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Chemistry laboratory management in senior high schools: a competency analysis

Rody Putra Sartika, Maisyaroh, Agus Timan, Juharyanto
Department of Educational Administration, Faculty of Education Sciences, Universitas Negeri Malang, Malang, Indonesia

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ABSTRACT

Laboratory management is crucial in improving the quality of chemistry learning in senior high schools. However, there has been limited research on the managerial competence of chemistry teachers in managing laboratories. This study aims to analyze the managerial competence of high school chemistry teachers in laboratory management. The study used a survey method with non-probability sampling and involved 99 high school chemistry teachers from 476 high schools in West Kalimantan Province. The results showed that the average managerial competence of these teachers was only 16.26%. Further analysis revealed that teachers' competencies in planning (19.19%), organizing (2.53%), implementing (28.08%), controlling (22.89%), and evaluating (7.32%) were significantly lacking. The findings highlight the need to improve the managerial competencies of chemistry teachers in this region. This study provides a foundation for developing a chemistry laboratory management model to enhance these competencies, contributing to better implementation of experiments and improved quality of chemistry learning in high schools.

Corresponding Author:

Rody Putra Sartika
Department of Educational Administration, Faculty of Education Sciences, Universitas Negeri Malang
Semarang street, No. 5, Sumbersari, 65145, Malang, Indonesia
Email: rody.putra.2201329@students.um.ac.id

1. INTRODUCTION

The existence of a laboratory helps students improve the achievement of chemistry learning in the Merdeka curriculum. Laboratories provide a space to conduct scientific experiments that support various aspects of chemistry education [1], [2]. This environment is ideal for meaningful learning, especially at the secondary and undergraduate levels [3]. Laboratories help develop experimental skills, encourage innovation, and improve students' understanding of concepts, interests, motivation, teamwork, safety, and alertness [4]–[6]. Laboratories are also essential for chemists to demonstrate facts and data directly and test hypotheses [7].

Learning theory and conducting experiments in the laboratory are interrelated and inseparable. Experimentation is a means to test fundamental principles in science to gain knowledge and improve the discovery process [8]. It involves investigating phenomena and conducting experiments under controlled conditions [9]. If chemistry learning relies solely on theory without experiments, students' understanding of the material will be less than optimal [10]–[12]. Research shows that chemistry experiments increase students' motivation, learning outcomes, concept understanding, and scientific skills [13]–[15].

A previous study found that 45% of schools in some countries have no laboratories due to difficulties in providing such facilities and infrastructures [16]. Even when facilities are available, better laboratory management is needed. Similar issues are present in Indonesia due to time constraints, high

teacher workload, lack of expensive chemical tools and materials, insufficient laboratory assistants, the use of laboratories for other purposes, and inadequate infrastructure to support laboratory activities [17]. In West Kalimantan Province, almost 92.92% of surveyed high school chemistry teachers reported difficulties conducting experiments due to limited tools and chemicals in the laboratory.

The challenges in conducting chemistry experiments stem from inadequate and poorly organized school laboratory management systems. These issues arise from the need for dedicated and professional human resources, communication barriers between teachers and laboratory managers, and difficulties procuring, using, and maintaining chemical equipment and materials [11]. Generally, problems in chemistry laboratory management include planning, implementation, and evaluation [18]. Ineffective laboratory management has affected the smooth implementation of chemistry experiments in high schools in West Kalimantan Province.

West Kalimantan Province, comprising two cities and 12 administrative districts, has 285 public and 191 private high schools. The province borders Malaysia and is considered the country's frontier in various aspects of life, including education. However, most border areas in Indonesia, including West Kalimantan, still lack adequate social, economic, and educational facilities and infrastructure. Therefore, effective laboratory management is essential to achieving equitable quality of chemistry learning in this province. Standardized laboratory management reflects school quality [19].

To achieve this, chemistry teachers must possess managerial competence to manage laboratories effectively. Teachers need the competence, ability, and specific skills to complete their tasks using the right strategies [20]. Curriculum development emphasizes the need for teachers to be skilled in laboratory management and conducting experiments [21]. Teachers' education and professional development level determine their competence [22].

Regulation of the Minister of National Education No. 26 of 2008 has regulated the managerial competence of teachers in managing laboratories. However, its implementation in West Kalimantan Province has not met expectations. This study aims to analyze the managerial competence of teachers in West Kalimantan high schools in managing chemistry laboratories. Effective laboratory management requires teachers to plan, organize, actuate, control, and evaluate processes. Good knowledge of laboratory management will benefit teachers in managing laboratories effectively and efficiently [16].

This research provides insights into the problems teachers face when applying managerial competence in managing chemistry laboratories in high schools in West Kalimantan Province. Identifying these issues can lead to solutions that improve the smooth running of laboratory activities to achieve chemistry learning objectives in the Merdeka curriculum. High learning quality signifies a well-executed, beneficial, and effective learning process for student development [23]. Teachers who perform their roles professionally can achieve optimal learning quality [24], the primary target of every educational organization [25].

2. METHOD

This research employs a quantitative approach through a survey. Surveys help gather data about the research subject [26]. The study population consisted of chemistry teachers from every public and private high school in West Kalimantan, totaling 476 schools. The sampling method used was non-probability sampling, with purposive sampling as the technique. The research sample included 99 chemistry teachers who manage laboratories in high schools in West Kalimantan Province, representing more than 20% of the population with a precision level of ±10% [27].

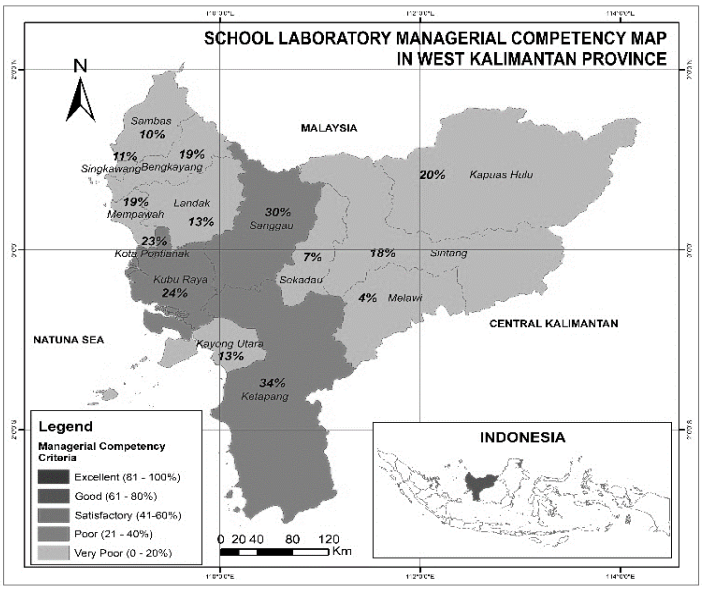
Indirect data collection method, in which researchers circulated questionnaires to gather information about the managerial competence of teachers in managing chemistry laboratories in West Kalimantan high schools. The focus of the research is on managerial competence, which includes several indicators such as activity planning and laboratory development, organizing the duties of laboratory technicians and laboratory assistants, implementing laboratory activities, monitoring laboratory facilities and infrastructure, and performance evaluation of technicians and laboratory assistants and activities in high schools.

The data collection procedure involved setting research objectives, compiling a clear list of questions to obtain respondents' opinions, testing the questionnaire with representative respondents, determining the population and sample, disseminating the questionnaire via Google Forms, verifying and validating the data, and analyzing the data using descriptive statistics. This analysis included calculating percentages, averages, and variability measurements [26]. Data analysis techniques by scoring "yes" answers with 1 and "no" with 0. Categorizing the results into criteria ranging from very good (81-100), good (61-80), satisfactory (41-60), poor (21-40), and very poor (0-20), then visualized using the ArcGIS application.

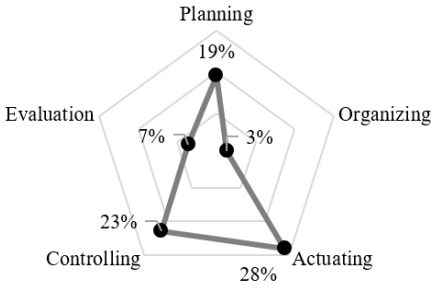
3. RESULTS AND DISCUSSION

According to the regulation of the Minister of National Education No. 26 of 2008, the managerial competence of chemistry teachers in managing laboratories includes planning, organizing, actuating,

controlling, and evaluating. However, the average managerial competence of chemistry teachers in managing laboratories across high schools in West Kalimantan Province is only 16.26%. Figure 1(a) indicates that the management of chemistry laboratories by high school teachers in West Kalimantan, like Kubu Raya, Sanggau, Ketapang, and Pontianak City, is generally poor. At the same time, others fall under the "very poor" category. Figure 1(b) shows that the management of chemistry laboratories in West Kalimantan Province predominantly focuses on implementing activities and monitoring laboratory facilities and infrastructure.



(a)



(b)

Figure 1. Implementation of managerial competencies, (a) West Kalimantan Province and (b) percentage of each indicator

3.1. Activity planning and laboratory development

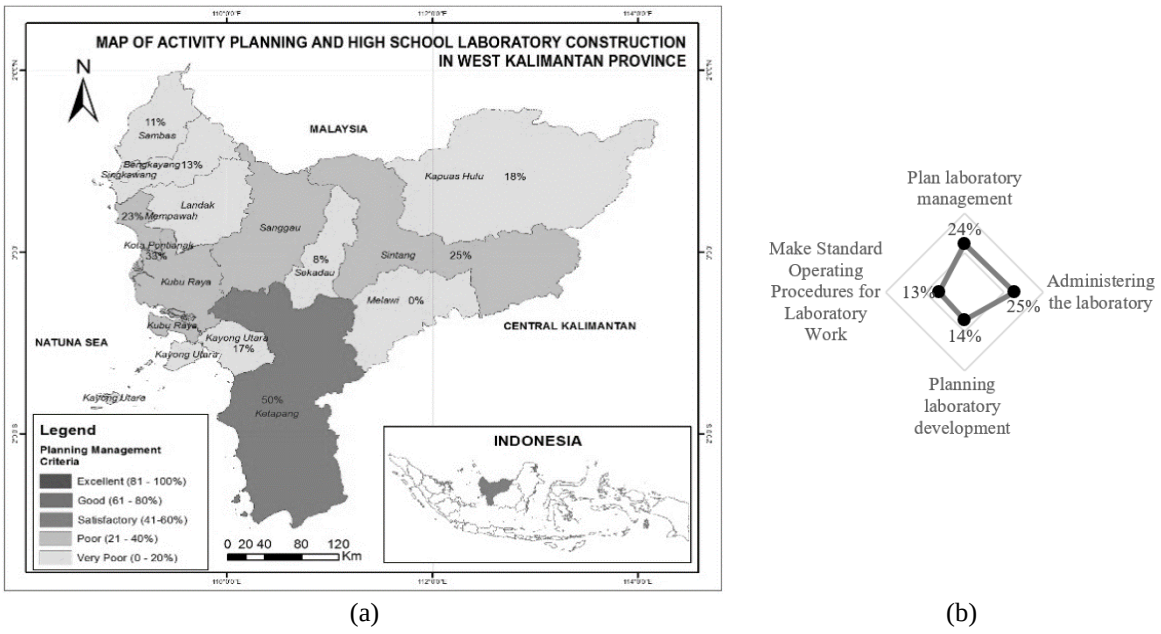
The planning aspect includes planning laboratory management and development, laboratory administration, and making standard operating procedures (S.O.P.s) for laboratory work. Figure 2(a) shows that district Ketapang has reached satisfactory criteria. However, most remain poor (districts Mempawah, Kubu Raya, Sanggau, Sintang, and Pontianak City) and very poor (districts Sambas, Bengkayang, Landak, Sekadau, Melawi, Kapuas Hulu, Kayong Utara, and Singkawang City). Figure 2(b) shows that laboratory management and administration planning dominate the planning activities. Laboratory administration is the main focus for chemistry teachers, including the management of equipment data, material data, and activity data in the laboratory. However, teachers still need to implement a comprehensive administration related to data on space, goods, and personnel in the laboratory. Good laboratory administration is crucial to prevent loss, misuse, and overlapping requests, facilitating inventory checks and the smooth implementation of practical activities [28].

In addition, most chemistry teachers still need to do planning related to laboratory development. This situation is further complicated because S.O.P.s for laboratory work are unavailable to ensure smooth operational activities. Efficient management requires careful planning to prevent unwanted errors and failures. Laboratory managers must plan activities at the end of the year to prepare for next year's learning and improve its quality [29].

3.2. Organizing the duties of laboratory technicians and laboratory assistants

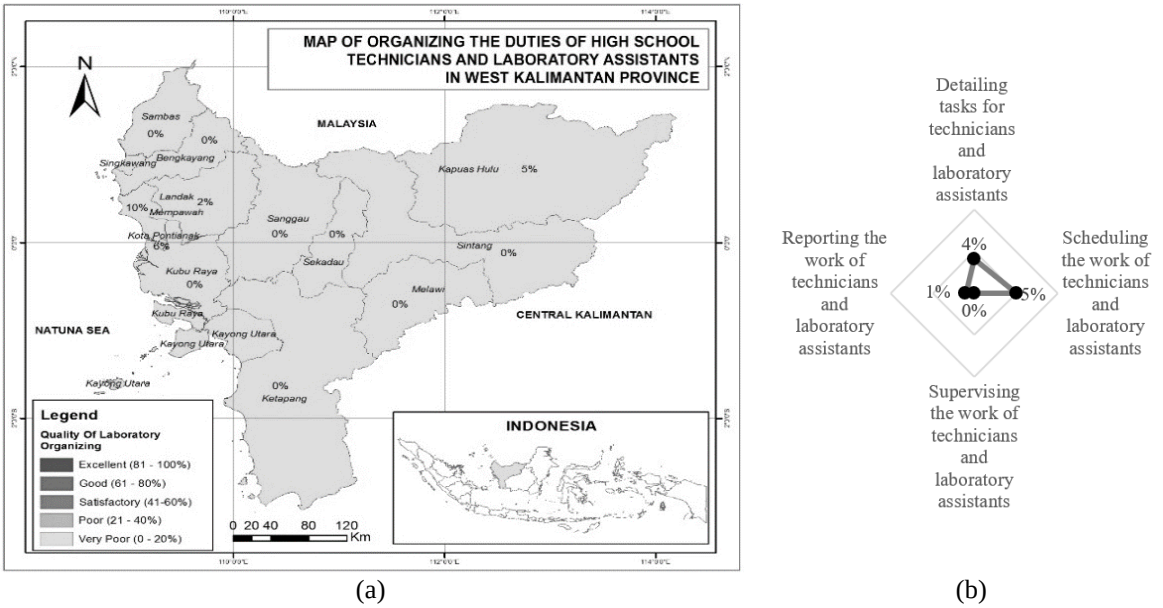
Organizing tasks involves detailing tasks, preparing work schedules, supervising the implementation of tasks, and reporting the work results of technicians and laboratory assistants. Figure 3(a) shows that the implementation of this aspect is still very poor. Even though the organizational aspect greatly influences school continuity [30]. Figure 3(b) highlights that organizing duties is not well established. According to survey results, most schools lack laboratory assistants (only 14.14%) and technicians (only 1.01%), causing chemistry teachers to take on multiple roles. The lack of supervision of technicians and laboratory assistants

results in low competence and commitment. Adequate supervision and collaboration are needed to ensure proper task management and policy adherence [30]–[32].



(a) (b)

Figure 2. Implementation of activity planning and laboratory development, (a) West Kalimantan Province and (b) percentage of each sub-indicator



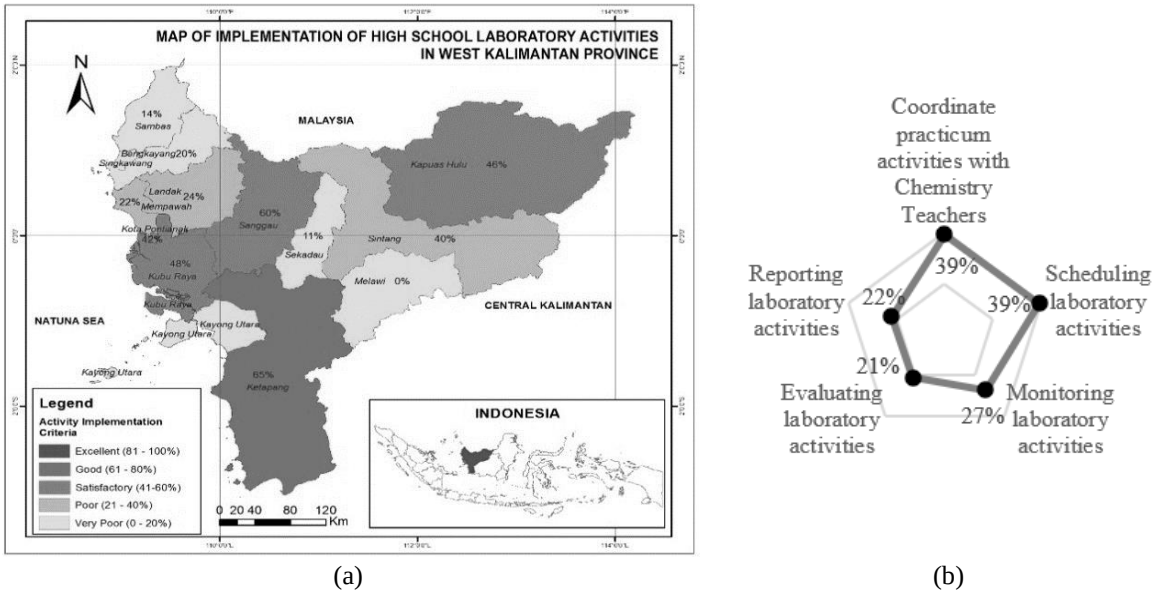
(a) (b)

Figure 3. Implementation of task organization in the laboratory, (a) West Kalimantan Province and (b) a percentage of each sub-indicator

3.3. Implementation of laboratory activities

Implementation includes coordinating experiments with chemistry teachers, preparing schedules, monitoring, evaluating, and reporting experiment implementation. Figure 4(a) indicates varying levels of implementation across districts. District Ketapang shows good criteria; others are satisfactory (districts Kubu Raya, Sanggau, Kapuas Hulu, and Pontianak City), poor (districts Mempawah, Landak, Sintang), and very poor (districts Sambas, Bengkayang, Sekadau, Melawi, Kayong Utara, and Singkawang City).

Coordination and schedule preparation are the most dominant activities (Figure 4(b)), aiming to realize planning and organizing results [30]. Monitoring laboratory activities that chemistry teachers have carried out include preparing tools and chemicals, carrying out experiments, packing tools and chemicals, and ensuring laboratory cleanliness. Furthermore, the evaluation of laboratory activities focuses on identifying obstacles that arise during the implementation of experiments.



(a) (b)

Figure 4. Implementation of laboratory activities, (a) West Kalimantan Province and (b) percentage of each sub-indicator

3.4. Monitoring laboratory facilities and infrastructure

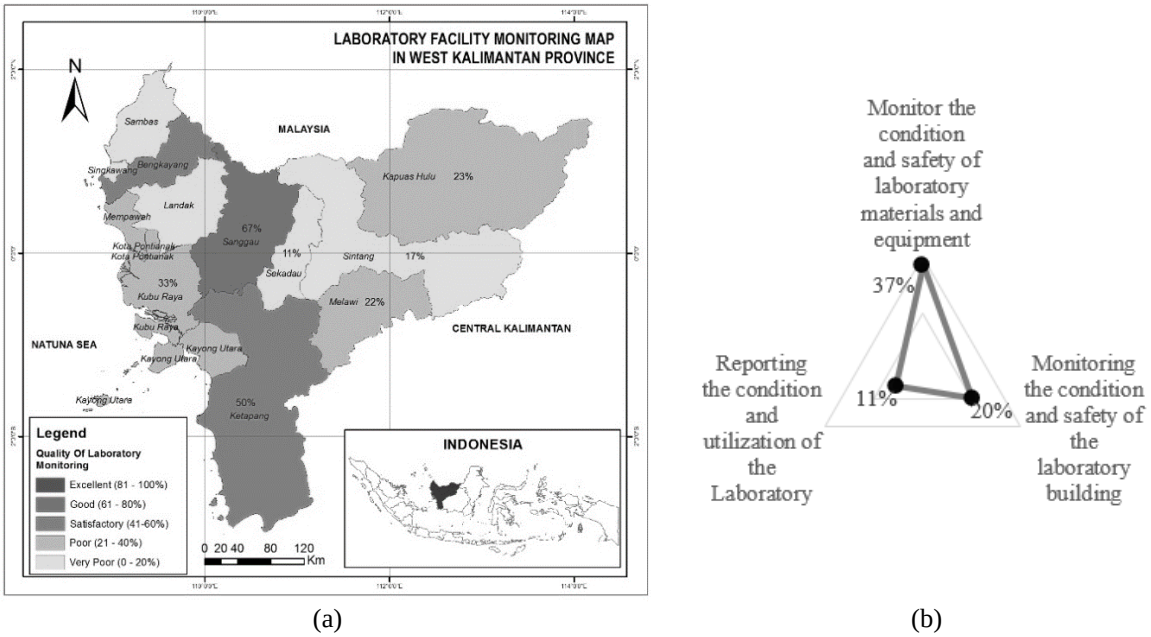
Monitoring involves monitoring the security conditions of buildings, materials, and laboratory equipment and reporting the condition and utilization of laboratories. Figure 5(a) shows varying implementation levels. District Sanggau is good; others are satisfactory (districts Bengkayang and Ketapang), poor (districts Mempawah, Kubu Raya, Kayong Utara, Melawi, Kapuas Hulu, and Pontianak City), and very poor (districts Sambas, Landak, Sekadau, Sintang, and Singkawang City).

Figure 5(b) highlights that monitoring security is the most frequent activity, especially regarding the feasibility of equipment and storing chemicals in the laboratory, but still overlooks building and facility conditions. Effective monitoring ensures proper functioning and adherence to standards. Managers must monitor the organization's performance to ensure everything goes as it should [33], [34].

3.5. Performance evaluation of technicians and laboratory assistants and laboratory activities

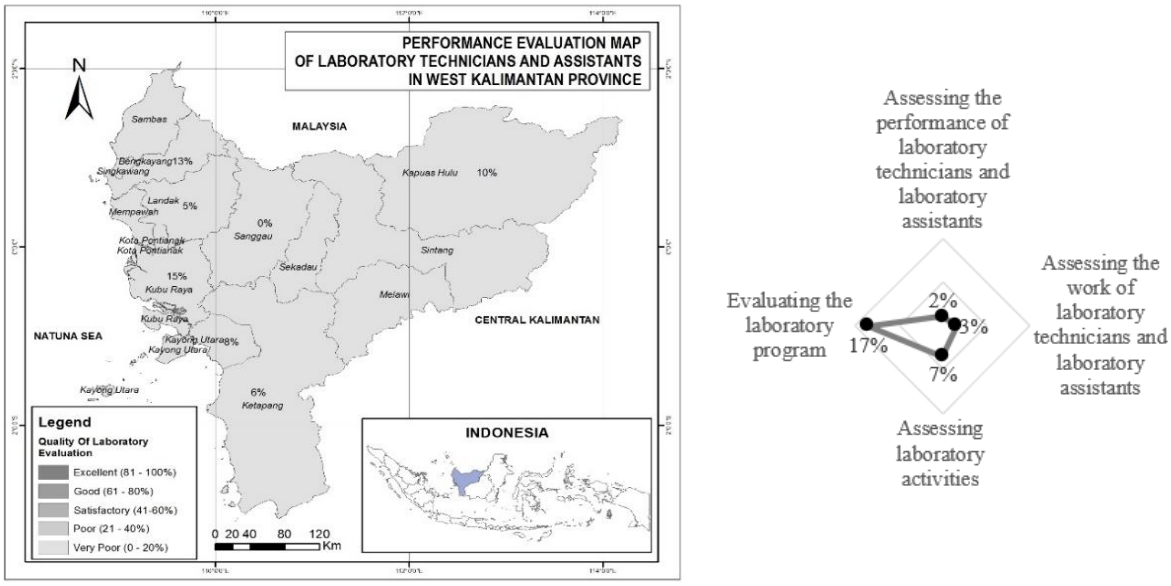
Evaluation includes assessment of the performance and work of technicians and laboratory assistants, assessment of laboratory activities, and evaluation of laboratory programs. Figure 6(a) shows very poor performance across most districts. Figure 6(b) shows that evaluating the performance of technicians, laboratory assistants, and laboratory activities is still not carried out optimally, which causes obstacles to implementing chemistry practicum in high school always to recur every year. This finding aligns with the survey results, where 69.70% of chemistry teachers confirmed this. Evaluating laboratory facilities and performance is a material for future laboratory management [35].

This research aligns with previous findings that ineffective management processes are a primary cause of problems in chemistry laboratory management [18], [19], [36]. However, this study also uncovers significant variability in the managerial competence of chemistry teachers across different cities and districts in West Kalimantan Province. This inconsistency indicates that comprehensive chemistry laboratory management, covering planning to evaluation, is lacking. The leading cause of this deficiency is the absence of a standardized chemistry laboratory management model applicable across high schools in West Kalimantan Province.



(a) (b)

Figure 5. Implementation of monitoring laboratory facilities and infrastructure, (a) West Kalimantan Province and (b) a percentage of each sub-indicator



(a) (b)

Figure 6. Implementation of performance evaluation and laboratory activities, (a) West Kalimantan Province and (b) percentage of each sub-indicator

This study offers a basis for developing a chemistry laboratory management model in high school. The survey shows 92.93% of West Kalimantan Province's chemistry teachers support that. One of the most suitable management models for chemistry laboratories is the formal model, which relies on a hierarchical organizational structure and predefined goals [37]. A hierarchical structure can effectively support chemistry learning by improving the utilization of laboratory equipment, encouraging independent student learning, and promoting standardization in laboratory construction [38].

Moreover, developing a chemical laboratory management system leveraging the latest technology can improve efficiency. Technological advancements have increased accessibility and can drive better

standardization [39], [40]. Traditional laboratory management models are often inefficient due to their labor-intensive nature, underutilization of equipment, lack of constant monitoring, and misalignment with modern trends [38], [41].

A promising solution is to package the chemistry laboratory management system in an application. The growth of computer technology facilitates the development of applications for various fields, including laboratory management [42]. Digital tools are becoming a prominent trend in educational development [43]. Studies have shown that an application-based laboratory management system can significantly streamline processes and improve management [11], [44]. Implementing a chemistry laboratory management system with application-based S.O.P.s can positively impact the execution of chemistry practicums in high schools. This advancement will ultimately improve the quality of chemistry education in West Kalimantan and Indonesia.

4. CONCLUSION

The study reveals that the managerial competence of chemistry teachers in managing high school laboratories in West Kalimantan Province is significantly lacking, with an average competency level of only 16.26%. Most teachers face challenges due to inadequate infrastructure, lack of laboratory assistants and technicians, and insufficient planning and implementation strategies. The laboratory management process must be adequately addressed, including planning, organizing, actuating, controlling, and evaluating. Therefore, developing a laboratory management model is necessary for the chemistry experiment to run smoothly. Developing an application-based laboratory management system provides convenience for better laboratory management, thus improving the quality of learning in West Kalimantan.

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BIOGRAPHIES OF AUTHORS

Rody Putra Sartika is a Doctoral Candidate at the Department of Educational Administration, Universitas Negeri Malang, Semarang street, No. 5, Sumbersari, 65145, Malang, Indonesia, and a lecturer at the Department of Mathematics and Natural Sciences, Universitas Tanjungpura, Indonesia. His research focuses on chemistry education, learning device development, the 5E learning cycle model, and laboratory management. He can be contacted at email: rody.putra.2201329@students.um.ac.id.

Maisyaroh is a Professor and lecturer at the Department of Educational Administration, Universitas Negeri Malang, Indonesia. Her research interests include training management, office management, education organization, supervision, monitoring and evaluation, and school and community relations management. She can be contacted at email: maisyaroh.fip@um.ac.id.

Agus Timan is a lecturer at the Department of Educational Administration, Universitas Negeri Malang, Indonesia. His research interests include education planning, organization, supervision, monitoring and evaluation, integrated quality management, and financial management. He can be contacted at email: agus.timan.fip@um.ac.id.

Juharyanto is a lecturer at the Department of Educational Administration, Universitas Negeri Malang, Indonesia. His research interests include digital-based educational leadership, digital-based educational supervision, educational supervision approaches, and models, educational leadership approaches and models, and educational leadership types and styles. He can be contacted at email: juharyanto.fip@um.ac.id.