work programs, laboratory safety guidelines, and material procurement plans were collaboratively drafted by the head of the laboratory, the laboratory technician, and biology teachers. However, formal planning for routine performance evaluations was absent. As noted by the Head of Laboratory at School A (Informant KL-A): *"Every academic year, we construct the tool and material budget together with the technician and subject teachers. However, we have not established a structured written schedule for formal management evaluation."*

Conversely, School B satisfied only 2 out of 5 planning indicators. Planning was restricted to basic manual guidelines and informal lesson preparations by biology teachers. Budget allocations for laboratory materials were not systematically planned due to institutional funding constraints. The Biology Teacher at School B (Informant GB-B) stated: *"We do not have a separate annual budget plan for the laboratory. Tool procurement is submitted incidentally when a practical topic urgently requires specific reagents."*

Operational Implementation

Observation notes and administrative document reviews demonstrated marked operational differences (Table 2). School A executed 7 out of 8 implementation indicators, maintaining structured practical schedules, student regulation boards, administration logs, and defined equipment storage protocols. Observations during photosynthesis practical sessions confirmed that the laboratory technician pre-arranged apparatus and chemical solutions before class.

In contrast, School B fulfilled 3 out of 8 implementation indicators (Table 2). Although safety procedures and practical activities were conducted during classes, School B lacked formal laboratory coordination meetings, dedicated technician work schedules, administrative inventory logs, and standardised spatial room organisation. Because School B lacked a dedicated biology laboratory room, practical activities were conducted in a shared science space that also served general institutional functions. Field observation during food test practicals at School B revealed that teachers spent up to 20 minutes of class time gathering reagents from storage cabinets due to the absence of technical support.

Laboratory Utilisation and Student Perceptions

Triangulation of student questionnaire data ( ) with observation records showed that laboratory facilities at School A were utilised more frequently for practical sessions (Table 2). At School A, 84.5% of student respondents agreed or strongly agreed that laboratory equipment was ready for use during practical hours. At School B, this proportion dropped to 52.1%, with students citing delayed practical setups and limited equipment availability as primary constraints.

Supervision, Evaluation, and Administrative Reporting

Supervision and evaluation mechanisms represented the weakest management aspect across both institutions (Table 2). Neither school implemented formal, structured performance evaluations or systematic follow-up procedures for laboratory management. While both schools generated basic end-of-year activity reports for institutional leaders, these documents focused primarily on inventory counts rather than assessing pedagogical effectiveness or managerial efficiency (Ardiansyah, 2020; Arum et al., 2024; Romadhoni & Saifuddin, 2021).

Table 2. Comparative Matrix of Biology Laboratory Management Across Evaluated Schools

Management Aspect	Operational Indicators	High School A	High School B	Primary Sources & Evidence Trail	Synthesis of Comparative Pattern
Planning	1) Annual program drafting 2) Tool/material budget planning 3) Guideline/manual development 4) Evaluation planning	Fulfilled 4 of 5 indicators: Structured planning involving Head of Lab, Technician, and Teachers; lacks formal evaluation planning.	Fulfilled 2 of 5 indicators: Planning limited to informal teacher deliberations and manual guidelines; no standalone lab budget.	1) Interviews (KL-A, L-A, GB-A, KL-B, GB-B) 2) Document Checklist (Annual Work Plans, Procurement Logs)	School A exhibits systematic planning supported by dedicated personnel; School B relies on ad-hoc teacher planning.
Implementation	1) Operational scheduling & rules 2) Administrative inventory logging 3) Room spatial standardization 4) Maintenance & safety execution	Fulfilled 7 of 8 indicators: Active execution of schedules, inventory logs, and standardized spatial organization led by lab technician.	Fulfilled 3 of 8 indicators: Executes basic practicals and safety rules; lacks inventory logs, room standardization, and coordination meetings.	1) Direct Field Observations (Photosynthesis & Food Test sessions) 2) Document Checklist (Schedule Boards, Lab Rules) 3) Student Questionnaire ($n = 60$ per school)	Operational execution in School B is constrained by the absence of a dedicated lab technician and lack of spatial standardization.
Utilization & Infrastructure	1) Practical session frequency 2) Dedicated space availability 3) Equipment readiness	Dedicated biology laboratory present; 84.5% student satisfaction on equipment readiness.	No dedicated biology laboratory (utilizes a shared science room); 52.1% student satisfaction on equipment readiness.	1) Direct Field Observations 2) Student Questionnaire Summary ($N = 120$)	Infrastructure availability and technical support directly enhance facility utilization efficiency.
Supervision & Evaluation	1) Formal performance review 2) Systemic follow-up mechanisms 3) Activity & usage reporting	Weak formal supervision: Generates inventory reports; lacks structured performance evaluation and follow-up.	Weak formal supervision: Generates basic usage reports; lacks structured performance evaluation and follow-up.	1) Interviews (KL-A, KL-B) 2) Document Checklist (End-of-year Reports)	Both institutions display structural deficits in formal supervision, performance evaluation, and follow-up mechanisms.
Primary Constraints	Operational & resource barriers	Time allocation constraints and absence of formal evaluation mechanisms.	Budget deficits, absence of dedicated laboratory personnel, and shared space limitations.	1) Interviews (L-A, GB-B) 2) Field Observation Notes	Constraints in School A are operational; constraints in School B are structural and financial.

School A had separate biology, chemistry, and physics laboratories. One laboratory assistant managed the three science laboratories. School B had a biology laboratory but did not employ a laboratory assistant or laboratory technician. Biology teachers at School B consequently performed several operational duties, including preparing equipment, arranging materials, and maintaining laboratory facilities.

Planning of Biology Laboratory Management

The evaluation of biology laboratory management planning revealed structural differences between High School A and High School B (Table 3). Rather than demonstrating direct causality, the availability of dedicated laboratory funding and specialised personnel in High School A appeared to support a more structured planning framework compared to High School B. In High School A, operational planning was conducted through routine annual coordination meetings involving the head of the laboratory, biology teachers, and the laboratory technician. Based on qualitative document checklists and interviews, High School A fulfilled 4 out of 5 operational planning indicators aligned with standard laboratory administration practices. Planning in High School A encompassed annual work programs, practical manual preparation, and equipment procurement routines. However, planning for systematic supervision and routine performance evaluation remained unaddressed in both institutions (Table 3).

The contrast in planning practices was strongly associated with physical infrastructure provision and compliance with national benchmarks. Under the Regulation of the Ministry of Education, Culture, Research, and Technology Number 22 of 2023 regarding school facility standards (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2023), Standard senior high schools are required to provide functional, dedicated laboratory space and systematic management routines. As detailed in Table 3, High School A met the physical space criteria by maintaining three separate laboratories for biology, chemistry, and physics, which minimised scheduling conflicts and supported planned practical sessions. Conversely, High School B fulfilled only 2 out of 5 planning indicators (Table 3). Planning was limited to basic manual guidelines compiled directly by subject teachers. Furthermore, High School B lacked a dedicated biology laboratory (utilising a shared science room) and operated without a dedicated annual laboratory budget or formal procurement coordination.

These findings suggest that financial stability and personnel availability significantly influence the comprehensiveness of laboratory planning. Schools with stable institutional support tend to implement more structured laboratory management processes. Effective science laboratory management requires planning, organising, implementation, supervision, evaluation, adequate facilities, and competent personnel (Samputri et al., 2024; Suseno et al., 2022). Limited facilities, weak management, and inadequate support can reduce the effectiveness of science laboratory use in secondary schools (Etiubon & Udoh, 2020; Pareek, 2019; Tamatompol et al., 2026; Wahidah et al., 2021).

Despite these operational differences, both schools showed persistent weaknesses in format planning for supervision and evaluation programs (Table 2; Table 3). Neither institution implemented formal planning for staff performance assessment or systematic evaluation of laboratory management. This condition indicates that the management cycle remained incomplete across both settings, particularly in the monitoring and continuous improvement stages.

Implementation of Biology Laboratory Management

The implementation of biology laboratory management displayed distinct operational patterns across the two evaluated schools, as structured within the standard operational framework (Figure 1; Table 4). Rather than relying on broad qualitative designations, operational performance was evaluated against eight functional implementation indicators derived from document audits, inventory logs, and direct session observations. High School A satisfied 7 out of 8 implementation indicators (Table 4). Laboratory operations in High School A were supported by formal administrative logging, published safety regulations, spatial room standardisation, and dedicated routine maintenance managed by a full-time laboratory technician. Field observations during photosynthesis practical sessions confirmed that equipment and chemical reagents were prepared before class hours.

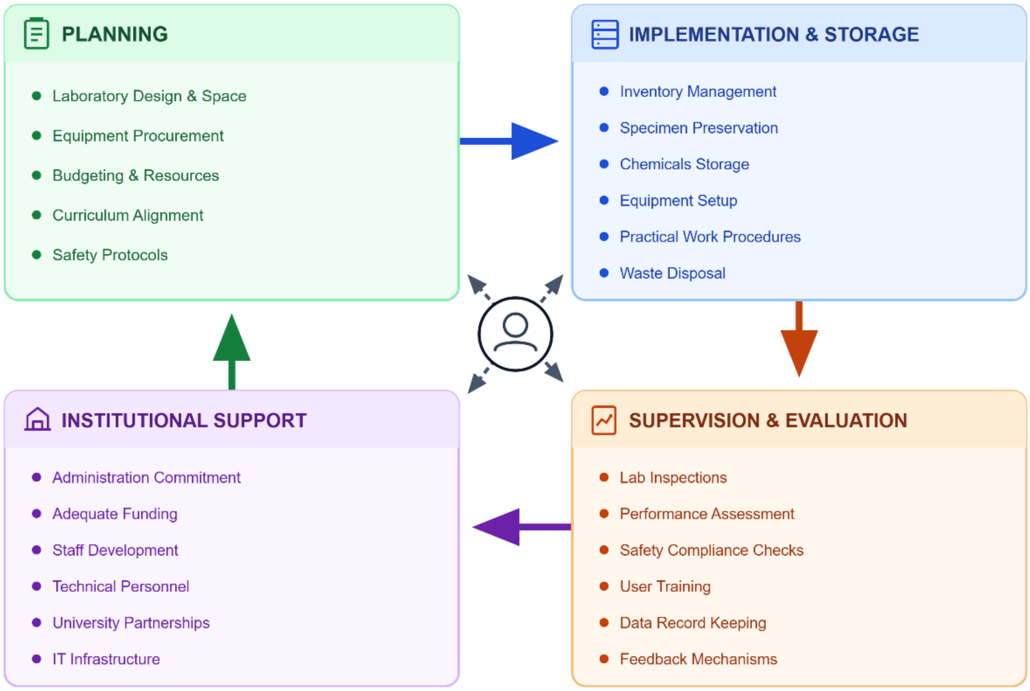

Figure 2. Conceptual Framework of Biology Laboratory Management Standards and Operational Workflows.

Conversely, High School B satisfied 3 out of 8 implementation indicators (Table 4). Operational execution was primarily limited to conducting required practical sessions, enforcing basic safety rules, and teacher-led equipment maintenance. High School B lacked formal administrative inventory logs, regular coordination meetings, spatial standardisation, and dedicated laboratory personnel. Field observations revealed that High School B operated a shared science room that also functioned as a general meeting space and institutional assembly area. Participants reported that this multifunctional setup constrained laboratory availability, occasionally requiring practical sessions to be rescheduled or conducted within standard classrooms. Furthermore, acute storage deficits at High School B resulted in delicate apparatus being left outside designated cabinetry, exposing sensitive tools to environmental degradation and increasing long-term replacement costs. These conditions reinforce prior findings that suboptimal storage oversight and a lack of dedicated personnel accelerate equipment depreciation and disrupt daily operational readiness (Julian & Sumah, 2023; Suseno et al., 2022).

Despite these operational differences, several critical management functions remained underdeveloped across both institutions (Table 4). Formal supervision, systematic performance appraisals, and structured evaluations of laboratory management had not yet been institutionalized in either school. From a managerial standpoint, these oversight activities constitute essential components of quality assurance that facilitate continuous monitoring, early identification of operational bottlenecks, and ongoing service improvement. The absence of such mechanisms restricts institutional capacity to evaluate program effectiveness and make data-driven managerial decisions. Qualitative data from interviews indicated that severe time constraints and heavy teacher workloads were the primary impediments constraining these evaluative functions.

These operational constraints present distinct conditions that shape opportunities for practical instruction. While this study did not directly measure student learning outcomes or inquiry skill acquisition, spatial conflicts and preparation delays were observed to reduce the effective time allocated for direct experimentation. Furthermore, these insights demonstrate that laboratory effectiveness is fundamentally driven by robust management practices rather than the mere presence of hardware. Administrative cohesion, rigorous inventory control, and standardized maintenance protocols dictate overall laboratory readiness, expediting equipment tracking and mitigating resource loss (Suseno et al., 2022). This reinforces the paradigm that laboratory management must be approached as an integrated process encompassing planning, organization, execution, supervision, and evaluation rather than a basic logistical exercise in infrastructure provisioning (Evana et al., 2021; National Research Council, 2006).

In sum, the findings reveal that biology laboratory management across the surveyed institutions has yet to be fully realized across all managerial dimensions. While High School A exhibits a more resilient operational framework, both schools grapple with persistent gaps in supervision, evaluation, specialized staffing, and optimal use of space. Ultimately, enhancing laboratory efficacy demands a shift beyond mere facility provision toward systemic, sustainable managerial practices that prioritize continuous monitoring, resource optimization, and institutional support.

Table 4. Comparative Matrix of Biology Laboratory Implementation Practices

Operational Implementation Indicator	High School A (SMAN 1 Gamping)	High School B (SMA Islam 1 Sleman)	Primary Evidence Source	Observed Operational Effect
1. Management Coordination Meetings	Fulfilled: Routine coordination between Head of	Unfulfilled: No formal management coordination	1) Interview (KL-A, L-A, GB-B)	Facilitates structured preparation in School A; reliance

Operational Implementation Indicator	High School A (SMAN 1 Gamping)	High School B (SMA Islam 1 Sleman)	Primary Evidence Source	Observed Operational Effect
	Lab, Technician, and Teachers.	meetings conducted.	2) Document Checklist	on informal teacher setup in School B.
2. Laboratory Rules & Schedules	Fulfilled: Formal schedule boards and posted safety regulations active.	Fulfilled: Operational rules posted; practical schedules arranged informally.	1) Direct Field Observation 2) Document Checklist	Basic safety protocols maintained in both institutions.
3. Administrative Inventory Logging	Fulfilled: Standardized usage logs and material inventory records maintained by the technician.	Unfulfilled: No formal administrative inventory logging system present.	1) Document Checklist (Logbooks) 2) Interview (L-A, GB-B)	Enables systematic material tracking in School A; unmonitored consumption in School B.
4. Spatial Room Standardization	Fulfilled: Dedicated biology lab room standardized for experimental work.	Unfulfilled: Shared science room used for general meetings and institutional events.	1) Direct Field Observation 2) Facility Audit (Thesis Table 5)	Minimizes scheduling conflicts in School A; constrains room availability in School B.
5. Dedicated Technician Work Routine	Fulfilled: Full-time technician manages setup, storage, and maintenance.	Unfulfilled: No laboratory technician is employed; teachers manage duties.	1) Interview (KL-A, GB-B) 2) Thesis Table 7	Pre-arranged experiment setups in School A; setup delays during class time in School B.
6. Equipment & Storage Maintenance	Fulfilled: Scheduled maintenance routines executed by dedicated personnel.	Unfulfilled: Acute storage deficits; apparatus left outside cabinets, exposing tools to degradation.	1) Interview (L-A, GB-B) 2) Field Observation Notes	Storage deficits in School B accelerate tool depreciation and inflate capital costs.
7. Execution of Practical Sessions	Fulfilled: Practicals executed systematically within dedicated lab space.	Fulfilled: Practicals executed but occasionally relocated due to spatial conflicts.	1) Field Observation Notes 2) Student Questionnaire Summary	Practical sessions maintained in both schools despite spatial constraints in School B.
8. Performance Supervision & Appraisal	Unfulfilled: No formal supervision or staff performance evaluation.	Unfulfilled: No formal supervision or staff performance evaluation due to time constraints.	1) Interview (KL-A, KL-B) 2) Document Checklist	Quality oversight and formal feedback routines missing across both settings.

Utilization of Laboratory Facilities and Evaluation Practices

Regarding facility utilisation, High School A deployed its laboratory resources much more intensively and effectively than High School B. The employment of dedicated laboratory assistants proved to be a critical differentiator; these staff members effectively absorbed routine administrative overloads and managed pre-session equipment setup. Consequently, biology teachers at High School A could protect their instructional time and focus squarely on guiding students through hands-on practical exercises. Conversely, laboratory utilisation at High School B was severely bottlenecked by scarce equipment, deferred maintenance, and a lack of operational support. While the school did not abandon practical activities entirely, execution was compromised, forcing teachers to constantly scale back or alter experiments to fit these systemic constraints.

Beyond room utilisation, field observations and student survey data across both institutions revealed persistent operational gaps in laboratory sanitation and biosafety. The surveyed student population comprised 627 secondary students across 21 study groups (High School A: n = 389 across 12 study groups; High School B: n = 238 across 9 study groups). Data gathered through a 16-item descriptive questionnaire, combined with direct facility observations, confirmed that basic sanitation infrastructure fell short of standard laboratory operational requirements (Kementerian Pendidikan dan Kebudayaan, 2007). Specifically, direct observations showed irregular access to running water at student lab benches, an insufficient number of dedicated handwashing sinks, and no structured hazardous chemical waste disposal system. Furthermore, personal protective equipment (PPE) (such as laboratory coats and safety eyewear) was neither systematically stored nor enforced during experimental sessions. When sanitation and biosafety protocols are compromised during biology practicals, cross-contamination risks increase during specimen handling and post-lab cleanup, undermining overall operational integrity.

When examining evaluative practices, both schools met basic compliance standards by compiling annual laboratory reports and logbooks. However, they lacked rigorous, systematic evaluation mechanisms anchored to national school laboratory management standards (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2023; Kementerian Pendidikan Nasional, 2008). An audit of administrative documentation (Thesis Table 8) revealed that while both schools completed routine activity and usage logs, they completely omitted formal staff performance appraisals (Indicator 1e) and structured post-evaluation action plans (Indicator 1f). Feedback loops operated almost entirely on an informal, interpersonal basis rather than through structured departmental reviews. Without formalised oversight, schools lose the ability to diagnose chronic operational bottlenecks or build long-term institutional memory to optimise laboratory efficacy. These gaps align with prior studies observing that supervision, systematic monitoring, and formal follow-up procedures frequently represent the weakest components of school laboratory management frameworks (Manlea, 2017; Mohzana et al., 2023; Nurhamudin, 2024).

This institutional reality reflects broader structural discussions in science education pedagogy. Hofstein and Lunetta (2003) emphasise that while the laboratory environment offers a unique instructional landscape, its actual educational dividends hinge entirely on the deliberate design, execution, and assessment of the lab experience. Similarly, Abrahams and Millar (2008) caution that while hands-on activities effectively engage students with physical apparatus, manual manipulation does not automatically yield conceptual mastery unless explicit cognitive scaffolding is built into the task. Within the context of this study, High School A successfully sustained routine practical sessions but lacked evaluative scaffolding to assess conceptual progression. In contrast, High School B faced physical resource limitations that altered how lab tasks were delivered. Although student learning outcomes, inquiry process skills, and long-term safety behaviours were not directly measured in this study, these observed operational constraints present theoretical challenges to achieving meaningful inquiry-based science education as documented in pedagogical literature.

Contribution and Implications of the Findings

Empirically, this study underscores how systemic disparities in funding allocation, staffing models, and physical infrastructure directly shape the day-to-day realities of secondary school laboratory management. Rather than merely cataloging missing equipment, these findings demonstrate that operational sustainability is inextricably linked to institutional commitment and strategic resource allocation.

To translate these findings into structured interventions, recommendations are categorized into direct empirical actions supported by field data and broader policy measures requiring institutional feasibility assessments.

Table 4. Contribution and Implications of the Findings

Recommendation Category	Problem Evidence	Recommended Action	Responsible Actor	Priority / Time Frame
Direct Empirical Findings	Absence of dedicated laboratory assistants (High School B), forcing biology teachers to double as technicians (Thesis Table 6–7).	Recruit dedicated laboratory personnel or formalize technical support duties to relieve teachers of administrative setups.	School Principal, Local Education Office	High / Short-term (1–6 months)
Direct Empirical Findings	Deficits in running water access, dedicated sinks, and chemical waste management identified in field observations and student surveys.	Install dedicated handwashing sinks, biosafety drainage, and hazardous chemical waste segregation protocols.	School Infrastructure Committee, Head of Laboratory	High / Short-term (1–3 months)
Direct Empirical Findings	Unorganized storage cabinet space causing equipment accumulation in dust-prone, non-protective zones.	Standardize equipment maintenance schedules, secure protective storage cabinets, and update inventory logbooks.	Head of Laboratory, Science Teachers	Medium / Continuous
Direct Empirical Findings	Total omission of formal staff performance appraisals (Indicator 1e) and post-evaluation action plans (Indicator 1f, Thesis Table 8).	Institute structured peer reviews, documented staff performance evaluations, and formalized quality feedback loops.	Head of Laboratory, School Quality Assurance Unit	Medium / Mid-term (6–12 months)
Policy & Feasibility Considerations	Absence of dedicated laboratory operational accounts, relying solely on general BOS funds (High School B).	Conduct financial feasibility reviews to establish ring-fenced budgets earmarked exclusively for lab maintenance and consumables.	School Board, Regional Educational Finance Department	High / Long-term (Policy-dependent)
Policy & Feasibility Considerations	Multifunctional laboratory usage (High School B used lab space as an auditorium and general classroom).	Phase out general-purpose facility usage to safeguard spatial integrity dedicated strictly to scientific inquiry.	School Leadership, Educational Planning Board	Medium / Long-term (Infrastructure expansion)

Crucially, administrative and logistical constraints do not completely halt scientific practicals. Teachers in resource-constrained environments routinely display pedagogical resilience, adapting their curricula through makeshift setups and alternative learning environments (Ramrathan & Ngubane, 2013; Rivera & Deleon, 2026). However, while these creative workarounds sustain basic practical exposure, they cannot substitute for structured biosafety protocols, institutionalized evaluation mechanisms, and sustained infrastructure investments.

Limitations of the Findings

Several methodological boundaries must be explicitly noted when interpreting the findings of this study. First, because the inquiry was restricted to two secondary schools within a single sub-district (Gamping), potential selection bias exists, and cross-institutional comparisons are inherently constrained by structural resource inequalities between the public school (which possessed dedicated lab personnel and funding) and the private school, which operated without a laboratory technician or allocated budget. Second, while data were gathered across a total student population of 627 students (High School A: n = 389 across 12 study groups; High School B: n = 238 across 9 study groups), the 16-item student questionnaire served strictly as supplementary descriptive support, and evidence of formal psychometric validity and reliability testing was not reported. Third, the reliance on self-report interviews and incomplete institutional documentation, particularly regarding unrecorded staff appraisals and informal oversight logbooks, may introduce reporting bias. Fourth, the qualitative analytical process carries potential researcher bias, as structured intercoder agreement protocols or formal peer-debriefing mechanisms were not documented during data synthesis. Finally, because this research employed a descriptive qualitative case study design, the findings do not support causal inferences regarding the direct impact of laboratory management on student academic achievement or inquiry skills. Consequently, these results should be interpreted as contextual organisational insights rather than broad, generalizable causal claims.

CONCLUSION

This study evaluated biology laboratory management across secondary schools, demonstrating that operational efficacy varies significantly based on technical staffing and resource allocation. Regarding comparative management practices, High School A sustained structured planning, routine practical implementation, and intensive facility utilisation through dedicated laboratory technicians and specialised lab spaces. In contrast, High School B experienced operational constraints due to technician shortages, ad hoc procurement, and spatial compromises that displaced practical sessions. Despite these operational differences, both institutions shared a critical administrative weakness in evaluative governance, completely omitting formal staff performance appraisals (Indicator 1e) and structured post-evaluation action plans (Indicator 1f). The highest-priority institutional recommendation is to recruit dedicated technical personnel and implement standardised performance evaluation frameworks to secure continuous operational quality.

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