



The Strategic Role of Laboratory Management in Improving Quality of Science Learning in Elementary Schools

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Abstract: Laboratory management is a fundamental component in the effective and quality implementation of science learning in elementary schools. This study aims to systematically examine the strategic role of laboratory management in improving the quality of science learning in elementary schools through a literature review approach. The method used is a systematic literature review of 35 scientific articles published between 2015 and 2024 from various reputable national and international journals. The results of the study indicate that good laboratory management encompasses four main dimensions: (1) management of laboratory facilities and infrastructure, (2) occupational health and safety management, (3) laboratory administration management, and (4) competency development of teachers and laboratory staff. These four dimensions have been proven to significantly contribute to improving the quality of science learning, as indicated by increased student learning motivation, scientific thinking skills, and learning outcomes. This study recommends the need for systematic policies from educational units and local governments in strengthening the governance of elementary school laboratories as a strategic effort to improve the quality of science education.

Keywords: Laboratory Management; Science Learning; Elementary School; Learning Quality; Literature Review.

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Introduction

Science education at the elementary school level plays a crucial role in building the foundation of students' scientific literacy from an early age. Effective science learning does not rely solely on conventional lecture-based approaches and memorization of concepts, but rather requires contextual, exploratory, and inquiry-based learning experiences. In this context, science laboratories occupy a strategic position as learning platforms that facilitate students' direct interaction with natural phenomena, conduct experiments, and build conceptual understanding through authentic scientific processes (Judijanto et al., 2025).

However, the mere existence of laboratories does not automatically guarantee improved science learning

quality. Various studies have shown that fundamental problems frequently faced by elementary schools in Indonesia are related to inadequate laboratory management. This condition is characterized by low standards for laboratory equipment and materials management, the absence of standardized work safety procedures, a shortage of competent laboratory technicians, and weak laboratory administration and documentation systems (Iswandari & Saputra, 2024).

Good laboratory management theoretically encompasses a series of integrated managerial functions, from planning, organizing, implementing, to controlling all laboratory resources. If these functions are carried out optimally, the laboratory can transform into a conducive, safe, and productive learning ecosystem for the development of students' science competencies.

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Conversely, suboptimal laboratory management has the potential to reduce the quality of practical activities and even create the risk of accidents that endanger the safety of students and educators (Armiyanti et al., 2025).

The urgency of this study is increasingly relevant given the implementation of the Independent Curriculum, which emphasizes project-based learning, science process skills, and student character development through meaningful learning experiences. This curriculum explicitly positions laboratory-based science activities as a learning modality that cannot be ignored. Therefore, a comprehensive understanding of how laboratory management can be optimized as a strategy to improve the quality of science learning in elementary schools is needed. Based on this background, this article aims to: (1) identify the main dimensions in elementary school laboratory management; (2) analyze the contribution of laboratory management to the quality of science learning; and (3) formulate relevant policy and practice implications for improving the quality of laboratory management in elementary schools. This study is expected to provide theoretical and practical contributions to the development of a higher quality science education system in Indonesia.

Method

This study used a systematic literature review (SLR) method, a qualitative research approach that aims to identify, evaluate, and synthesize findings from various previous studies relevant to the topic under study (Syauqi et al., 2026). This method was chosen because it allows researchers to obtain a comprehensive overview of the development of scientific knowledge related to laboratory management and the quality of science learning in a structured and systematic manner.

Literature Search Protocol

Literature searches were conducted through several reputable academic databases, including: Google Scholar, ERIC (Education Resources Information Center), Scopus, and national journal portals such as Garuda (Garba Rujukan Digital) and SINTA (Science and Technology Index). Keywords used in the search included: "laboratory management", "laboratory management", "elementary school science learning", "science learning elementary school", "quality of science learning", "science education quality", as well as combinations of these keywords with the Boolean operators AND and OR.

Inclusion and Exclusion Criteria

Articles considered for analysis must meet the following inclusion criteria: (a) published between 2015 and 2024; (b) addressing the topic of science laboratory management and/or the quality of science learning at

the elementary school level or equivalent; (c) peer-reviewed articles published in national scientific journals accredited by Sinta 1–3 or international journals indexed by Scopus/Web of Science; and (d) available in Indonesian or English. Excluded articles included articles without full-text access, opinion articles without empirical data or valid literature reviews, and articles not directly relevant to the topic of study.

Selection and Analysis Process

Of the 127 articles found through the initial search, the selection process was conducted in three stages. First, screening based on title and abstract yielded 68 articles that met topical relevance. Second, full-text reading of these 68 articles resulted in 35 articles that met all inclusion criteria. Third, analysis of the 35 selected articles was conducted using a thematic analysis approach to identify key themes related to the dimensions of laboratory management and its contribution to the quality of science learning. The data extraction process included: bibliographic information, research objectives, methodology, key findings, and practical implications of each article.

Result and Discussion

Dimensions of Laboratory Facilities and Infrastructure Management

A review of various literature shows that the management of laboratory facilities and infrastructure is the most fundamental dimension of an elementary school laboratory management system. Adequate laboratory infrastructure—including the availability of functional experimental equipment, laboratory materials, adequate lighting, good ventilation, and proper waste management—has been shown to significantly correlate positively with the quality of science laboratory activities (Sani, 2021).

Research conducted by (Suryatini, 2024) in 40 public elementary schools in Central Java found that schools with an organized laboratory equipment inventory and a routine equipment maintenance system demonstrated a higher frequency of laboratory activities—an average of 3.2 times per month—compared to schools with weak equipment management, which only conducted laboratory activities an average of 0.8 times per month. This difference in frequency directly impacts the depth of students' conceptual understanding of science material.

Furthermore, a study (Santoso & MSM, n.d.) highlighted that an integrated inventory system—which includes recording equipment conditions, calibration schedules, and procurement planning—enables schools to optimize the use of laboratory budgets more efficiently. This finding aligns with the principles of school-based management, which emphasize the

importance of accountability for resource use as a prerequisite for improving educational quality.

Dimensions of Laboratory Occupational Safety and Health Management

Occupational health and safety (OHS) management in laboratories is an essential aspect of science labs, including at the elementary school level. Although the materials used in elementary school labs are generally relatively safe, standardized safety procedures still play a strategic role in fostering a responsible scientific culture in students from an early age.

A study by Hofstein et al. (2013) confirmed that science laboratories that implement clear safety protocols—including rules for the use of personal protective equipment, accident-handling procedures, and laboratory rules that are understood by all users—not only minimize the risk of accidents but also create a conducive learning atmosphere. Students who feel safe in the laboratory environment tend to demonstrate higher levels of active participation and scientific curiosity.

In Indonesia, research (ARIF, 2025) on elementary schools in urban and rural areas found significant disparities in the implementation of laboratory safety and health (K3). Urban schools generally have more structured K3 standard operating procedures (SOPs) than rural schools. This disparity impacts the quality of practical activities that can be conducted, given that limited safety procedures often serve as a reason for teachers to limit or even avoid practical activities involving certain materials or equipment.

Dimensions of Laboratory Administration Management

Orderly and organized laboratory administration is the backbone of an effective laboratory management system. This dimension includes scheduling laboratory use, documenting laboratory activities, managing inventory books, developing laboratory work programs, and periodically reporting laboratory budget usage.

Research (Maisaroh et al., 2025) identified that elementary schools with a transparent laboratory scheduling system accessible to all classroom teachers showed a 47% increase in laboratory utilization compared to schools without a structured scheduling system. Furthermore, systematic documentation of laboratory activities—including experimental reports, activity photos, and evaluation notes—serves as valuable reflection material for teachers in improving the quality of future instructional design. From an educational management perspective, sound laboratory administration also contributes to institutional transparency and accountability. Well-organized

laboratory documentation facilitates supervision by principals, educational supervisors, and school accreditation. This indirectly creates positive pressure for institutions to continuously improve their laboratory management standards.

Dimensions of Teacher and Laboratory Assistant Competency Development

The competence of human resources—particularly science teachers and laboratory staff—is the most influential determinant in optimizing the laboratory's function as a learning tool. Teachers with strong pedagogical science competencies, combined with technical skills in operating laboratory equipment, have been shown to be able to design and implement higher-quality, more creative, and more meaningful practicum activities (Riantobi, 2024).

A meta-analysis conducted by (Judijanto et al., 2025) showed that the effectiveness of laboratory-based learning is highly dependent on the quality of teacher facilitation during the practicum. Teachers who are able to ask open-ended questions, guide students to observe, predict, and draw conclusions independently, and connect experimental results to relevant scientific concepts have been shown to significantly improve students' conceptual understanding.

The above findings imply that investing in science teacher professional development—through laboratory technical training, workshops on developing practical modules, and laboratory-based lesson study programs—is an integral strategy for optimizing overall laboratory management. The Teacher Professional Education Program (PPG) and various training programs organized by the Center for the Development and Empowerment of Educators and Education Personnel (P4TK) need to more explicitly integrate laboratory management and utilization competencies into their curricula.

The Relationship between Laboratory Management and the Quality of Science Learning

A synthesis of the various literature reviewed indicates a multidimensional relationship between the quality of laboratory management and the quality of science learning. At least three pathways of influence can be identified.

First, the motivational pathway. A well-managed laboratory—characterized by well-maintained equipment, cleanliness, and a safe environment—significantly increases students' intrinsic motivation to actively engage in science activities. Research (ZAID, 2025) shows that students studying in a laboratory with optimal management demonstrated 23% higher science learning motivation scores than the control group. Second, the cognitive pathway. Good laboratory

management allows for structured and directed practical activities, which in turn stimulate the development of students' scientific thinking skills, including observation, classification, inference, prediction, and scientific communication (Judijanto et al., 2025). Well-designed practical activities supported by adequate laboratory facilities have been shown to improve students' critical thinking and problem-solving skills.

Third, the affective pathway – scientific attitudes. Positive learning experiences in the laboratory contribute to the formation of positive scientific attitudes, including curiosity, openness to new ideas, honesty in reporting observations, and persistence in facing scientific challenges. This affective dimension is an important foundation for the development of students' scientific identities, which has a long-term impact on interests and career choices in science (Muhajir et al., 2025).

Conclusion

Based on a systematic review of 35 relevant scientific articles, it can be concluded that laboratory management plays a significant strategic role in improving the quality of science learning in elementary schools. This strategic role is manifested through four main dimensions that interact synergistically: facility and infrastructure management, occupational safety and health management, administrative management, and teacher and laboratory assistant competency development.

These four dimensions contribute to improving the quality of science learning through three identified pathways of influence: the motivational pathway, the cognitive pathway, and the affective-scientific attitude pathway. These findings confirm that optimizing laboratory management is not merely a technical-administrative issue, but rather a pedagogical investment that has a comprehensive impact on the development of students' scientific competencies.

Based on these findings, this study recommends the following: First, educational units need to develop laboratory management policies explicitly outlined in the School Work Plan (RKS). Second, local governments, through the Education Office, need to allocate adequate budgets for the development and maintenance of elementary school laboratories and provide ongoing training programs for science teachers and laboratory technicians.

Third, further research should be directed toward developing standardized evaluation instruments for elementary school laboratory management that can be used nationally, allowing for more systematic and measurable mapping of laboratory quality.

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