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Science Laboratory Management and the Implications for Students' Motivation and Learning Achievement

Evi Wasitoh[1*], Bambang Ismaya[1], Abduloh[1], Maman Suryaman[1]

[1] Universitas Singaperbangsa Karawang, Karawang, Indonesia

[*] *Corresponding author: Evi Wasitoh (eviwasitoh71@guru.sma.belajar.id)*

Abstract

The management of science laboratories plays a strategic role in supporting experiment-based learning, which can enhance students' motivation and academic achievement. However, many schools still face challenges related to limited equipment, inadequate maintenance, and the inconsistent implementation of laboratory activities. This study aims to explore in depth how science laboratories are managed in secondary schools and how such management influences students' motivation and academic performance. A qualitative approach with a case study design was employed. Data were collected through observations, in-depth interviews with teachers, students, and laboratory personnel, and document analysis, including inventory records, practicum schedules, and laboratory SOPs. Data analysis followed Miles, Huberman, and Saldaña's interactive model. The findings indicate that the laboratory management is functional but not optimal due to limited resources, the absence of laboratory assistants, and irregular practicum implementation. Both teachers and students express highly positive perceptions of laboratory activities, which are shown to significantly increase motivation through engaging and meaningful hands-on experiences. The results also reveal that students who actively participate in laboratory work demonstrate better conceptual understanding and higher academic achievement. The study concludes that science laboratories have substantial potential as pedagogical spaces that mediate improvements in motivation and learning outcomes.

Keywords

Academic Achievement, Learning Motivation, Practical-Based Learning, Science Laboratory Management, Science Education Management.

1. Introduction

Science learning plays a strategic role in shaping students' scientific literacy and preparing them to face technological developments and the challenges of the 21st century. In the context of modern education, science learning is no longer sufficient if it relies solely on the delivery of theoretical material, but must emphasize critical thinking skills, science process skills, and investigative learning experiences (Chu, 2024). Science laboratories serve as important spaces that allow students to conduct observations, experiments, and direct testing of concepts so that they can build a deeper understanding. Ideally, laboratories function as centers of active learning that are able to foster curiosity, creativity, and students' learning motivation (Anjiana et al., 2025).

However, the reality of science laboratory management in many schools shows conditions that are not yet fully optimal. Generally, schools face various constraints such as limited facilities and infrastructure, inadequate practicum tools and materials, limited competence of laboratory staff, and the absence of systematically structured practicum schedules (Ana et al., 2025). In several schools, laboratory administration has not been well organized, and equipment maintenance has not been carried out routinely (Ikranbegiin et al., 2019). As a result, laboratories are often underutilized and are only used at certain moments, rather than being an integral part of the science learning process. This condition is further exacerbated by the perception of some teachers who view practicum activities as time-consuming additional tasks, resulting in low levels of integration into classroom learning (Anjiana et al., 2025).

This situation has a direct impact on students' learning experiences. The lack of practicum activities causes science learning to tend to be monotonous and less engaging. Sormin (2023) indicates that practicum activities make a significant contribution to increasing learning motivation, fostering curiosity, and strengthening conceptual understanding, which in turn affects students' learning achievement. When students' opportunities to engage in laboratory activities are limited, their intrinsic motivation to learn science may decrease, and academic achievement tends to be less optimal. In addition, quasi-experimental research shows that students who regularly participate in laboratory practicums achieve higher academic performance compared to students who are taught solely through conventional methods (Shan, & Abulibdeh, 2020; Fikri et al., 2025). This indicates that the quality of science laboratory management is not only related to technical aspects but is also closely associated with the quality of learning experiences obtained by students.

On the other hand, the urgency to improve the quality of science laboratory management has become increasingly prominent in line with curriculum demands that emphasize experiential learning and scientific investigation (Fitri, 2024). Effective laboratory management includes planning laboratory use, organizing equipment and materials, ensuring work safety, managing inventory administration, and utilizing laboratories in a planned and sustainable manner within the learning process (Oliveira et al., 2023). However, study by Chu (2024) have tended to focus more on quantitative aspects, such as the relationship between laboratory facilities and learning outcomes, the effectiveness of practicum models, or technical evaluations of facilities. Meanwhile, qualitative studies by Anjiana et al. (2025) explore how laboratories are managed, how teachers and students perceive their use, and how such management has implications for motivation and learning achievement remain relatively limited.

The limited number of studies in this field has created an important knowledge gap that needs to be addressed. Qualitative research is required to provide a deeper understanding of laboratory management practices in real school contexts, including

the dynamics involved, the challenges encountered, and the perceptions of relevant stakeholders. Therefore, this study focuses on exploring science laboratory management and its implications for students' motivation and learning achievement at the secondary school level as an effort to respond to the need for a comprehensive understanding of the managerial role of laboratories in improving the quality of science learning. Based on this background, the present study is designed to address questions regarding how science laboratory management is implemented, how teachers and students perceive such management, and how it impacts students' motivation and learning achievement. Through a qualitative approach, this study is expected to contribute empirically and conceptually to the understanding of the importance of laboratory management quality as a supporting factor in enhancing learning motivation and achievement, as well as to serve as a reference for schools in developing more effective and sustainable laboratory management practices.

2. Literature Review

2.1. Science Laboratory Management

Science laboratories serve as vital learning environments that enable students to engage in experimental activities, conduct observations, and reinforce conceptual understanding through hands-on experiences. The effective management of these laboratories involves careful planning, organization of equipment and materials, regular maintenance of facilities, ensuring safety protocols, and integrating laboratory activities into the broader learning process. Hofstein and Lunetta (2004) emphasize that well-managed science laboratories can significantly enhance student engagement, deepen conceptual understanding, and foster the development of scientific process skills through inquiry-based learning. In addition, effective management requires that facilities meet established standards, administrative systems are organized efficiently, and laboratory personnel are actively involved in supporting and sustaining practical activities (Santoso et al., 2024). Although regulatory frameworks, such as the Regulation of the Minister of National Education Number 26 of 2008, set clear guidelines for laboratory management, their implementation across schools remains inconsistent.

Research indicates that many schools continue to face challenges, including limited equipment, insufficient materials, and inadequate facility maintenance (Zakiyah et al., 2022). Such limitations lead to suboptimal management, which directly affects the frequency, quality, and effectiveness of laboratory practicums. Consequently, students may experience reduced opportunities for hands-on learning, limiting their ability to fully develop scientific skills and conceptual understanding. Given this context, laboratory management emerges as a critical factor in shaping the overall quality of science education. Properly managed laboratories not only enhance the practical learning experience but also serve as an essential foundation for motivating students, fostering curiosity, and supporting meaningful engagement in science learning.

2.2. Learning Motivation

Learning motivation refers to the internal and external drives that encourage students to actively engage in the learning process. Students' learning motivation strongly affects their understanding of concepts, as a mismatch between the material and their motivation can hinder effective learning (Wijiastuti & Nurhayati, 2021; Jiang & Fryer 2024). One motivational theory frequently applied in science education research is Self-Determination Theory (SDT) proposed by Deci and Ryan (2000), which views motivation as a function of three basic psychological needs: autonomy, competence, and relatedness. Science laboratory activities provide direct learning experiences that fulfill these three needs: students can explore independently

(autonomy), gain authentic experiences that enhance competence (competence), and collaborate with peers in group work (relatedness).

Research consistently demonstrates that laboratory practicum activities play a crucial role in enhancing students' learning motivation by providing hands-on experiences that stimulate curiosity and engagement (Chu, 2024). Practicum-based methods allow students to actively test the validity of scientific theories and concepts through experimentation, thereby fostering deeper understanding and intrinsic interest in the subject matter (Ramadhani et al., 2022). Direct interaction with experimental objects enables learners to construct knowledge independently, which has been shown to be more motivating than conventional lecture-based approaches (Hofstein & Lunetta, 2004). Furthermore, practical work serves as an effective platform to develop positive attitudes toward learning, enhance comprehension, and encourage collaboration among peers (Lee & Sulaiman, 2018). Students engaged in laboratory activities demonstrate higher interest, excitement, confidence, and problem-solving abilities, including answering questions and drawing graphs, compared to those taught through traditional methods that do not actively engage learners. Consequently, the quality of laboratory management, encompassing resource availability, organization, and facilitation of experiments directly and indirectly influences students' learning motivation, highlighting the importance of well-managed laboratory environments for effective science education.

2.3. Science Learning Achievement

Learning achievement refers to students' academic performance following participation in the learning process, encompassing conceptual understanding, application skills, and assessment results. In science education, achievement is heavily influenced by instructional methods, hands-on experimental experiences, and students' engagement in laboratory activities. Practicum-based learning allows students to observe scientific phenomena concretely, which strengthens mental representations and improves retention of concepts (Widiartini et al., 2023). Empirical evidence further supports the positive impact of laboratory utilization on learning outcomes, showing that students who frequently participate in practicum activities tend to achieve higher science test scores compared to peers who rely solely on conventional classroom instruction (Oliveira et al., 2023). Shana and Abulibdeh (2020) also report a positive correlation between practical work and academic attainment, highlighting that experimental groups often demonstrate greater understanding, particularly in tasks requiring interpretation and reasoning.

The relationship between laboratory management, learning motivation, and achievement is equally critical. Effective laboratory management creates an environment that facilitates exploration, creativity, and curiosity, which in turn enhances students' intrinsic motivation (Sadiqin et al., 2020). Increased motivation through consistent practicum experiences positively influences learning achievement, illustrating the interdependence between these variables. Conversely, poorly managed laboratories with limited equipment, irregular scheduling, or minimal hands-on opportunities reduce meaningful learning experiences, thereby diminishing both motivation and achievement. Studies indicate that well-organized laboratories not only enrich experimental learning but also strengthen conceptual understanding and academic performance (Shana & Abulibdeh, 2020; Zakiyah et al., 2022). Therefore, laboratory quality and management emerge as essential factors in supporting science learning outcomes, emphasizing the need for strategic investment in both facilities and pedagogical practices.

3. Methods

This study employed a qualitative approach with a case study design to explore in depth how science laboratory management is implemented in schools and how it

impacts students' learning motivation and achievement. A qualitative approach was chosen to allow the researcher to investigate the meanings, perceptions, and subjective experiences of teachers and students within a real school context. The case study design enabled a holistic and comprehensive description of phenomena within a specific setting, aligning with the characteristics of science education research (Creswell & Poth, 2018).

The research was conducted at SMAN 1 Cikarang Pusat, which has a science laboratory whose utilization varies according to scheduling and instructional policies. This site was selected purposively because it represents typical public schools in Indonesia facing challenges in laboratory management. Research participants included science teachers, the head of the laboratory or laboratory staff, and students in grades XI and XII, chosen for their direct involvement in laboratory management or utilization. Purposive sampling was employed to ensure that participants provided relevant and informed perspectives.

Data were collected from primary and secondary sources. Primary data were obtained through in-depth interviews, direct observations of laboratory activities, and interactions with participants. Secondary data consisted of practicum schedules, equipment and material inventories, laboratory standard operating procedures (SOPs), photographs, and school policy documents related to laboratory use. Multiple data sources were used to enhance understanding and validate research findings. Three main data collection methods were employed: observation, in-depth interviews, and documentation study. Observations focused on the physical condition of the laboratory, facility utilization, practicum activity flow, and student behavior. Semi-structured interviews were conducted with teachers, laboratory staff, and students, allowing for rich narratives about experiences and perceptions of laboratory management. Documentation supported observations and interviews, validating information on facility management and practicum implementation.

The researcher served as the primary instrument, supported by interview guides, observation sheets, and document analysis checklists. Interview guides addressed laboratory management aspects (planning, utilization, administration, maintenance), students' learning experiences and motivation, and teachers' perceptions of practicum impact on achievement. Observation sheets captured laboratory conditions, equipment completeness, practicum processes, and teacher–student interactions. Documentation checklists evaluated the completeness of inventories, SOPs, and practicum records.

Data analysis followed Miles et al. (2014) model, including data condensation (summarizing and organizing key information), data display (presenting narratives, matrices, or charts), and conclusion drawing/verification (formulating and continuously verifying provisional conclusions). Analysis was conducted concurrently with data collection to ensure depth and flexibility. Trustworthiness was examined using Lincoln and Guba's (1985) criteria: credibility was achieved through triangulation, member checking, and prolonged field engagement; transferability through thick description; dependability via an audit trail; and confirmability by grounding findings in data rather than researcher bias. The research procedure included: (1) preliminary study of laboratory conditions and policies, (2) preparation of interview, observation, and documentation guides, (3) initial laboratory observations, (4) in-depth interviews, (5) simultaneous data analysis, (6) triangulation and verification, and (7) drawing conclusions and reporting. All stages were conducted systematically to ensure validity, credibility, and alignment with the research objectives.

4. Results

4.1. Implementation Management Pattern of Science Laboratory

Observations indicate that the science laboratory at the research school is in a moderately adequate condition in terms of space, but still faces limitations regarding equipment completeness, maintenance, and utilization management. The laboratory is equipped with practical tables, sinks, whiteboards, cabinets, and several basic tools such as microscopes, measuring glasses, and simple electrical devices. However, their quantity is limited and insufficient for the number of student groups conducting experiments, which aligns with previous reports on resource constraints in school laboratories (Zakiyah et al., 2022). Some equipment appears worn and shows signs of damage, while certain chemicals are occasionally unavailable when practical sessions are scheduled.

The inventory documents also record several items as "minorly damaged" or "severely damaged," but replacements have not been made due to the school's budget constraints. This situation is further supported by a statement from one of the science teachers, who explained that most of the laboratory equipment is quite old. While some items remain functional, they require careful handling. For instance, microscopes are shared among multiple student groups, with each device being used in rotation due to the limited number available. From the perspective of administration and planning, the school prepares a practical schedule at the beginning of each semester. However, its implementation in the field does not always align with the planned schedule. Practical sessions are sometimes canceled or replaced with regular classroom lessons due to various reasons, such as time constraints, the readiness of equipment and materials, or content considered too difficult to be conducted as a practical activity. The laboratory provides a basic framework for practical learning, its limitations in equipment, maintenance, and consistent implementation hinder its full potential as an effective hands-on learning environment (May et al., 2023).

The science teacher also mentioned that although practical activities are formally included in the lesson plans and syllabus, in practice, not all scheduled sessions are successfully carried out. The teacher explained that this often occurs when the available time is limited or when the laboratory equipment is insufficient to support the planned experiments. Such discrepancies between planned and actual implementation reflect common systemic challenges in laboratory-based learning, where logistical and resource limitations often hinder the execution of practical sessions (Ana et al., 2025). As a result, some practical activities have to be postponed, modified, or replaced with theoretical classroom lessons, which can affect the intended learning outcomes and reduce opportunities for students to gain hands-on experience.

Laboratory management is largely handled directly by the science teacher, as the school does not yet have a dedicated laboratory technician. This situation requires the teacher to take on multiple roles simultaneously: as an instructor, an administrator managing the laboratory, and as the person responsible for the equipment and materials. Limited time availability results in several management aspects, such as recording the in-and-out flow of equipment, organizing materials, and performing routine maintenance, not being carried out according to ideal standards (Mohzana et al., 2023). Compared to recommended laboratory management standards, which include having a dedicated technician, an updated inventory system, and a consistent practical schedule, it is evident that the laboratory management at this school remains functional but not yet fully optimized.

4.2. Teachers and Students Perceptions of Management of Science Laboratory

Teachers generally hold a positive perception of the science laboratory. They view the laboratory as an essential component that can transform the learning

environment from abstract to concrete. They acknowledge that laboratory practicums help students grasp difficult concepts while also providing hands-on experiences that are difficult to achieve through lectures alone. The results of interviews and observations indicated that the teacher explained that when students engage in laboratory practicums, they tend to understand the material more clearly. Concepts that previously existed only as abstract ideas in textbooks become tangible, as students can see and perform the experiments themselves (Asyari et al., 2021). However, the teacher also noted that not all topics could be covered through practicums due to limitations in available facilities and time constraints, which sometimes hinder the full implementation of hands-on activities for every lesson.

However, the teacher also expressed feeling burdened by the dual role of serving both as an instructor and as the laboratory manager. The absence of a dedicated laboratory technician meant that all technical tasks, including preparing equipment, organizing materials after practicums, and managing chemical inventories, had to be handled personally by the teacher. This additional responsibility often became a limiting factor in how frequently practicums could be conducted, a challenge similarly noted in studies where teachers' dual roles constrain the optimal use of laboratory facilities (Santoso et al., 2024). The teacher noted that having a laboratory technician would significantly ease the workload, as currently, all duties fall on the teacher; consequently, when teaching schedules are particularly tight, practical activities are sometimes neglected or postponed.

From the students' perspective, the laboratory was perceived as a more "lively" learning environment compared to the regular classroom. They described it as a place where they could truly engage in learning science, as it allowed them to directly observe phenomena that they had previously only read about in textbooks. This aligns with findings that hands-on laboratory experiences enhance student engagement and curiosity by bridging theoretical knowledge with real-world observation (Lee & Sulaiman, 2018). Several students expressed that learning in the laboratory felt different, making them more curious and helping them remember the material better. However, they also noted that practical sessions were infrequent, occurring only a few times per semester, and emphasized that more regular practicums would make learning science more engaging and less monotonous.

Interestingly, some students reported feeling less confident during practical sessions due to fear of making mistakes or handling certain equipment, especially that considered hazardous. This indicates that, beyond the availability of facilities and their utilization, guidance and a culture of laboratory safety are also important components of students' perceptions of the laboratory. Some students mentioned feeling excited about practicums but expressed anxiety when handling chemicals, worried about spilling or measuring incorrectly. These perceptions highlight that while the laboratory has the potential to be a strong source of learning motivation, the extent to which this potential is realized largely depends on the quality of management, supervision, and safety practices within the laboratory environment (Diwakar et al., 2023).

4.3. Role of Laboratory Management on Motivation and Achievement

Data from interviews, observations, and field notes indicate a strong correlation between the frequency and quality of practical laboratory sessions and students' motivation in learning science. When practicums are conducted effectively, with clear instructions, sufficient equipment and materials, and opportunities for students to explore independently, students demonstrate higher levels of enthusiasm (Galana et al., 2023). They exhibit curiosity, engage in discussions with peers, and actively participate in activities. Several students reported feeling more alert and engaged during practical sessions, as the hands-on experience allowed them to test concepts and observe results directly, enhancing their intrinsic motivation to learn.

Conversely, when practicums are canceled or replaced with purely theoretical explanations in the classroom, students tend to feel disappointed and perceive the lessons as less engaging. Some students expressed that when scheduled practical activities could not be carried out due to equipment unavailability or other logistical issues, their interest and motivation decreased. These findings suggest that the quality and consistency of laboratory management, including adequate preparation, supervision, and access to materials, play a critical role in fostering students' motivation and active participation in science learning (Essien et al., 2024).

Academically, teachers observed that students who actively participated in laboratory practicums and demonstrated high engagement during activities tended to achieve better results in both formative and summative assessments. This observation is consistent with research indicating that practical work significantly improves students' conceptual understanding and academic performance in science (Shana & Abulibdeh, 2020; Iyamuremye et al., 2023). Teachers noted that when concepts were taught through a combination of explanation and hands-on practice, students were more capable of answering comprehension-based questions rather than relying solely on memorization. One teacher explained that topics accompanied by practical sessions generally allowed students to recall and apply what they had done in the laboratory, which enhanced their problem-solving skills.

Document analysis, such as daily scores and practicum assignments, revealed a pattern in which topics with associated laboratory activities had slightly higher average scores compared to topics taught only theoretically. This finding echoes previous studies that report improved assessment outcomes when practical experiences are integrated into science instruction (Widiartini et al., 2023). Although no statistical tests were conducted due to the qualitative research design, this trend aligns consistently with teacher and student narratives. Students themselves expressed that practical activities significantly aided their understanding and recall. Some students mentioned that when learning was limited to reading, they struggled to visualize concepts, but after performing the practicum, they could better remember the steps during assessments. Others noted that they found it easier to comprehend lessons with practicums, which helped them perform more confidently during exams.

In synthesis, the results of this study indicate that laboratory management at the school functions at a "moderately effective" level but does not yet meet the ideal standards in terms of facilities, maintenance, and governance. Teachers' and students' perceptions of the laboratory are highly positive; they view it as a crucial asset that makes science learning more concrete, engaging, and meaningful. Student motivation noticeably increases when practicums are conducted effectively, but declines when practical activities are infrequent or replaced by theoretical lessons. Academic achievement tends to be higher for topics accompanied by laboratory activities, although the full potential of the laboratory as a learning resource has not yet been fully realized.

5. Discussion

The results of this study indicate that the science laboratory at the research site is "adequately sufficient" in terms of physical space; however, it faces notable limitations regarding equipment availability, maintenance, and utilization management. While the laboratory is furnished with basic facilities such as practical tables, sinks, whiteboards, and storage cabinets, and contains essential instruments such as microscopes, measuring glasses, and simple electrical tools, the quantity of these resources is insufficient for the number of student groups. Some equipment is outdated or shows signs of damage, and certain chemicals are not consistently available during practical sessions. Observations and interviews further revealed that laboratory activities are frequently modified, delayed, or even canceled due to

limited resources, tight schedules, or incomplete preparation of materials. Laboratory management largely depends on the science teachers themselves, who simultaneously serve as instructors, administrators, and supervisors of equipment and materials. This situation indicates that, although functional, laboratory management at the school has not yet reached an optimal standard. These challenges reflect similar findings reported by Zakiyah et al. (2022), who highlighted that many Indonesian schools struggle with limited infrastructure, the absence of dedicated laboratory staff, and the lack of systematic laboratory administration.

The study's findings, showing that the frequency, quality, and implementation of practical activities are positively correlated with students' learning motivation, align with Self-Determination Theory (Deci & Ryan, 2000). According to this theory, intrinsic motivation arises when individuals' basic psychological needs, competence, autonomy, and relatedness, are fulfilled. Laboratory practicums support these needs by allowing students to feel competent through performing procedures and observing experimental results, fostering autonomy by providing opportunities for experimentation, prediction, and discussion, and encouraging relatedness through group work and interactions with peers and teachers (Bazie et al., 2024). Conversely, suboptimal laboratory management manifested in limited equipment, inconsistent scheduling, or teacher-dominated activities may hinder the fulfillment of these needs, thereby diminishing the motivational benefits that practicums can provide. These results confirm prior research by Hofstein and Lunetta (2004) and Chu (2024) which emphasizes that well-structured and properly managed laboratory activities enhance learning motivation through hands-on and minds-on experiences. In the context of the school studied, the partial and inconsistent management of the laboratory limits the motivational impact of practical activities.

From an academic performance perspective, students who actively engage in laboratory practicums and demonstrate high interest tend to achieve better scores in both formative and summative assessments. This observation corroborates the conclusions of Shana & Abulibdeh (2020) and Oliveira et al. (2023), who found that laboratory practicums significantly enhance conceptual understanding and academic achievement in science. However, in this study, the potential benefits of laboratory activities remain underutilized due to limitations in management and practical frequency. In other words, a more systematic and well-planned laboratory management approach, such as the presence of dedicated laboratory staff, routine equipment maintenance, and stronger integration of practical activities with the curriculum has the potential to exert a greater positive impact on students' science learning outcomes (Ulya & Kurniawan, 2024).

The findings reinforce the notion that the science laboratory functions not merely as a physical space but as a pedagogical environment that can serve as a mediator between effective management and learning outcomes, including student motivation and academic performance. Framed within existing theoretical perspectives and prior research by Deci and Ryan (2000), Hofstein and Lunetta (2004), and Zakiyah et al. (2022), it can be concluded that improving laboratory management in terms of organization, facilities, and pedagogical integration constitutes a critical strategy for enhancing the quality of science learning at SMAN 1 Cikarang Pusat. Optimizing these aspects is essential to unlock the full potential of laboratory practicums, fostering both higher motivation and better academic achievement among students.

6. Conclusion

This study concludes that the management of the science laboratory at the research school is functionally adequate but has not reached an optimal level to consistently support practical-based learning. The laboratory possesses basic facilities that enable practical activities, yet limitations in equipment quantity, condition, and regular updates, coupled with the absence of dedicated laboratory

staff, hinder effective administration. Consequently, practical activities are irregular, despite being outlined in lesson plans. Both teachers and students perceive the laboratory positively, recognizing its potential to make science learning more concrete, engaging, and meaningful. However, these benefits are constrained by current management shortcomings.

The findings demonstrate that effective laboratory management directly influences students' motivation and academic achievement. Regularly conducted practicums with sufficient equipment enhance intrinsic motivation, engagement, and active participation, whereas infrequent or substituted practical sessions reduce interest and learning outcomes. Students involved in practical activities exhibit stronger conceptual understanding and improved performance compared to those receiving only theoretical instruction. These results underscore the laboratory's dual role as a motivational and pedagogical mediator, confirming that well-managed laboratories can transform learning experiences into more active and meaningful engagement.

Despite these insights, the study is limited to a single school context, and findings may not fully generalize to other educational settings with different resource availability or management practices. Future research should explore innovative approaches, including digital laboratory management systems, virtual labs, or integration with STEAM-based curricula. Additionally, action research and design-based research methodologies could evaluate the effectiveness of such models in enhancing laboratory management, student motivation, and achievement.

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