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Research Artikel

UNCOVERING THE MANAGERIAL DIMENSIONS OF CHEMISTRY LABORATORY MANAGEMENT: AN EXPLORATORY FACTOR ANALYSIS IN SENIOR HIGH SCHOOLS OF THE BORDER REGION OF WEST KALIMANTAN

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Abstract

Effective chemistry laboratory management is fundamental to supporting meaningful laboratory-based learning; however, empirical evidence validating the structural relationships among managerial dimensions remains limited, particularly in geographically disadvantaged regions. This study employed Exploratory Factor Analysis (EFA) to identify and validate the underlying managerial dimensions of chemistry laboratory management in senior high schools located in the border region of West Kalimantan, Indonesia. Data was collected from 99 chemistry teachers using a Guttman-scale questionnaire measuring five managerial dimensions: planning, organizing, actuating, monitoring, and evaluation. The Kaiser–Meyer–Olkin (KMO) value of 0,807 and a significant Bartlett's Test of Sphericity ($\chi^2 = 261,424$, $p < 0,001$) confirmed the suitability of the data for factor analysis. Principal Component Analysis extracted one component with an eigenvalue of 3,210, explaining 64,208% of the total variance. Planning (0,936) and organizing (0.877) demonstrated the highest loading factors, whereas actuating showed the lowest loading (0,552). These findings indicate that planning and organizing represent the core managerial dimensions underpinning effective chemistry laboratory management, while the implementation of laboratory activities varies across schools. The findings highlight the need to strengthen systematic planning, organizational coordination, and integrated laboratory management systems to improve sustainable laboratory governance. This study provides empirical evidence that supports the development of laboratory management policies and practices, particularly for secondary schools in geographically disadvantaged border regions.

Keywords*: Chemistry; factor analysis; management laboratory.*

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INTRODUCTION

Quality chemistry education in senior high schools depends not only on well-designed curricula and effective instructional strategies but also on the availability and effective management of laboratory facilities. Chemistry laboratories constitute an indispensable component of science education because they enable students to transform abstract chemical concepts into observable scientific phenomena through experimentation. Laboratory-based activities foster conceptual understanding, strengthen experimental competencies, and enhance students' engagement and motivation toward chemistry learning (Seery, 2020; A'yuniah et al., 2022). Through hands-on investigations, students actively construct scientific knowledge while developing higher-order thinking and problem-solving skills that cannot be effectively achieved through theoretical instruction alone.

In the context of Indonesia's *Merdeka Curriculum*, laboratory-based learning plays a strategic role in achieving the expected learning outcomes, particularly in strengthening students' conceptual understanding and science process skills. Experimental activities are no longer regarded as supplementary instructional tasks but as an integral component of chemistry education. Empirical studies consistently demonstrate that laboratory experiments significantly improve students' motivation, academic achievement, conceptual understanding, and scientific skills (Riswanto, 2019; Juniar et al., 2020; Redhana & Suardana, 2021; Sartika & Hadi, 2023; Sormin, 2023). Consequently, the quality of laboratory-based learning depends not only on the availability of laboratory facilities but also on the effectiveness of laboratory management practices that support the planning, implementation, and evaluation of practical activities. Therefore, effective laboratory management constitutes a fundamental prerequisite for improving the quality of chemistry education.

Despite the recognized importance of chemistry laboratories in science education, their provision and management remain challenging in many educational settings. A previous study reported that approximately 45% of schools in several countries lack adequate laboratory facilities due to infrastructural limitations (Mahanani et al., 2020). Even in schools where laboratory facilities are available, ineffective management practices frequently hinder their optimal utilization. Common challenges include inadequate planning of laboratory activities, poor organization of laboratory equipment and chemicals, weak monitoring systems, and limited evaluation of laboratory operations. These deficiencies reduce both the frequency and quality of practical activities, ultimately affecting students' learning experiences and academic outcomes.

In Indonesia, similar challenges continue to impede the effective implementation of chemistry laboratory activities. Nuswowati et al. (2020) identified several constraints, including limited instructional time, heavy teaching and administrative workloads, the high cost of laboratory equipment and chemical procurement, the shortage of qualified laboratory assistants, and the use of laboratory spaces for non-practical purposes. These findings indicate that laboratory-related problems extend beyond the physical availability of facilities and encompass managerial, organizational, and human resource dimensions. Without systematic and professional management, laboratory facilities cannot function effectively as learning resources or adequately support meaningful laboratory-based instruction.

To strengthen laboratory governance, the Indonesian government enacted the Regulation of the Minister of National Education No. 26 of 2008 concerning standards for laboratory personnel. The regulation requires laboratory managers to possess competencies in five managerial functions: planning, organizing, actuating, monitoring, and evaluation. These functions provide the managerial foundation for ensuring that laboratory activities are implemented systematically, safely, and accountably. Effective implementation of these competencies is essential for improving

institutional performance and achieving educational quality objectives (Maisyaroh et al., 2024). Nevertheless, despite the existence of these national standards, their implementation remains inconsistent across Indonesian schools, indicating that the availability of regulatory guidelines alone is insufficient to ensure effective laboratory management.

The situation in West Kalimantan Province further demonstrates the urgency of strengthening chemistry laboratory management. A preliminary survey involving 99 chemistry teachers from 476 senior high schools revealed that 92.93% experienced difficulties in conducting chemistry experiments, primarily because of insufficient laboratory equipment and chemical supplies. These findings indicate that laboratory management challenges remain widespread and substantially hinder the implementation of laboratory-based learning. Given that practical activities constitute a fundamental component of chemistry education, ineffective laboratory management not only limits students' opportunities to develop scientific skills but also affects the overall quality of chemistry learning. These preliminary findings underscore the need to investigate the managerial dimensions underlying chemistry laboratory management to identify the key managerial functions requiring improvement.

Previous studies have identified several managerial challenges affecting the effectiveness of chemistry laboratory management. These include the shortage of qualified laboratory personnel, limited coordination between chemistry teachers and laboratory managers, and inadequate communication regarding laboratory administration (Riswanto, 2019). In addition, the procurement, utilization, and maintenance of laboratory equipment and chemicals are frequently conducted inefficiently and without systematic long-term planning (Sawuwu, 2017). Collectively, these findings indicate that chemistry laboratory management is a multidimensional process influenced by interrelated managerial, organizational, and institutional factors rather than by a single operational issue.

The geographical and socio-economic characteristics of West Kalimantan further increase the complexity of chemistry laboratory management. As one of Indonesia's frontier provinces, West Kalimantan comprises two municipalities and twelve regencies, several of which share a direct international border with Malaysia. Although this strategic location provides opportunities for regional development, many border areas continue to experience disparities in educational infrastructure, accessibility, and the distribution of qualified educational personnel. Education plays a fundamental role in promoting economic growth, social development, and human capital formation (Hai, 2021). Therefore, ensuring equitable access to quality educational facilities, including science laboratories, is essential for achieving national education standards (Bueraheng & Hamidi, 2019). In addition to infrastructure disparities, schools located in border regions frequently encounter delays in laboratory equipment procurement, shortages of laboratory technicians, and limited access to laboratory resources. These conditions increase the complexity of laboratory management and reinforce the importance of strengthening managerial capacity in geographically disadvantaged schools.

Although previous studies have examined laboratory implementation, teacher competence, and laboratory utilization in science education (Mahanani et al., 2020; A'yuniah et al., 2022), most have primarily described laboratory conditions or evaluated individual managerial practices without empirically examining how the five managerial functions interact as an integrated management system. Furthermore, previous research has rarely employed Exploratory Factor Analysis (EFA) to validate whether the managerial competencies prescribed in the Regulation of the Minister of National Education No. 26 of 2008 constitute a coherent latent construct or to determine the relative contribution of each managerial dimension. Consequently, the structural relationships

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among planning, organizing, actuating, monitoring, and evaluation remain insufficiently understood, particularly in geographically disadvantaged border regions.

Unlike previous studies, this research investigates chemistry laboratory management from a structural managerial perspective rather than merely describing laboratory conditions or evaluating individual managerial activities. By integrating descriptive survey findings with Exploratory Factor Analysis, this study identifies the latent managerial structure underlying chemistry laboratory management and examines the relative importance of each managerial dimension. Accordingly, the principal novelty of this study lies in revealing the discrepancy between managerial practices implemented in schools and the latent managerial dimensions that structurally underpin effective laboratory management. This approach not only provides empirical validation of the managerial competencies prescribed in the national laboratory standards but also offers a stronger evidence base for developing integrated laboratory management policies, particularly for secondary schools located in Indonesia's border regions.

Accordingly, this study aims to identify and validate the underlying managerial dimensions influencing chemistry laboratory management in senior high schools located in the border region of West Kalimantan using Exploratory Factor Analysis (EFA). Specifically, the study examines the relative contribution of the five managerial functions planning, organizing, actuating, monitoring, and evaluation to the overall construct of chemistry laboratory management. In this study, the term *actuating* is intentionally retained to maintain consistency with the classical POAC (Planning, Organizing, Actuating, and Controlling) management framework, which remains widely adopted in educational management literature and Indonesian educational governance.

The findings of this study are expected to contribute both theoretically and practically. Theoretically, this study provides empirical validation of the managerial dimensions underlying chemistry laboratory management by applying Exploratory Factor Analysis within the context of Indonesian secondary education. Practically, the findings provide evidence-based recommendations for strengthening managerial capacity, improving laboratory governance, and supporting the development of integrated laboratory management systems, particularly for secondary schools located in geographically disadvantaged border regions. These findings are also expected to inform educational policymakers and school administrators in designing strategies to improve the effectiveness and sustainability of chemistry laboratory management. Accordingly, this study addressed the following research question: What are the underlying managerial dimensions of chemistry laboratory management in senior high schools located in West Kalimantan's border region, and how do these dimensions contribute to the overall laboratory management construct?

METHOD

This study employed a quantitative research design using a cross-sectional survey approach to collect empirical data relevant to the research objectives (Gurbuz, 2017). A quantitative survey was considered appropriate because the study aimed to identify and validate the underlying managerial dimensions of chemistry laboratory management using Exploratory Factor Analysis (EFA). The target population consisted of chemistry teachers from all public and private senior high schools in West Kalimantan Province, representing 476 schools. The study employed a non-probability sampling technique, specifically purposive sampling, to select chemistry teachers who were directly responsible for managing school laboratories. A total of 99 chemistry teachers participated in the study, representing more than 20% of the target population with an estimated precision level of ±10% (Islam, 2018). The selection criteria ensured that respondents possessed direct experience and responsibility in chemistry laboratory management, thereby providing information relevant to the research objectives.

Data were collected using a Guttman-scale questionnaire administered online through

Google Forms. The instrument measured chemistry laboratory management as the primary construct and was operationalized into five managerial dimensions derived from the Regulation of the Minister of National Education No. 26 of 2008, namely: (a) planning and development of laboratory activities, (b) organizing laboratory personnel, including laboratory technicians and assistants, (c) actuating laboratory activities, (d) monitoring laboratory facilities and infrastructure, and (e) evaluation of laboratory personnel performance and laboratory activities.

Before data collection, the questionnaire underwent qualitative content validation through expert judgment involving two experts, comprising one experts in chemistry education and one expert in educational management. The experts evaluated the relevance, clarity, and representativeness of each questionnaire item with respect to the managerial competencies prescribed in the national laboratory standards. Revisions were made based on their recommendations before the instrument was administered to the respondents. Subsequently, the construct validity of the instrument was evaluated using Exploratory Factor Analysis (EFA), while its internal consistency was assessed through reliability analysis.

The research procedure consisted of four stages. First, the research objectives were established and the questionnaire items were developed based on the national laboratory management standards and relevant literature. Second, the instrument underwent qualitative content validation through expert judgment, and revisions were made according to the experts' recommendations before distribution. Third, the validated questionnaire was administered to the selected respondents, and the collected data were screened, verified, and coded to ensure completeness and consistency. Finally, the validated dataset was analyzed using Exploratory Factor Analysis.

Exploratory Factor Analysis (EFA) was performed using IBM SPSS Statistics version 22 to identify and validate the underlying managerial dimensions of chemistry laboratory management. EFA was selected because the study sought to examine the latent structure underlying the observed managerial variables rather than to test a predetermined measurement model (Safavi et al., 2021; Shrestha, 2021). Sampling adequacy was evaluated using the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy, whereas Bartlett's Test of Sphericity was employed to determine whether the correlation matrix was appropriate for factor analysis.

Factor extraction was conducted using Principal Component Analysis (PCA), and components with eigenvalues greater than 1.0 were retained following the Kaiser criterion. Factor loadings of 0.50 or higher were considered acceptable for interpretation. Because only one component satisfied the eigenvalue criterion, factor rotation was not performed. The extracted component was interpreted based on the component matrix, communalities, and the proportion of total variance explained to identify the dominant managerial dimensions underlying chemistry laboratory management.

RESULTS AND DISCUSSIONS

The questionnaire initially consisted of 20 items representing the five managerial dimensions of chemistry laboratory management: planning (4 items), organizing (5 items), actuating (4 items), monitoring (3 items), and evaluation (4 items). Prior to the Exploratory Factor Analysis (EFA), item validity was examined using Pearson product-moment correlation analysis between each item and the total score. Items with a significance level of $p <$ 0,05 were considered valid.

The validity analysis indicated that 19 of the 20 questionnaire items met the established validity criterion and were retained for subsequent analyses. One item within the organizing dimension did not satisfy the validity requirement because it exhibited no response variability, resulting in a constant value across respondents. Consequently, this item could not produce a valid correlation coefficient and was excluded from further analysis. The final

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instrument therefore consisted of 19 valid items representing the five managerial dimensions of chemistry laboratory management.

The internal consistency of the validated instrument was subsequently assessed using Cronbach's Alpha. The reliability analysis produced a Cronbach's Alpha coefficient of 0.912 based on the 19 retained items, indicating excellent internal consistency and exceeding the minimum recommended threshold of 0,70 (Shrestha, 2021). This finding confirms that the questionnaire was sufficiently reliable for measuring the managerial dimensions of chemistry laboratory management and was therefore appropriate for subsequent Exploratory Factor Analysis.

Prior to factor extraction, the suitability of the dataset for Exploratory Factor Analysis (EFA) was evaluated using the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The analysis yielded a KMO value of 0,807, indicating good sampling adequacy and exceeding the recommended minimum threshold of 0,50. Furthermore, Bartlett's Test of Sphericity was statistically significant ($\chi^2 = 261{,}424$, df = 10, $p < 0{,}001$), confirming that the correlation matrix differed significantly from an identity matrix. These results demonstrate that the dataset satisfied the assumptions required for Exploratory Factor Analysis.

The adequacy of each managerial dimension was subsequently examined using the Measures of Sampling Adequacy (MSA) obtained from the Anti-Image Correlation Matrix. As shown in Table 1, all five managerial dimensions produced MSA values above the minimum acceptable threshold of 0,50, indicating that each variable contributed sufficiently to the common factor structure and was therefore retained for factor extraction.

Table 1. Measures of Sampling Adequacy (MSA) of the Managerial Dimensions

Managerial Dimension	MSA
Planning	0,727
Organizing	0,788
Actuating	0,886
Monitoring	0,905
Evaluation	0,853

Among the five managerial dimensions, monitoring demonstrated the highest MSA value (0,905), followed by actuating (0,886) and evaluation (0,853). These results indicate that these dimensions exhibited the strongest shared variance with the remaining variables in the dataset. Although planning produced the lowest MSA value (0,727), it remained well above the recommended threshold, confirming that all five managerial dimensions were appropriate for inclusion in the Exploratory Factor Analysis.

Following confirmation that the dataset satisfied the assumptions for Exploratory Factor Analysis (EFA), factor extraction was performed using the Principal Component Analysis (PCA) method. The communalities were first examined to determine the proportion of variance in each managerial dimension explained by the extracted component.

Table 2. Communalities of the Managerial Dimensions

Managerial Dimension	Initial	Extraction
Planning	1,000	0,876
Organizing	1,000	0,768
Actuating	1,000	0,304
Monitoring	1,000	0,618
Evaluation	1,000	0,644

As presented in Table 2, the extracted component explained a substantial proportion of variance for most managerial dimensions. Planning exhibited the highest communality (0,876), followed by organizing (0,768), evaluation (0,644), and monitoring (0,618). In contrast, actuating showed the lowest communality (0,304), indicating that this dimension shared comparatively less common variance with the underlying construct than the other managerial dimensions.

The number of retained components was subsequently determined based on the Kaiser criterion, in which only components with eigenvalues greater than 1,0 were retained.

Table 3. Total Variance Explained

Component	Eigenvalue	% of Variance	Cumulative %
1	3.210	64.208	64.208
2	0.797	15.936	80.144
3	0.497	9.937	90.081
4	0.351	7.015	97.095
5	0.145	2.905	100.000

Only the first component achieved an eigenvalue greater than 1,0 (3,210), whereas the remaining four components produced eigenvalues below the retention criterion. The retained component explained 64,208% of the total variance, indicating that the five managerial dimensions were adequately represented by a single latent construct.

This finding was further supported by the Scree Plot presented in Figure 1, which shows a distinct break immediately after the first component. The sharp decline from the first to the second component and the relatively flat slope thereafter indicate that only one meaningful component should be retained. Therefore, the chemistry laboratory management construct demonstrated a unidimensional factor structure.

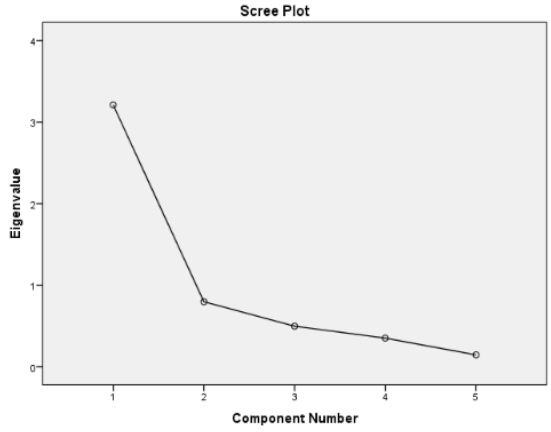

Figure 1. Scree Plot of the Extracted Components

To determine the contribution of each managerial dimension to the extracted component, the component matrix was subsequently examined.

Table 4. Component Matrix

Indicator	Component 1
Planning	0,936
Organizing	0,877
Actuating	0,552
Monitoring	0,786
Evaluation	0,802

All five managerial dimensions produced factor loadings exceeding the recommended minimum threshold of 0,50, confirming that each dimension contributed meaningfully to the extracted component. Planning demonstrated the highest loading (0,936), followed by organizing (0,877), evaluation (0,802), monitoring (0,786), and actuating (0,552). Since only one component satisfied the eigenvalue criterion, factor rotation was not performed, and interpretation was based on the unrotated component matrix. These factor loadings indicate the relative contribution of each managerial dimension to the underlying latent construct of chemistry laboratory management. They should not be interpreted as evidence of causal relationships or predictive effects among the managerial dimensions.

The descriptive findings presented in Figure 2 indicate that chemistry laboratory management in senior high schools across West Kalimantan Province is predominantly characterized by actuating and monitoring activities, whereas planning, organizing, and evaluation receive comparatively less attention in everyday laboratory practices.

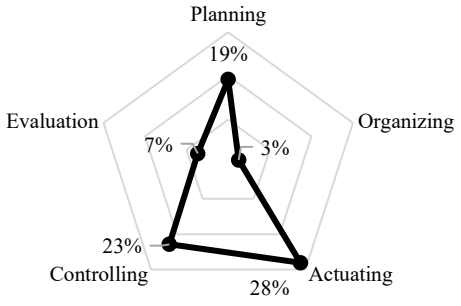

Figure 2. Chemistry Laboratory Management Process in Senior High Schools in West Kalimantan Province

This pattern suggests that laboratory management is largely driven by immediate operational demands, such as preparing practical activities, maintaining laboratory facilities, and

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monitoring equipment and chemicals, rather than by systematic managerial planning and organizational development. Consequently, laboratory management tends to function as an activity-oriented process instead of a strategically managed system. Such conditions imply that laboratory personnel devote considerable attention to ensuring the continuity of daily laboratory operations while giving relatively limited emphasis to long-term planning, organizational coordination, and continuous evaluation.

Interestingly, the descriptive findings contrast with the results of the Exploratory Factor Analysis (EFA). While Figure 2 illustrates that planning and organizing receive relatively limited attention in practice, the EFA identified these two dimensions as the strongest managerial components underlying chemistry laboratory management, with planning exhibiting the highest factor loading (0,936), followed by organizing (0,877). This finding indicates that although planning and organizing are not yet optimally implemented in schools, they constitute the fundamental managerial dimensions shaping effective laboratory governance. In other words, the dimensions that receive the least practical attention are those that contribute most substantially to the overall managerial structure.

This discrepancy highlights a critical gap between operational practices and managerial priorities, suggesting that improvements in chemistry laboratory management should focus not merely on increasing laboratory activities but on strengthening the strategic managerial functions that support sustainable laboratory governance. This issue becomes particularly important in border-region schools, where geographical isolation, limited institutional support, and unequal access to educational resources often compel laboratory personnel to prioritize immediate operational needs over long-term managerial planning.

The finding that planning and organizing emerged as the strongest managerial dimensions indicates that these functions contribute most substantially to the latent managerial structure identified through EFA. Rather than implying causal relationships, these findings demonstrate the relative structural importance of planning and organizing within the overall chemistry laboratory management construct. Although descriptive findings revealed that these functions receive relatively limited attention in everyday laboratory practices, the EFA demonstrates that they constitute the structural foundation upon which the remaining managerial functions operate. This result suggests that successful laboratory management depends primarily on the quality of strategic planning and organizational coordination rather than solely on the execution of routine laboratory activities.

Planning represents the initial stage of the managerial cycle and determines the direction of all subsequent laboratory activities. Effective laboratory management requires systematic planning to ensure that laboratory programs, practical schedules, equipment procurement, chemical inventories, budgeting, maintenance, and safety procedures are aligned with educational objectives. Ideally, laboratory managers should prepare annual laboratory work plans before the beginning of each academic year to anticipate resource requirements and support the implementation of practical learning (A'yuniah et al., 2022). Planning also involves determining what activities should be implemented, when and where they should be conducted, how they should be organized, and what resources are required to achieve the intended learning outcomes (Nashrullah & Rindaningsih, 2023; Najah et al., 2022; Palah et al., 2022). Without comprehensive planning, laboratory management becomes reactive rather than strategic, resulting in inefficient resource utilization and increasing the likelihood of recurring operational problems (Bueraheng & Hamidi, 2019).

The descriptive findings indicate that planning activities in many schools remain largely administrative and have not yet evolved into comprehensive managerial planning. Laboratory planning is frequently limited to recording laboratory equipment and consumable materials, whereas broader managerial aspects

including laboratory development programs, personnel planning, maintenance schedules, risk management, and systematic documentation are often overlooked. Furthermore, the absence of standardized operating procedures (SOPs) weakens the planning function by reducing consistency in laboratory administration and operational decision-making. As emphasized by Siregar et al. (2020), effective laboratory administration not only supports inventory management but also prevents resource misuse, minimizes equipment loss, improves accountability, and facilitates continuous laboratory development. These findings explain why planning emerged as the most influential managerial dimension in the EFA despite receiving relatively limited practical attention in schools.

The strategic importance of planning becomes even more evident in border-region schools, where the procurement of laboratory equipment and chemicals frequently requires longer distribution chains, higher transportation costs, and more complex administrative procedures than in urban areas. Under these conditions, inadequate planning may result not only in inefficient laboratory management but also in delays to practical learning activities. Consequently, systematic planning is particularly critical for ensuring the continuity and sustainability of chemistry laboratory instruction in geographically remote schools.

The organizing dimension exhibited a similar pattern. Although organizing demonstrated the second-highest factor loading, descriptive findings indicate that its implementation remains inadequate in many senior high schools. Organizing encompasses the allocation of responsibilities, coordination among laboratory personnel, distribution of workloads, and establishment of communication mechanisms that ensure laboratory activities operate efficiently (Nashrullah & Rindaningsih, 2023; Palah et al., 2022).

However, the survey revealed that only a small proportion of schools employ qualified laboratory technicians or laboratory assistants, forcing chemistry teachers to simultaneously perform multiple responsibilities as teachers, laboratory managers, technicians, and administrative staff. Such overlapping responsibilities reduce managerial effectiveness and limit opportunities for systematic laboratory development. These organizational challenges are further intensified in border regions, where recruiting and retaining qualified laboratory technicians remains difficult because of limited human resources and unequal educational infrastructure. As a result, chemistry teachers frequently assume multiple managerial responsibilities, reducing the effectiveness of laboratory governance.

Weak organizational structures are further reflected in the limited implementation of managerial supervision. Effective supervision ensures that laboratory activities remain consistent with institutional policies, safety standards, and educational objectives while simultaneously promoting continuous professional development among laboratory personnel (Alfian et al., 2019). Wiyono et al. (2021) further argue that supervisory practices should function as collaborative mentoring processes that strengthen managerial competence and institutional accountability rather than merely evaluating administrative compliance. Therefore, the relatively high structural importance of organizing identified through the EFA indicates that strengthening organizational coordination, clarifying managerial roles, and improving supervisory mechanisms should become priority strategies for enhancing chemistry laboratory management, particularly in schools experiencing shortages of laboratory personnel.

Although actuating, monitoring, and evaluation represent the operational stages of laboratory management, the present findings indicate that these functions have not yet been implemented as components of a continuous managerial cycle. The descriptive findings presented in Figure 2 show that actuating and monitoring receive greater attention than planning and organizing in daily laboratory practices. However, the EFA results demonstrate that these dimensions contribute less strongly to

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the underlying managerial construct, particularly actuating, which exhibited the lowest communality (0,304) and the lowest factor loading (0,552). This finding suggests that operational activities are frequently performed independently of strategic managerial planning and organizational coordination. Consequently, laboratory management tends to emphasize the execution of routine activities rather than the systematic management processes required to achieve sustainable laboratory governance.

The predominance of actuating in daily laboratory practice reflects the immediate responsibility of chemistry teachers to ensure that practical activities can still be conducted despite various institutional constraints. Actuating refers to the managerial process of mobilizing available resources and personnel to implement planned activities and achieve organizational objectives (Indrihapsari & Wibowo, 2020). Within the classical POAC framework, however, actuating should function as the implementation of well-established planning and organizing processes rather than as an isolated managerial activity (Palah et al., 2022). The relatively lower structural contribution of actuating identified in this study indicates that laboratory implementation remains highly dependent on individual initiatives rather than on institutional management systems. This interpretation is consistent with the descriptive findings showing that many chemistry teachers simultaneously perform multiple roles as teachers, laboratory managers, laboratory technicians, and laboratory assistants, thereby limiting the effectiveness of laboratory implementation despite their strong commitment to maintaining practical learning activities.

A similar pattern was observed for monitoring and evaluation. Although monitoring activities are routinely conducted, they are generally limited to checking the availability and physical condition of laboratory equipment and chemicals. More comprehensive monitoring activities, including infrastructure assessment, occupational safety, laboratory documentation, and systematic performance reporting, remain relatively limited. Effective monitoring should provide continuous feedback regarding organizational performance and ensure that laboratory management is implemented in accordance with established standards and institutional objectives (Indrihapsari & Wibowo, 2020; Bueraheng & Hamidi, 2019). Likewise, evaluation should function as a cyclical managerial process through which laboratory managers assess program effectiveness, identify operational constraints, and formulate evidence-based improvement strategies.

However, the survey findings revealed that evaluation practices are predominantly reactive and are generally conducted only after operational problems occur. Consequently, similar laboratory management issues tend to recur from one academic year to the next because systematic reflective evaluation has not yet become an integral component of laboratory governance. The geographical characteristics of West Kalimantan's border region further complicate monitoring and evaluation processes. Schools located in remote areas often experience limited access to technical assistance, professional development opportunities, and external supervisory support. Consequently, monitoring activities tend to focus on immediate operational needs rather than systematic quality assurance and continuous managerial improvement.

Taken together, these findings indicate that chemistry laboratory management in West Kalimantan remains predominantly activity-oriented rather than management-oriented. Laboratory personnel demonstrate strong commitment to implementing practical activities and maintaining daily laboratory operations; however, these operational efforts are not yet supported by equally strong strategic planning, organizational coordination, monitoring systems, and continuous evaluation. This imbalance explains why the descriptive findings portray actuating and monitoring as dominant daily activities, whereas the EFA identifies planning and organizing as the principal managerial dimensions underpinning effective laboratory management. The integration of these

findings suggests that sustainable laboratory governance requires a balanced implementation of all managerial functions within the POAC framework rather than emphasizing operational activities alone.

The findings of this study have important implications for both educational policy and laboratory management practices, particularly for senior high schools located in geographically disadvantaged border regions. The discrepancy between the descriptive findings and the EFA results demonstrates that improving chemistry laboratory management cannot rely solely on increasing laboratory activities or providing additional laboratory facilities. Rather, sustainable laboratory governance requires strengthening the managerial functions that underpin operational activities, particularly planning and organizing, while ensuring that actuating, monitoring, and evaluation are implemented as an integrated management cycle. Consequently, professional development programs for chemistry teachers and laboratory managers should prioritize strategic planning, organizational management, supervisory competence, and evidence-based evaluation in accordance with the managerial competencies prescribed in the Regulation of the Minister of National Education No. 26 of 2008.

The findings also highlight the importance of adopting integrated laboratory management systems to address the managerial challenges identified in this study. Advances in digital technology have created new opportunities to improve laboratory administration, standardize operational procedures, strengthen inventory management, and facilitate data-driven decision-making (Xu, 2022). Digital transformation has been recognized as an important catalyst for improving accountability, transparency, and efficiency in educational management systems (Triwiyanto et al., 2024). Similarly, the increasing use of computer-based laboratory management applications has expanded the capacity of schools to organize laboratory documentation, monitor equipment utilization, schedule maintenance, and improve administrative efficiency (Yang et al., 2021). Previous studies further demonstrate that application-based laboratory management systems contribute to greater operational efficiency, improved resource utilization, and more systematic laboratory administration (Ezeano & Ezeude, 2018; Suseno et al., 2019). Therefore, the development of an integrated digital chemistry laboratory management system represents a promising strategy for supporting standardized and sustainable laboratory governance in Indonesian secondary schools.

These implications are particularly relevant for schools located in West Kalimantan's border region, where laboratory management challenges are compounded by geographical isolation, unequal distribution of educational resources, shortages of qualified laboratory personnel, and logistical constraints affecting the procurement of laboratory equipment and chemicals. Under these conditions, strengthening managerial competence alone is insufficient unless accompanied by institutional support and equitable educational policies.

Consequently, efforts to improve chemistry laboratory management should integrate managerial capacity development, digital innovation, infrastructure enhancement, and continuous institutional assistance within a unified policy framework. Such an approach would not only improve laboratory governance but also contribute to reducing educational disparities between border and non-border regions while supporting the broader objective of improving the quality and sustainability of science education in Indonesia. Accordingly, laboratory management policies for border-region schools should not simply replicate approaches developed for urban schools but should consider the unique geographical, logistical, and institutional challenges that characterize frontier educational settings.

Overall, this study makes three important contributions to the literature on chemistry laboratory management. First, it provides empirical evidence that the five managerial competencies prescribed in the Regulation of the Minister of National Education No. 26 of 2008

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converge into a single latent managerial construct, thereby reinforcing the applicability of the classical POAC framework in the context of chemistry laboratory governance. Second, by integrating descriptive survey findings with Exploratory Factor Analysis, this study demonstrates that the managerial functions receiving the greatest operational attention are not necessarily those that contribute most strongly to the underlying managerial structure.

This finding extends previous studies that primarily described laboratory conditions or evaluated individual managerial practices without examining their structural relationships. Third, the study offers empirical evidence from senior high schools located in Indonesia's border region, illustrating how geographical and institutional constraints influence laboratory management practices. Consequently, the findings provide an evidence-based foundation for developing more integrated laboratory management policies and managerial capacity-building programs, particularly for schools operating in geographically disadvantaged areas.

CONCLUSION

This study employed Exploratory Factor Analysis (EFA) to uncover the underlying managerial dimensions of chemistry laboratory management in senior high schools located in West Kalimantan's border region. The findings reveal that planning, organizing, actuating, monitoring, and evaluation collectively constitute a single integrated managerial construct, confirming that effective laboratory management should be viewed as a coherent management system rather than as a collection of independent operational activities. Although descriptive findings indicate that laboratory management practices are predominantly characterized by actuating and monitoring activities, the EFA demonstrates that planning and organizing are the most influential managerial dimensions. This discrepancy reveals a critical gap between managerial practice and managerial priorities, indicating that strategic managerial functions remain underemphasized in everyday laboratory management.

The findings indicate that strengthening chemistry laboratory management requires more than improving laboratory facilities. Sustainable laboratory governance depends on reinforcing strategic planning, organizational coordination, supervision, and continuous evaluation supported by integrated digital laboratory management systems. These implications are particularly relevant for schools in geographically disadvantaged border regions, where strengthening managerial systems is essential for improving educational quality and reducing regional disparities.

This study was limited to senior high schools in West Kalimantan Province and employed EFA to identify the underlying managerial structure. Future studies are recommended to validate the proposed model using Confirmatory Factor Analysis (CFA) or Structural Equation Modelling (SEM) with broader geographical coverage and to evaluate the effectiveness of digital laboratory management systems in improving laboratory governance and student learning outcomes. Ultimately, this study demonstrates that sustainable chemistry laboratory management depends not merely on the availability of laboratory facilities, but on strengthening the integrated managerial system that connects planning, organizing, actuating, monitoring, and evaluation within a continuous cycle of improvement.

REFERENCES

A'yuniah, Q., Sukestyarno, Y. L., & Mulyono, S. E. (2022). Management of Utilization of Chemistry Laboratory Based on Instructional Group Classroom to Support the Learning Process. *Educational Management*, *11*(2), 133–144.

Alfian, Wiyono, B. B., Imron, A., Arifin, I., & Humaisi, M. S. (2019). Development of the Supervision Model Based on Clinical Approach to Increase Managerial Competence of School Principal.

Universal Journal of Educational Research, *7*(11), 2472–2481. https://doi.org/10.13189/ujer.2019.071126

Bueraheng, A., & Hamidi, N. (2019). Implementation of Education Management in Thailand (Case Study Mulnithi Azizstan School). *International Journal of Research*, *6*(6), 427–431.

Ezeano, A., & Ezeude, F. (2018). Application of Laboratory Management Skills by Chemistry Teachers in Enugu State. *Journal of Education and Practice*, *4*(18), 159–165.

Gurbuz, S. (2017). Survey as quantitative research method. *Research Methods and Techniques in Public Relations and Advertising*, 141–161.

Hai, N. C. (2021). Factors Affecting Student Satisfaction with Higher Education Service Quality in Vietnam. *European Journal of Educational Research*, *11*(1), 339–351. https://doi.org/10.12973/eu-jer.11.1.339

Indrihapsari, Y., & Wibowo, U. B. (2020). Learning Management for Vocational High Schools in the Industry 4.0. *2nd Yogyakarta International Conference on Educational Management/Administration and Pedagogy (YICEMAP 2019)*, *511*, 254–256. https://doi.org/10.2991/assehr.k.201221.055

Islam, M. R. (2018). Sample Size and its Role in Central Limit Theorem (CLT). *International Journal of Physics and Mathematics*, *4*(1), 1–7. https://doi.org/10.31295/pm.v1n1.42

Juniar, A., Silalahi, A., & Suyanti, R. D. (2020). The effect of guided inquiry model on improving students' learning outcomes and science process skills in qualitative analytical chemistry practicum. *Universal Journal of Educational Research*, *8*(11), 5457–5462. https://doi.org/10.13189/ujer.2020.081149

Mahanani, C., Wening, S., Susanto, M. R., & Sudirman, A. (2020). The Effect of Laboratory Knowledge, Teaching Practice Experience, and Work Motivation on Laboratory Management. In *The 2nd International Conference on Vocational Education of Mechanical and Automotive Technology 2019* (Vol. 1446, Issue 012042, pp. 1–7). https://doi.org/10.1088/1742-6596/1446/1/012042

Maisyaroh, M., Wiyono, B. B., Chusniyah, T., Adha, M. A., Valdez, A. V., & Lesmana, I. (2024). Existence of independent learning curriculum and portrait of ideal curriculum management in laboratory schools. *Journal of Education and Learning (EduLearn)*, *18*(4), 1187–1196. https://doi.org/10.11591/edulearn.v18i4.21729

Najah, Setiadi, D., & Master, F. (2022). Development of Human Resources Management in Increasing the Quality of Education Reviewing from Planning Aspects. *International Journal of Social Science Research and Review*, *5*(7), 159–165. https://doi.org/10.47814/ijssrr.v5i7.334 Abstract

Nashrullah, M., & Rindaningsih, I. (2023). Improving Educator Recruitment Management in Primary and Secondary Education Institutions. *Middle European Scientific Bulletin*, *32*, 71–80.

Nuswowati, M., Sumarni, W., & Taufiq, M. (2020). Analysis of Quantity and Quality the Implementation of High School Chemical Practicum in Semarang City. *6th International Conference on Mathematics, Science, and Education (ICMSE 2019)*, *1567*(042011), 1–5. https://doi.org/10.1088/1742-6596/1567/4/042011

Palah, S., Wasliman, I., Sauri, S., & Gaffar, M. A. (2022). Principal Strategic Management in Improving the Quality of Education. *International Journal of Educational Research & Social Sciences*, *3*(5), 2041–2051. https://doi.org/10.51601/ijersc.v3i5.497

Redhana, I. W., & Suardana, I. N. (2021). Green Chemistry Practicums at Chemical Equilibrium Shift to Enhance Students' Learning Outcomes. *International Journal of Instruction*, *14*(1), 691–708. https://doi.org/10.29333/IJI.2021.14142A

Riswanto. (2019). School Laboratory Management Information System. In *Journal of Physics: Conference Series* (Vol. 1361, Issue 1). https://doi.org/10.1088/1742-

 | p-ISSN 1979-7281 | e-ISSN 2443-1281

6596/1361/1/012068

Safavi, S., Tabibi, S., Riahi, L., & Farahani, M. M. M. (2021). Factors Affecting Lean Management: Designing a Model for Teaching Hospitals. *Journal of Complementary Medicine Research*, *12*(4), 74. https://doi.org/10.5455/jcmr.2021.12.04.11

Sartika, R. P., & Hadi, L. (2023). The implementation of online learning using the PQ4R assisted the 5E learning cycle model in understanding the concept of buffer solution. *The 2nd International Conference on Chemistry and Science Education 2021*, *120001*, 1–5. https://doi.org/https://doi.org/10.1063/5.0125240

Sawuwu, B. Y. (2017). Problems in the Indonesian Chemistry Laboratory Classes. *The 2nd International Seminar on Chemical Education*, *2001*, 12–13.

Seery, M. K. (2020). Establishing the laboratory as the place to learn how to do chemistry. *Journal of Chemical Education*, *97*(6), 1511–1514. https://doi.org/10.1021/acs.jchemed.9b00764

Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics*, *9*(1), 4–11. https://doi.org/10.12691/ajams-9-1-2

Siregar, L. F., Marpaung, D. N., & Sumanik, N. B. (2020). Administration of High School Chemistry Laboratory to Facilitate the Implementation of Practicum. *Proceedings of the 3rd International Conference on Social Sciences (ICSS 2020)*, *473*, 459–462. https://doi.org/10.2991/assehr.k.201014.100

Sormin, E. (2023). Use of Practicum Learning Methods in Improving Learning Outcomes. *International Journal of Social Science and Human Research*, *06*(07), 4183–4190. https://doi.org/10.47191/ijsshr/v6-i7-40

Suseno, N., Partono, Riswanto, Harjati, P., & Dedy, H. A. (2019). School Laboratory Management Information System. *1st International Conference of SNIKOM 2018*, *1361*(012068), 1–8. https://doi.org/10.1088/1742-6596/1361/1/012068

Triwiyanto, T., Kusumaningrum, D. E., Sobri, A. Y., & Maitreepun, W. (2024). Accountability Management System of Superior Elementary School for igital transformation. *Journal of Education and Learning (EduLearn)*, *18*(4), 1514–1526. https://doi.org/10.11591/edulearn.v18i4.21692

Wiyono, B. B., Rasyad, A., & Maisyaroh. (2021). The Effect of Collaborative Supervision Approaches and Collegial Supervision Techniques on Teacher Intensity Using Performance-based Learning. *SAGE Open*, *11*(2), 1–9. https://doi.org/10.1177/21582440211013779

Xu, Y. (2022). Assisting Laboratory Management Based on Network Big Data Mining Technology. *Journal of Function Spaces*, *2022*, 1–7. https://doi.org/10.1155/2022/2087287

Yang, S., Jia, H., & Bai, Y. (2021). Research on the Application of Computer Cloud Computing Technology in Laboratory Management Based on Docker Platform. *International Conference on Computer Technology and Power Electronics (ICCTPE 2021)*, *2023*(012016), 1–5. https://doi.org/10.1088/1742-6596/2023/1/012016