Available online at BIOMA: Jurnal Ilmiah Biologi
Websites:http://journal.upgris.ac.id/index.php/bioma/index
BIOMA: Jurnal Ilmiah Biologi, 14 (2), October 2025, 105-120
DOI: https://doi.org/10.26877/bioma.v13i1.2396

THE IMPACT OF INADEQUATE LABORATORY PERSONNEL (LABORATORY HEADS, TECHNICIANS, AND ASSISTANTS) ON BIOLOGY PRACTICUM ACTIVITIES

Ana, Dhea Aprilia Ayu Wulandari, Rifatul Mafimudah, Fatma Mutia Sari, Much Fuad Saifuddin*, Etika Dyah Puspitasari
Biology Education, Faculty of Teacher Training and Education, Universitas Ahmad Dahlan
Jl. Ringroad Selatan, Kragilan, Tamanan, Kec. Banguntapan, Bantul, Yogyakarta Special Region 55191
**Corresponding author: fuad.saifuddin@pbio.uad.ac.id*

ARTICLE INFO

Article history
Submission 2025-07-18
Revision 2025-09-24
Accepted 2025-10-08

Keywords:
Competence
Laboratory
Practicum
School staff

ABSTRACT

This study aims to examine the limitations of human resources (HR) in school laboratories and their profound impact on the implementation of biology practicum activities at the senior high school level. A descriptive qualitative method was employed in Kotagede District, Yogyakarta, using purposive sampling to select two schools with active biology laboratories. Data were collected through in-depth interviews with laboratory personnel and biology teachers to explore the availability, involvement, and roles of laboratory staff in supporting practicum activities. The findings revealed significant differences between the two schools. The school had a complete laboratory staff, including a head and an assistant, enabling well-structured practicum activities that effectively enhanced students' conceptual understanding and scientific skills.On the other hand, School B was facing a different reality. The school was lacking in laboratory personnel, which meant that all practicum responsibilities were shouldered by the biology teacher. This led to a suboptimal implementation of practicum activities and severely limited the students' learning experiences. Therefore, it is clear that efforts to increase the availability and competence of laboratory personnel, in line with national standards, are not just beneficial but necessary. The presence of professional laboratory staff is not just beneficial, but crucial in creating practical, meaningful, and skill-oriented biology learning through practicum-based approaches.

INTRODUCTION

At its core, biology learning is a process of discovery that demands critical thinking, not merely the memorization of facts (Papaneophytou & Nicolaou, 2025). This process trains students to master science skills such as observing, classifying, and formulating (Sudarisman, 2015). Therefore, biology learning serves as a means to develop critical and creative thinking skills (Nasution et al., 2023), ultimately aiming to enhance students' knowledge, attitudes, and responsibility toward the environment.

Biology is not only taught theoretically in the classroom, but it also requires practicum activities to deepen students' conceptual understanding and foster scientific thinking. The term 'practicum' refers to a practical application of theoretical knowledge, often in a laboratory setting, that allows students to gain hands-on experience and apply their learning in real-world situations. As a discipline that systematically studies natural phenomena, biology relies heavily on observation and experimentation. In this context, practicum plays a crucial role in providing students with direct, hands-on experiences through the five senses, fostering meaningful science learning.

Through practicum activities, students develop science process skills, including planning the use of tools and materials, observing phenomena, analyzing data, drawing conclusions, and cultivating scientific attitudes (Agustina et al., 2021; Surani, 2024). These activities not only strengthen conceptual understanding and memory retention but also enhance motivation and interest in learning, ultimately improving learning outcomes. Therefore, when conducted effectively, a practicum serves as a vital component in achieving the objectives of biology education. Through practical activities, it is hoped that learning objectives can be effectively achieved (Ambarwati & Prodjosantoso, 2018).

The implementation of the biology practicum requires an adequate laboratory, both in terms of facilities and infrastructure, as well as optimal management. The laboratory functions as a means to train skills and improve students' understanding of concepts through experiments (Emda, 2017). In addition, the laboratory also organizes various functions, including services, research and development, procurement of learning materials, and other activities that support the efficiency and effectiveness of the teaching and learning process (Oladejo et al., 2023). Laboratory management and preservation are critical because they play a role in increasing the effectiveness and optimization of learning. This management encompasses spatial arrangement, equipment maintenance,

and the implementation of work safety procedures. For management to run effectively, it requires the support of competent human resources in their respective areas of expertise.

Several studies have demonstrated that many high schools struggle to manage their biology laboratories effectively. One major challenge is the lack of adequate facilities and resources. This includes the lack of separate laboratory space, shortages of laboratory equipment and materials, and inadequate supporting facilities (Rahmah et al., 2021), as well as the absence of Standard Operating Procedures (Pratiwi et al., 2024). Furthermore, human resources are also a limiting factor, such as a lack of competent laboratory staff and excessive teacher workloads (Aulia et al., 2024). The management of a laboratory cannot only be judged by the completeness of its facilities and infrastructure, but also by the active role of its human resources. Professional human resources, complete facilities, and effective management can significantly improve the overall quality of the laboratory (Safitri et al., 2024). The presence of professional laboratory staff is not just a necessity, but a key factor in enhancing the quality of the laboratory.

In the context of school laboratories, the presence of competent human resources, such as laboratory heads, laboratory assistants, and technicians, is needed to ensure practicum activities run smoothly, safely, and support the practice-based learning process. The support of professional laboratory personnel is not just a formality, but a crucial factor in making students' learning experience more meaningful. Their expertise and guidance help teachers design and implement applicable Biology learning, enhancing the quality of education. Therefore, this study contributes to analyzing the role of each biology laboratory resource in schools, so that it can be used as evaluation material for both schools and government regulations.

MATERIALS AND METHODS

This descriptive qualitative research was conducted in Kotagede Sub-district, Yogyakarta. The selected population in this study was schools in Kotagede Sub-district, Yogyakarta. Two schools were selected using purposive sampling, based on the criteria of having an active biology laboratory, available laboratory personnel, and biology teachers involved in its management. This criterion was chosen because it provides researchers with initial information that the biology laboratory at the school has been

managed effectively, allowing research to be focused on its objectives. Data were collected through open-ended interviews with human resources in the biology laboratory and biology teachers. This instrument has been validated by experts with a background in laboratory management of more than three years, ensuring the quality and reliability of the data. The interview sheet encompasses aspects of the existence and role of human resources, in accordance with Ministry of National Education Regulation No. 26 of 2008 concerning school laboratory personnel standards, specifically the presence of human resources in school laboratories and their respective roles. Indicators in the competency aspect of each human resource serve as a basic reference for creating instruments, ensuring that the compiled questions provide information on the competencies possessed by each human resource in the school's biology laboratory. The data obtained were analyzed descriptively and narratively to give an overview of laboratory conditions and human resources in each school based on the results of interviews with laboratory and biology teachers in high school.

RESULTS AND DISCUSSION

Our research reveals that the state of human resources is a significant hurdle in the management of high school biology labs. Schools are grappling with a shortage of personnel and the need for more precise execution of their duties. Tables 1 and 2 provide a comprehensive overview of these challenges, detailing the availability of personnel and their roles at each institution.

Table 1. The existence of human resources in the biology laboratory of SMA A

No	Aspect	Indicator	Standard	Findings
1	Existence of Human Resources	Number and type of laboratory personnel (laboratory head, laboratory assistant, technician)	Head of laboratory, laboratory assistant and laboratory technician	School A has a laboratory head and a laboratory assistant. Special technicians for biology laboratories are not available, assisted by computer technicians if related to digital tools.
2	Role Human Resources	Role head laboratory, laboratory assistant, technician in supporting practicum	The head of the laboratory manages, the laboratory assistant prepares the tools / materials, the technician maintains the tools	The laboratory head is in charge of receiving report and submit to the school. The laboratory assistant prepares the tools/materials and report the damage. Technicians only assist with computer equipment.

Table 2. The existence of human resources in the biology laboratory of SMA B

No	Aspect	Indicator	Standard	Findings
1	Existence of source human power	Number and type personnel laboratory (laboratory head, laboratory assistant, technician)	Head laborotory, laboran and technician laboratory	School B not has head laboratory, laboratory assistant and technician
2	Role source human resources	Roles laboratory head, laboratory assistant, technicians in supporting practicum	The head of the laboratory manages, the laboratory assistant prepares the tools/materials, the technician maintains the tools.	All roles are duplicated by subject teachers. The teacher doubles all tasks practicum, preparation, implementation, checking equipment

The research findings reveal significant disparities and deficiencies in the human resource structure of the biology laboratories at the two sampled schools, with neither institution meeting the established standards fully. It is crucial that these standards are adhered to and that management is improved to ensure the best possible learning environment for students. The specific conditions regarding the existence and roles of laboratory personnel highlight distinct operational challenges at each school.

At SMA A, the laboratory has a partially complete human resource structure. The school has appointed a laboratory head and a laboratory assistant, thus meeting part of the standard. However, a notable deficiency is the absence of a dedicated biology laboratory technician. This role is partially filled on an ad-hoc basis by a computer technician, but only for issues related to digital equipment. The delineation of roles also deviates from the standard; the laboratory head's function is primarily administrative (reporting), while the laboratory assistant handles both the preparation of tools and the reporting of damages, a task that would typically fall to a technician.

In stark contrast, SMA B is in a critical situation with a complete absence of dedicated laboratory personnel. The findings indicate that the school lacks a laboratory head, a laboratory assistant, or a technician. As a result, the biology subject teacher is burdened with the full responsibility for all laboratory management tasks, highlighting the urgent need for immediate improvements in resource management.

Human resources in the biology laboratory of School A

The availability of laboratory human resources is a crucial aspect in supporting the quality of biology learning in high school. Thus, human resources in the laboratory must work professionally in accordance with the assigned tasks (Budiarti et al., 2021). Based

on the data in Table 1 at SMA A, this school has a laboratory head and a laboratory assistant, but does not have a laboratory technician. The Government, through Regulation No. 26 of 2008 by the Minister of National Education, has attempted to regulate the standards of school/madrasah laboratory personnel, stating that each school laboratory should have a human resource structure that includes a laboratory head, a laboratory assistant, and a technician. This initiative aims to enhance laboratory governance, thereby supporting the achievement of learning objectives (Safitri et al., 2024). The head of the laboratory is responsible for managing facilities and planning activities. Laboratory assistants support the implementation of the practicum, while technicians ensure that the tools are ready for use. The main task of the laboratory head is to carry out academic and managerial tasks in educational units, which include preparing laboratory work programs, implementing programs (Metcalfe et al., 2007; White et al., 2021), fostering technicians and laboratory assistants, assessing the performance of technicians and laboratory assistants, and evaluating the results of the implementation of laboratory programs (Baily et al., 2013; Duphily, 2014).

The role of the head of the laboratory in SMA A has been running smoothly, serving as a liaison between laboratory assistants and school management, particularly in the procurement of equipment and the repair of laboratory facilities. The laboratory assistant oversees the classification of practicum materials and equipment according to their type. They arrange these materials in a structured manner in the cupboard according to their classification. The laboratory assistants also prepare practicum materials according to the practicum schedule and are assisted by subject teachers who will conduct the practicum (Nurul et al., 2021). SMA A has a laboratory assistant who actively coordinates with teachers in preparing practicum activities, as well as reporting equipment damage. The human resources in the biology laboratory of SMA A are quite adequate, although the school does not have a dedicated technician for the laboratory. However, technical problems related to computers or LCD devices are handled by school technicians.

Technicians play a crucial role in maintaining laboratory equipment, which not only impacts safety but also the continuity of the teaching and learning process (Gusmanto, 2023). Additionally, a clear division of tasks between the laboratory head and subject teachers can reduce workload and enhance the effectiveness of laboratory operations (Setiawan & Mujahid, 2023). Technicians must be able to perform basic repairs and

equipment servicing, while laboratory assistants must prepare practicum materials, general laboratory management skills, and equipment safety and calibration (Putri et al., 2018). The absence of a dedicated laboratory technician at SMA A means that some technical tasks are often outsourced to other personnel who may lack specific competencies, which can ultimately impact the effectiveness of the laboratory work program. In the long run, this can affect the quality of laboratory services provided to students, including limitations in the implementation of complex practicums that require specialized equipment.

This condition suggests that the adequacy and competence of available human resources have a significant impact on the implementation of laboratory management and work programs. Competencies required include technical skills in preparing and maintaining equipment, managerial skills in creating schedules and maintaining inventories, and an understanding of work safety. In addition, the ability to compile laboratory documentation, supervise the use of tools and materials by students, and the skills to systematically compile reports on laboratory activities are also needed. Therefore, it is crucial for the school to prioritize the fulfillment of the structure and strengthening of laboratory human resources' competence. This will ensure that the laboratory can function optimally as a safe, organized, and high-quality scientific learning facility. Professional human resources, complete infrastructure, and exemplary management implementation can improve laboratory quality (Fiska et al., 2022; Romadhoni & Saifuddin, 2021).

The Biology Laboratory of SMA A meets the conditions outlined in PERMENDIKNAS No. 24 of 2007. This laboratory is equipped with facilities and infrastructure to support biology practicum, including furniture, teaching aids, educational media, experimental tools and materials, and safety equipment such as fire extinguishers. These facilities and infrastructure are important factors in supporting students' teaching and learning activities at school (Munarti & Sutjihati, 2018). However, the existence of laboratory facilities must be balanced with adequate human resource competencies. Human resources with knowledge and skills relevant to their fields will be better equipped to utilize the facilities optimally and support the implementation of a structured, efficient, and sustainable laboratory work program. This competency also plays a role in creating a disciplined and orderly work culture in the laboratory

environment, for example, by establishing procedures for the use of tools, a loan recording system, and adhering to work safety standards. With good management and support from professional human resources, the laboratory is not only a place for practicum, but also a learning vehicle that directly trains students' scientific and critical thinking skills.

This collaboration between teachers and laboratory personnel at SMA A creates a conducive and efficient learning environment, where teachers can focus on the learning process and students gain hands-on experience through structured and meaningful experimental activities. The impact of good laboratory management is highly influential for students at SMA A. Laboratories that are well-managed and have adequate personnel will greatly assist students in understanding biological material directly through practical experience (Safitri et al., 2024). Practicum can be done regularly according to a predetermined schedule, not only as a complement to theory, but as an integral part of the learning process. Students in SMA A are more enthusiastic about learning because they are actively involved in observing, testing, and analyzing biological phenomena directly. Practical activities, planned and supported by professional laboratory human resources, also help students develop science process skills, such as observing, measuring, drawing conclusions, and compiling reports on practical results systematically. Thus, concept understanding becomes stronger, interest in learning biology increases, and learning feels more contextual and fun.

Laboratory human resources are a key component in supporting the quality of biology learning in high schools (Iqbal et al., 2023; Zulfaa et al., 2022). As shown in Table 1, SMA A has a complete structure consisting of a laboratory head and an assistant, although it lacks a specific laboratory technician. According to PERMENDIKNAS No. 26 of 2008, ideal laboratory staffing includes a head, assistant, and technician to ensure effective management, safety, and learning support (Safitri et al., 2024). Each role has distinct responsibilities: the laboratory head manages planning and coordination, assistants handle the preparation and organization of practicum materials, and technicians maintain the functionality of equipment (Kementerian Pendidikan Nasional, 2008; Munandar & Jofrishal, 2021; Putri et al., 2023).

In SMA A, the laboratory head serves effectively as a liaison between laboratory staff and school management, particularly in the procurement and maintenance of

equipment. The laboratory assistant actively supports biology teachers in preparing practicum materials, organizing tools, and reporting equipment damage (Nurul et al., 2021). Although the school does not have a dedicated lab technician, general technical issues—such as problems with computers or LCDs—are managed by school technicians, allowing practicum activities to proceed smoothly.

The adequacy and coordination of human resources contribute significantly to the success of laboratory operations. Practicum activities at SMA A are conducted regularly, following a structured schedule, and supported by competent personnel. This not only improves student motivation but also enhances conceptual understanding and science process skills, such as observation, measurement, analysis, and reporting (Putri et al., 2018). A well-managed laboratory environment fosters a scientific work culture, ensures equipment safety, and promotes the effective use of facilities, all of which contribute to an engaging and contextual biology learning experience (Fiska et al., 2022; Romadhoni & Saifuddin, 2021).

Human resources in the school biology laboratory B

Based on the results in Table 2, the condition of human resources in the biology laboratory at SMA B remains very limited. The absence of a laboratory head, laboratory assistant, or technician indicates that laboratory management does not meet the standards that should be in place. Ideally, a laboratory has laboratory human resources that handle all activities, ranging from planning to equipment maintenance. Laboratory human resource managers play a crucial role in planning, administration, security, maintenance, and supervision of all laboratory activities to ensure effective operation (Fiska et al., 2022). However, in SMA B, all of these tasks are actually assigned to teachers who usually use the laboratory. This is undoubtedly challenging for teachers, as they must divide their time between teaching and managing practicum activities, which should be the responsibility of laboratory personnel (Putri et al., 2023).

Laboratory human resources play a crucial role in planning, administration, security, maintenance, and supervision of all activities in the laboratory, ensuring its effective operation. The head of the laboratory is responsible for planning, organizing, and evaluating all laboratory activities. Laboratory assistants play a crucial role in preparing practicum tools and materials to ensure activities run smoothly. Meanwhile, laboratory technicians are responsible for maintaining and repairing damaged equipment

(Pratiwi et al., 2024; Putri et al., 2023; Zulfaa et al., 2022). Therefore, human resources play a crucial role in implementing effective laboratory management, particularly in terms of quality assurance. The competencies and responsibilities of each individual involved directly affect the operational effectiveness, accuracy of procedures, and achievement of overall laboratory goals (Ekwen & George, 2018; Sugrah et al., 2019).

This condition underscores the importance of human resources in ensuring the smooth operation of practicum activities. A well-managed laboratory with adequate personnel will greatly assist students in understanding biological material directly through practical experience (Safitri et al., 2024). Therefore, SMA B schools need to prioritize the procurement and placement of suitable laboratory personnel to ensure that learning activities in the laboratory run optimally and align with educational objectives. If all of these tasks are assigned to teachers, the workload will be too heavy and can reduce the quality of learning. Teachers should focus more on teaching and guiding students, rather than handling laboratory technical matters.

In the absence of specialized personnel to manage the laboratory, practicum activities cannot run optimally. Based on Regulation of the Minister of National Education No. 26 of 2008 concerning School/Madrasah Laboratory Personnel Standards, laboratories are managed by the laboratory head, laboratory assistants, and technicians. The laboratory lacks an annual work plan, a regular practicum schedule, and a clear system for equipment maintenance. All practicum activities at SMA B are conducted in a makeshift manner, depending on the teacher's availability and the time allocated. Due to limited facilities and time, some practicums must be conducted in the classroom rather than the laboratory. This condition indicates that without adequate human resources, laboratory management becomes undirected and fails to support a productive learning process.

Competent laboratory human resources are crucial in supporting the creation of an effective, safe, and meaningful practicum process for students, thereby strengthening their understanding of concepts and science process skills directly (Zulfaa et al., 2022). The quality and capacity of laboratory human resources significantly determine the success of the laboratory as an integral part of biology education. Laboratory human resources, including laboratory heads, technicians, and laboratory assistants, are not only responsible for carrying out operational tasks effectively but also play a role in designing

practical strategies. Therefore, investing in the development of laboratory human resources through training, competency improvement, and structured performance management is essential to ensure the laboratory functions optimally and supports the learning process.

This condition also affects students. For instance, the lack of practicum experience makes students less enthusiastic and causes them difficulty in understanding material that requires direct observation. The practicum that should support understanding of concepts and scientific skills is limited and less in-depth. Practicum biology instruction plays a crucial role in science education (Abdullah et al., 2018; Perdana et al., 2022) because it provides students with training in the scientific method by following detailed instructions outlined in the instruction sheet. However, at SMA B, the biology learning process is not maximized, and the learning experience feels more theoretical and less engaging. To overcome this limitation, teachers attempt to make adjustments by selecting simple practicums that can be completed without specialized equipment. However, teachers still hope for support from the school, such as the addition of laboratory assistants who can help teachers in preparing and maintaining equipment. It would be even better if there were a laboratory head who could arrange work programs and technicians who could repair equipment if it were damaged, a special budget for the practicum, and a practicum schedule that was separate from regular class hours. With complete and competent human resources, practicum activities can run smoothly, teachers are not burdened, and students can learn more enjoyably and deeply, allowing practicum activities to be carried out more effectively and increasing students' understanding and interest in learning biology subjects.

In contrast, SMA B lacks a complete laboratory staffing structure. As shown in Table 2, the school lacks a laboratory head, assistant, or technician. These roles are instead carried out by subject teachers, which deviates significantly from the standards outlined in PERMENDIKNAS No. 26 of 2008. This situation places an additional burden on teachers, who must divide their time between instructional duties and laboratory responsibilities (Romadhoni & Saifuddin, 2021; Safitri et al., 2024). This compromises the effectiveness of both teaching and laboratory activities.

Without dedicated laboratory staff, SMA B faces several operational challenges. There is no annual work plan, no fixed practicum schedule, and no systematic equipment

check. Practicum activities are conducted irregularly, based solely on teacher availability and classroom time. In some cases, activities are moved to regular classrooms due to limited space or resources. These conditions reduce opportunities for students to engage in hands-on learning, weaken conceptual understanding, and limit the development of scientific skills (Heng et al., 2022; Shana & Abulibdeh, 2020; Yuan, 2022).

This situation underscores the importance of investing in qualified laboratory personnel. Laboratory heads are essential for planning and supervision, assistants support daily preparation, and technicians ensure equipment readiness (Romadhoni & Saifuddin, 2021; Safitri et al., 2024; Zulfaa et al., 2022). The absence of these roles at SMA B highlights a clear gap between expected standards and current practice. Teachers themselves recognize the need for support, expressing the desire for at least a laboratory assistant to share technical responsibilities and free them to focus on teaching.

To improve laboratory operations at SMA B, a multi-faceted approach involving both immediate and long-term strategies is recommended. As a short-term solution, the school could designate and train existing staff to serve as part-time lab assistants or heads, while gradually building a formal staffing structure. This should be supported by a school policy adjustment that allocates specific hours in the biology teacher's schedule for laboratory tasks to reduce their overload. To compensate for the absence of technicians, providing targeted professional development for teachers on basic lab management, tool maintenance, and safety procedures is essential. Furthermore, SMA B could explore cross-school collaboration by partnering with nearby schools to share resources or conduct joint practicum sessions. Finally, adopting best practices from schools like SMA A, such as implementing structured schedules, clear task delegation, and systematic inventory management, would create a more efficient and effective laboratory environment..

If these improvements are implemented, SMA B can progressively close the quality gap in laboratory management. Students will benefit from more frequent, structured, and meaningful practicum experiences. Moreover, teachers will be able to maintain focus on instruction without being overburdened by technical tasks.

Ultimately, the effectiveness of biology laboratories in both schools is closely tied to the adequacy, competence, and coordination of their human resources. A complete and professional laboratory team is essential not only for equipment management and safety

but also for ensuring that practicum becomes an integral and impactful part of the learning process. Schools must therefore consider human resource development in laboratories as a strategic investment in educational quality.

CONCLUSION

The availability and competence of laboratory human resources (HR) are very influential on the implementation of biology practicum activities in high schools. The results showed that SMA A has adequate laboratory human resources, namely the head of the laboratory and an active laboratory assistant. However, it does not yet have a special technician. This absence of a technician, while not as critical as the absence of a head or an assistant, could potentially enhance the practicum activities. In contrast, SMA B experiences limited human resources due to the absence of a laboratory head, a laboratory assistant, and a technician. All practicum tasks are duplicated by subject teachers, which has an impact on the less optimal implementation of the practicum and reduces the direct student learning experience.

This condition underscores the critical role of professional laboratory human resources in ensuring the sustainability and quality of practicum-based biology learning. It is the responsibility of schools and policymakers to ensure that the standards of laboratory personnel, as outlined in applicable regulations, are met. This is essential to establish an effective, safe, and supportive learning environment for students.

REFERENCES

Abdullah, A. G., Dewi, N. L. P. R., Suastra, I. W., Pujani, N. M., Foley, J., Suryaputra, I. G. N. A., & Hellman, A. (2018). Effectiveness of contextual science practicum module to improve science process skills and environmental caring character. *SHS Web of Conferences*, *42*. https://doi.org/10.1051/shsconf/20184200037

Agustina, P., Saputra, A., Anif, S., Rayana, A., & Probowati, A. (2021). Analisis Keterampilan Proses Sains Dan Sikap Ilmiah Siswa Kelas Xi Ipa Sma Pada Praktikum Biologi. *Edusains*, *13*(1), 1-7. https://doi.org/10.15408/es.v13i1.11015

Ambarwati, S., & Prodjosantoso, A. (2018). Analisis kelengkapan alat, bahan laboratorium, dan keterlaksanaan praktikum kimia di SMA Negeri 2 Yogyakarta. *Jurnal Riset Pembelajaran Kimia*, *7*(1), 9-18. https://journal.student.uny.ac.id/jrpk/article/view/13356

Baily, L., Bar-on, M., Yucha, C., & Snyder, S. J. (2013). Six challenges encountered in the opening of a multi-institutional, interprofessional simulation center. *Clinical Simulation in Nursing*, *9*(6), e219-e223. https://doi.org/10.1016/j.ecns.2011.12.002

Budiarti, R. S., Yelianti, U., Harlis, H., Sanjaya, M. E., & Mataniari, R. (2021). Optimalisasi pengelolaan laboratorium biologi bagi guru-guru MGMP di Tanjung Jabung Barat. *DEDIKASI: Jurnal Pengabdian Masyarakat*, *2*(2), 302-310. https://doi.org/10.32332/d.v2i2.2292

Duphily, N. H. (2014). Simulation education: A primer for professionalism. *Teaching and Learning in Nursing*, *9*(3), 126-129. https://doi.org/10.1016/j.teln.2014.03.003

Ekwen, T. V., & George, P. F. E. (2018). Human resources management and school effectiveness in government technical secondary and high schools in Cameroon. *International Journal of Trend in Scientific Research and Development*, *Volume-2*(Issue-6), 721-733. https://doi.org/10.31142/ijtsrd18728

Emda, A. (2017). Laboratorium Sebagai Sarana Pembelajaran Kimia Dalam Meningkatkan Pengetahuan Dan Ketrampilan Kerja Ilmiah. *Lantanida Journal*, *5*(1). https://doi.org/10.22373/lj.v5i1.2061

Fiska, M., Hamidah, A., & Budiarti, R. S. (2022). Analisis pelaksanaan manajemen laboratorium pada pembelajaran biologi kelas XI SMA Negeri Kabupaten Muaro Jambi. *Edu-Sains: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam*, *10*(1), 7-12. https://doi.org/10.22437/jmpmipa.v10i1.20692

Gusmanto, R. (2023). Manajemen pengelolaan alat dan bahan di Laboratorium Fakultas Tarbiyah dan Ilmu Keguruan (FTIK) IAIN Kerinci. *Leader: Jurnal Manajemen Pendidikan Islam*, *1*(2), 112-121. https://doi.org/10.32939/ljmpi.v1i2.3084

Heng, Z. S., Koh, D. W., Yeo, J. Y., Ooi, C. P., & Gan, S. K. (2022). Effects of different delivery modes on teaching biomedical science practical skills in higher education during the 2021 pandemic measures. *Biochem Mol Biol Educ*, *50*(4), 403-413. https://doi.org/10.1002/bmb.21637

Iqbal, M., Sumarni, Z., Yani Harahap, N. I., & Hadi, A. (2023). The role of human resources in improving school quality. *GIC Proceeding*, *1*, 58-65. https://doi.org/10.30983/gic.v1i1.144

Juwandi, M. A., & Legistia, Y. T. (2023). Pelatihan dan pengembangan SDM di SMA laboratorium percontohan UPI. *Jurnal Tata Kelola Pendidikan*, *5*(1), 35-42. https://doi.org/10.17509/jtkp.v5i1.61446

Kementerian Pendidikan Nasional. (2008). *Peraturan Menteri Pendidikan Nasional No 26 Tahun 2008 tentang Standar Tenaga Laboratorium Sekolah/Madrasah*. Jakarta: Kementerian Pendidikan Nasional Retrieved from https://jdih.kemdikbud.go.id/arsip/Permendikbud_Tahun2008_Nomor026.pdf

Metcalfe, S. E., Hall, V. P., & Carpenter, A. (2007). Promoting collaboration in nursing education: the development of a regional simulation laboratory. *J Prof Nurs*, *23*(3), 180-183. https://doi.org/10.1016/j.profnurs.2007.01.017

Munandar, H., & Jofrishal. (2021). *Analysis of problem in utilizing school laboratories in the chemistry learning* Proceedings of the 2nd International Conference on Science, Technology, and Modern Society (ICSTMS 2020)

Munarti, M., & Sutjihati, S. (2018). Standar sarana prasarana laboratorium IPA Sekolah Menengah Atas di Wilayah Bogor. *Pedagonal : Jurnal Ilmiah Pendidikan*, *2*(1), 56-62. https://doi.org/10.33751/pedagog.v2i1.743

Nasution, N. E. A., AlMuhdhar, M. H. I. A., Sari, M. S., & Balqis, B. (2023). Relationship between Critical and Creative Thinking Skills and Learning Achievement in Biology with Reference to Educational Level and Gender. *Journal of Turkish Science Education*, *20*(1), 66-83. https://doi.org/10.36681/tused.2023.005

Nurul, U., Amat, M., Azizatuz, Z., Andika Nur Rahma, P., & Hasan, A. (2021, 2021/11/26). The analysis of education standards achievement in the Internal Quality Assurance System (IQAS). Proceedings of the 7th International Conference on Education and Technology (ICET 2021),

Oladejo, A. I., Ademola, I. A., Ayanwale, M. A., & O, T. D. (2023). Concept difficulty in secondary school chemistry: An intra-play of gender, school location and school type. *Journal of Technology and Science Education*, *13*(1), 255-275. https://doi.org/10.3926/jotse.1902

Papaneophytou, C., & Nicolaou, S. A. (2025). Promoting Critical Thinking in Biological Sciences in the Era of Artificial Intelligence: The Role of Higher Education. *Trends in Higher Education*, *4*(2). https://doi.org/10.3390/higheredu4020024

Perdana, R., Asrial, A., & Maison, M. (2022). The effect of science attitudes toward science process skills of junior high school students in Jambi. *Jurnal Pendidikan MIPA*, *23*(2), 360-372. https://doi.org/10.23960/jpmipa/v23i2.pp360-372

Pratiwi, A. D., Maharani, A., Saifuddin, M. F., Syafani, I., Alfariz, A. J., Istiqomah, I. N., Puspitasari, E. D., & Ma'rifah, D. R. (2024). Standard operational procedures for organizing practical activities in high school biology laboratories in Yogyakarta city. *Indonesian Journal of Biology Education*, *7*(1). https://doi.org/10.31002/ijobe.v7i1.640

Putri, A. A., Indarti, L., Prastika, L. R., & Utami, A. D. (2018). Implementation analysis of the training of head of science laboratory candidates in 2017. The 8th annual basic science international conference: Coverage of basic sciences toward the world's sustainability challanges,

Putri, A. N., Wulandari, F. A., Suparno, A. W., Khasanah, A. M., Rahmadani, T. E., Saifuddin, M. F., & Puspitasari, E. D. (2023). Implementation of standard operating procedures in biology practicum high school. *Bioma : Jurnal Ilmiah Biologi*, *12*(1). https://doi.org/10.26877/bioma.v12i1.12376

Rahmah, N., Iswadi, I., Asiah, A., Hasanuddin, H., & Syafrianti, D. (2021). Analisis Kendala Praktikum Biologi di Sekolah Menengah Atas. *Biodik*, *7*(2), 169-178. https://doi.org/10.22437/bio.v7i2.12777

Romadhoni, T. E., & Saifuddin, M. F. (2021). Evaluasi pemanfaatan laboratorium biologi SMAN/MAN se-kecamatan Godean. *Jurnal Eksakta Pendidikan (JEP)*, *5*(1), 59-67. https://doi.org/10.24036/jep/vol5-iss1/566

Safitri, N. R., Ikrima, Z., Salsabilla, F., Insra, A. R., Saifuddin, M. F., & Puspitasari, E. D. (2024). Deskripsi manajemen sumber daya manusia pada laboratorium biologi SMA di Kota Yogyakarta. *Bioedukasi: Jurnal Pendidikan Biologi*, *15*(1), 124-133. https://ojs.fkip.ummetro.ac.id/index.php/biologi/article/view/5876

Setiawan, A., & Mujahid, M. A. (2023). Optimalisasi manajemen laboratorium melalui sistem berbasis web dengan pendekatan MVC. *Jurnal Responsif : Riset Sains dan Informatika*, *5*(2), 416-424. https://doi.org/10.51977/jti.v5i2.1342

Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, *10*(2). https://doi.org/10.3926/jotse.888

Sudarisman, S. (2015). Memahami hakikat dan karakteristik pembelajaran biologi dalam upaya menjawab tantangan abad 21 serta optimalisasi implementasi kurikulum 2013. *Florea : Jurnal Biologi dan Pembelajarannya*, *2*(1), 29-35. https://doi.org/10.25273/florea.v2i1.403

Sugrah, N., Nur Abu, S. H., Rahman, N. A., Rakhman, K. A., Danial, M., & Anwar, M. (2019). Assessment of processes and resources for knowledge of skills of a chemistry laboratory at the senior high school of Ternate Island. *Journal of Curriculum and Teaching*, *8*(1). https://doi.org/10.5430/jct.v8n1p11

Surani, S. (2024). Pengaruh penggunaan video tutorial merangkai alat praktikum terhadap pemahaman dan pengetahuan mahasiswa pada praktikum isolasi dan sintesis senyawa organik. *Indonesian Journal of Laboratory*, *1*(3). https://doi.org/10.22146/ijl.v1i3.90342

Susan, E. R. I. (2019). Manajemen sumber daya manusia. *Adaara: Jurnal Manajemen Pendidikan Islam*, *9*(2), 952-962. https://doi.org/10.35673/ajmpi.v9i2.429

White, T. E., Wong, W. B., Janowiak, D., & Hilborne, L. H. (2021). Strategies for laboratory professionals to drive laboratory stewardship. *Pract Lab Med*, *26*, e00249. https://doi.org/10.1016/j.plabm.2021.e00249

Yuan, X. (2022). Evidence of the spacing effect and influences on perceptions of learning and science curricula. *Cureus*, *14*(1), e21201. https://doi.org/10.7759/cureus.21201

Zulfaa, A. A., Yuliyanti, D., Amanda, S. D., Rusilawati, D. F., Saifuddin, M. F., & Puspitasari, E. D. (2022). Qualifications and competencies of high school biology laboratory human resources in Bantul Regency. *Journal on Biology and Instruction*, *2*(2), 61-70. https://doi.org/10.26555/joubins.v2i2.6951