Evaluating The Utilization Of Physics Laboratories in High Schools: A Case Study at SMAN 5 Metro

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Abstract *- This study evaluates the utilization of the physics laboratory at SMA Negeri 5 Metro and examines key factors hindering its optimal use in supporting physics education. Using a qualitative descriptive approach, data were collected through observations, interviews with physics teachers, and questionnaires distributed to Grade X students. Triangulation techniques were employed to validate the findings. Results indicate that although the school has a well-equipped laboratory meeting national standards, its use remains suboptimal. Approximately 80% of students reported limited engagement with the lab, while 86.4% expressed disinterest in physics, largely due to difficulties in grasping theoretical concepts without hands-on experience. Contributing factors include the absence of trained laboratory assistants, inadequate laboratory management, and the use of the lab space for non-academic activities. Moreover, physics practicums are often conducted in classrooms using mobile equipment, reducing students' exposure to experimental learning. To address these issues, the study proposes a Total Quality Management (TQM)-based framework, involving the establishment of a dedicated lab management team, structured practicum scheduling, enhanced teacher training, and the integration of virtual labs. These measures aim to improve lab functionality, boost student engagement, and enhance learning outcomes. This case study underscores the importance of strategic laboratory management and recommends further comparative and quantitative research across multiple schools to generalize findings and assess the direct impact of lab utilization on academic performance.*

Keywords*: Physics Laboratory; High School; Physics Learning*

INTRODUCTION

The Indonesian government has established eight educational standards through Government Regulation No. 19 of 2005(Republik Indonesia, 2005), which include content standards, learning processes, graduate competencies, educator qualifications, facilities and infrastructure, management, financing, and assessment. Furthermore, Regulation of the Minister of National Education No. 24/2007 (Permen RI, 2007) mandates that laboratories serve as an essential component of educational infrastructure in all formal educational institutions, including senior high schools (SMA), as they play a crucial role in supporting practicum-based learning.

Extensive research has emphasized the importance of physics laboratories in enhancing students' conceptual understanding and scientific skills (Puspitasari et al., 2023); (Aini et al., 2020); (Suseno, 2012). Laboratories provide an environment for experimentation, hypothesis testing, and problem-solving, allowing students to apply theoretical knowledge in a hands-on setting (Safaryan, 2023). However, despite their critical role, many schools fail to fully utilize their laboratory facilities, preventing students from gaining maximum benefits from practical learning experiences.

SMAN 5 Metro, a public high school in Metro Lampung, is equipped with a physics laboratory featuring a

comprehensive set of tools and materials. However, preliminary observations indicate that the laboratory is underutilized, with most practicum sessions still conducted in regular classrooms. Instead of engaging in direct experimental activities, students primarily rely on teacher demonstrations, limiting their practical engagement and reducing the effectiveness of inquiry-based learning.

Although previous studies have analyzed general issues related to laboratory utilization (Puspitasari et al., 2023), no specific study has evaluated the effectiveness of the physics laboratory at SMAN 5 Metro. Furthermore, while research has identified barriers such as inadequate resources, lack of teacher preparation, and mismanagement, there is limited investigation into how curriculum alignment, human resource availability, and school policies influence laboratory utilization. Additionally, alternative evaluation frameworks, such as comparative studies with other schools or student engagement assessments, have not been thoroughly explored, leaving a gap in understanding the broader impact of laboratory practices on physics learning outcomes.

This study aims to fill these research gaps by conducting an in-depth evaluation of the factors affecting laboratory utilization at SMAN 5 Metro. Specifically, this study will: (1) assess the current state of laboratory utilization and identify key obstacles, such as the absence of laboratory assistants, ineffective scheduling, and non-academic use of laboratory spaces; (2) evaluate students' perceptions of physics practicums, including their engagement levels and the impact of limited laboratory access on their learning experiences; and (3) propose practical solutions to optimize laboratory functionality, improve teaching and learning processes, and enhance overall physics education quality.

By addressing these gaps, this study aims to contribute not only to local educational improvements but also to the broader discussion on optimizing physics laboratory utilization in Indonesian high schools. The findings of this research may serve as a basis for policy recommendations on enhancing laboratory management, providing necessary resources, and integrating hands-on experiments into the curriculum. Ultimately, this study aspires to support the development of a more effective and engaging physics learning environment at SMAN 5 Metro and beyond.

RESEARCH METHODS

Research is a structured process in which researchers take systematic steps to obtain accurate and valid data, leading to correct and appropriate conclusions (Sari et al., 2019). This study employs a qualitative descriptive approach to provide an in-depth understanding of the conditions, processes, and interrelationships among research subjects. This method is particularly suited for capturing complex social phenomena as it allows for a comprehensive exploration of the research context. In line with (Umyati et al., 2022), a case study design was adopted, which enables researchers to examine a specific phenomenon within a particular setting or time frame, collecting rich and detailed information through multiple data collection techniques.

This study focuses on evaluating the utilization of the physics laboratory at SMA Negeri 5 Metro in supporting physics learning. To achieve this, three primary data collection methods were employed: observation, interviews, and questionnaires. Observations were conducted directly during classroom learning activities to identify challenges in laboratory-based physics

learning. Interviews were carried out with physics teachers, using a purposive sampling technique, in which respondents were selected based on their relevance to the study's objectives. This approach ensured that data was gathered from key stakeholders with direct experience in laboratory management and physics instruction.

Following the observations and interviews, a questionnaire was distributed to students of class X.1 to assess their perceptions of laboratory effectiveness in physics learning. Additionally, a literature review was conducted to support the findings with existing research and theoretical perspectives.

To ensure the validity and reliability of the collected data, a triangulation technique was applied, which involved comparing observational data, interview responses, and questionnaire results. Data validation was carried out by cross-checking interview findings with multiple informants, ensuring consistency in responses from different physics teachers. Furthermore, student responses from the questionnaire were examined alongside observational data to identify patterns or discrepancies in laboratory usage perceptions.

For data analysis, a qualitative thematic approach was utilized, where key themes were identified based on recurring patterns in interview transcripts, observational notes, and questionnaire responses. This process involved manual coding, where significant statements were categorized into themes related to laboratory utilization, challenges, and potential improvements. Future research could benefit from incorporating NVivo or other qualitative analysis software to further systematize and enhance the coding process.

By employing a rigorous triangulation and thematic analysis approach, this study ensures that the findings accurately reflect the real conditions of laboratory utilization at SMA Negeri 5 Metro, providing valuable insights for improving physics education practices.

RESULTS AND DISCUSSION

The laboratory serves as a crucial environment for students to engage in hands-on learning, reinforcing theoretical concepts through practicum-based activities. The role of laboratory personnel, particularly laboratory assistants and technicians, is essential in ensuring the smooth operation of laboratory activities (Purwanti & Fauzi, 2020). According to the Regulation of the Minister of National Education on School/Madrasah Laboratory Personnel Standards, laboratory management in schools involves laboratory heads, technicians, and assistants, whose responsibilities include equipment procurement, scheduling activities, maintaining inventories, and ensuring laboratory safety (Sarjono, 2018).

The duties of laboratory assistants that must be carried out by laboratory assistants are planning the procurement of tools and materials, compiling activity schedules and rules, preparing tools and materials, organizing the issuance and entry of tool storage, registering the use of tools and materials, making catalog lists, inventorying and administering the use of tools and materials, maintaining and repairing damaged equipment or tools and materials, inventorying data on students or research participants, and compiling reports on the implementation of laboratory activities (Nikmah et al., 2017).

Findings from this study at SMAN 5 Metro reveal that despite having a relatively well-equipped laboratory, its utilization remains suboptimal due to the absence of laboratory personnel and administrative

inefficiencies. This aligns with studies conducted by (Aini et al., 2020) in Temanggung, where laboratories were found to be underutilized due to a lack of trained staff and poor scheduling. Similarly, (Puspitasari et al., 2023) highlighted that physics teachers in several Indonesian schools face difficulties integrating practicum activities due to time constraints in lesson planning and the administrative burden of managing laboratory equipment without adequate support.

However, schools that have effectively addressed these challenges demonstrate higher levels of laboratory utilization and improved student engagement. (Hendrawan et al., 2023) studied a high school in Samarinda that successfully optimized laboratory use by implementing a dedicated laboratory management team, consisting of trained laboratory assistants and teachers collaborating to create structured practicum schedules. Additionally, (Hidayat et al., 2023) found that schools integrating digital tools for lab simulations were able to increase student engagement and compensate for the lack of direct access to physical experiments.

Factors that influence the implementation of physics practicum consist of supporting and inhibiting factors. Supporting factors include the readiness of educators and students, as well as the completeness of practicum tools and materials (Suseno & Riswanto, 2017). The inhibiting factors include the use of laboratory space for other activities such as MGMP and student council meetings, lack of time for educators to make teaching modules that support practicum, and the absence of laboratory assistants. The readiness of educators and students played a crucial role in the smooth running of the practicum. The high enthusiasm and curiosity of students support the smooth running of the practicum, while the ability of teachers to plan and implement the practicum creatively determines the success of the activity. The equipment and infrastructure in the laboratory is an important supporting factor because the completeness of the equipment ensures that the practicum is not interrupted (Suseno, 2017).

The physics laboratory at SMA Negeri 5 Metro is relatively complete based on Permendiknas standards, which include mechanics kits, optical kits, electricity and magnetism kits, telescopes, measuring instruments (electricity, temperature, time, length, and mass), and kits for studying waves. Teaching modules designed by educators also play an important role in facilitating practicum activities. According to (Nurdyansyah, 2018), teaching modules or Learning Implementation Plans (RPP) are designed to follow the independent curriculum and achieve the competencies set by educators. In physics learning, teaching modules that facilitate practicum activities are needed to help students understand the material.

One of the main obstacles at SMA Negeri 5 Metro is the absence of a specialized physics laboratory. According to the Regulation of the Minister of National Education No. 26/2008 (ahmad mujtaba, 2017), the laboratory assistant functions to prepare various types of equipment according to practicum guidelines and assist students during practicum activities. The absence of a laboratory assistant causes educators to take care of the preparation and arrangement of equipment themselves, hampering the implementation of practicum.

The results of observations in class X.1 SMA Negeri 5 Metro showed that physics learning was carried out in the classroom, with poorly maintained laboratory conditions. Although physics

practicum tools and materials are quite complete, stored in warehouses and storage cabinets, laboratory management that has not been optimal causes the laboratory to not function properly. Overall, optimizing the use of laboratories at SMA Negeri 5 Metro requires improved management and additional laboratory staff to support the practicum. Thus, the laboratory can be utilized more effectively to support physics learning and improve the quality of education in this school.

Based on the results of observations made in class X.1 SMA Negeri 5 Metro, the results obtained that learning Physics class X.1 at SMA Negeri 5 Metro is only carried out in the classroom, laboratory conditions are less well maintained but for physics practicum tools and materials are quite complete stored in warehouses and physics laboratory storage cabinets, it's just that the laboratory management is not optimal so that the laboratory does not function properly.

Figure 1. Demonstration of the use of length measuring instruments by physics teacher SMAN 5 Metro

Then the results of interviews with one of the educators at SMAN 5 Metro obtained the results that there are separate laboratories between the laboratories of biology, chemistry, and also physics. However, the implementation of practicum, especially physics lessons at SMA Negeri 5 Metro has not been carried out optimally due to the use of tools and materials in the implementation of practicum which is still lacking in learning, the use of laboratories that are not in accordance with their functions, and the absence of laboratory assistants or laboratory technicians.

Figure 2. The condition of the storage room of the physics laboratory of SMAN 5 Metro

Figure 3: Researcher conducting an interview with one of the physics teachers at SMA 5 Metro.

This is supported by response data from students of class X.1 that the implementation of practicum is only done in class with educators bringing physics practicum tools into the classroom, and students lack a new atmosphere in the learning process, namely in the laboratory. The results of the questionnaire filled out by students of SMAN 5 Metro are displayed in the form of a graph. The following is the percentage of the results of filling out the questionnaire by students of class 10 SMAN 5 Metro.

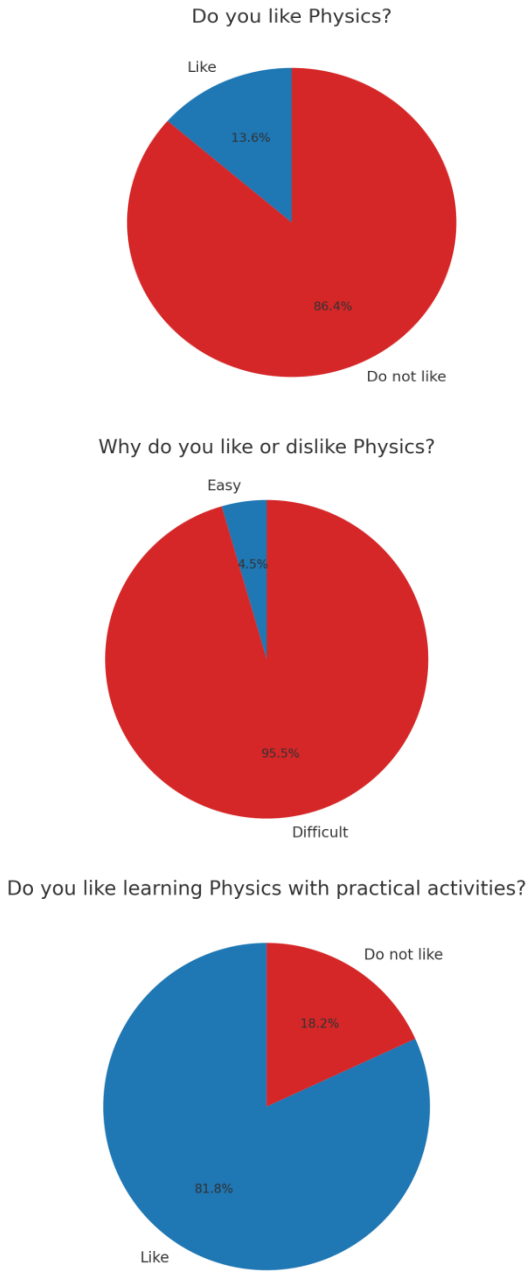

Figure 4. Graph of student response results of class X.1 SMAN 5 Metro

Students' response to physics learning at SMAN 5 Metro can be shown the results that students do not like physics lessons with a percentage of 86.4%, students like physics lessons with a percentage of 13.6%, students who state that the reason for not liking physics lessons is difficult with a percentage of 95.5%, students who like physics lessons with easy reasons with a percentage of 4.5%, Practical learning takes place coherently with a presentation of 81.8%, and students are enthusiastic enough to follow it even though only in class, students are less enthusiastic reluctant physics lessons using practicum with a percentage of 18.2%. The graph of the results of the questionnaire answered by students at SMAN 5 Metro shows that the majority of students are less interested in physics lessons with the reason that physics lessons are difficult. However, the majority of students are quite enthusiastic and interested if physics lessons are interspersed using practicum.

The results of the research that have been presented above can be seen that the physics laboratory at SMAN 5 Metro has the availability of tools and practicum materials that are quite complete, there is a storage cabinet for tools, a special room for laboratory assistants, a place to wash hands. Then seen from the human resources, the quality of physics teachers at SMAN 5 METRO is very good in terms of education and management of learning. However, with the completeness of the tools and materials that are quite complete, during physics learning the teacher conducts practicum in the classroom by bringing tools and practicum materials according to the material, this shows that the utilization of the laboratory has not been done optimally. One of the factors that make the use of the laboratory is not optimal, such as the absence of a laboratory assistant who is useful in laboratory management such as borrowing tools or inventory of tools, and the condition of the laboratory room which is less maintained so that the implementation is not good. In addition, sometimes the room becomes a function for other activities, such as being used for MGMP rooms and student council meetings.

Based on the data analysis that has been done, some solutions that can be offered to overcome the problem of physical laboratory utilization at SMA Negeri 5

Metro are as follows. First, optimizing laboratory management can be done by recruiting or appointing a laboratory assistant or laboratory technician who is fully responsible for laboratory management. The main tasks of this laboratory assistant include managing and maintaining equipment, organizing tools according to their code, type, and function, as well as creating and maintaining laboratory administration data. The appointed laboratory assistant also needs to receive special training on laboratory management, safety procedures, and maintenance of laboratory equipment.

The availability of funds significantly impacts laboratory maintenance, equipment procurement, and hiring of laboratory staff. Schools with limited budgets often prioritize classroom instruction over practical experiments, leading to poorly maintained facilities and inadequate resources for experimental learning.

The commitment of school principals plays a crucial role in supporting laboratory-based learning. In some schools, laboratory spaces are repurposed for administrative or non-academic activities, such as meetings, teacher training, or storage, reducing their accessibility for students (Hidayat et al., 2023). A school leadership model that prioritizes laboratory development and science education could significantly enhance its utilization.

Even when laboratory equipment is available, the effectiveness of practicum-based learning depends on the teacher's readiness to incorporate experiments into lesson plans. Teachers who lack training in experimental methods or face heavy administrative workloads may find it challenging to conduct regular practicum sessions, preferring classroom-based demonstrations instead (Riswanto & Dewi, 2017).

To enhance the efficiency and sustainability of laboratory utilization, schools can adopt Total Quality Management (TQM) principles for laboratory administration. TQM is a continuous improvement model that can be applied to educational institutions to ensure optimal resource management, stakeholder involvement, and structured learning experiences (Ayaz, 2023). Research has shown that implementing TQM in school laboratories leads to better organization, increased accountability, and improved student outcomes (Permana et al., 2021), making it a valuable framework for optimizing laboratory functionality in physics education..

Proposed TQM-Based Laboratory Management Model:

1. Establish a Laboratory Quality Management Team (Berte, 2007)
   a. Form a dedicated team comprising a laboratory head, trained laboratory assistants, and selected physics teachers to oversee all laboratory operations (Feisel & Rosa, 2005).
   b. Assign clear responsibilities, such as equipment maintenance, experiment scheduling, and student safety management.
2. Develop a Structured Laboratory Utilization Plan
   a. Implement a fixed weekly schedule for physics practicum activities, ensuring that all classes receive equal access to laboratory experiences (Suseno, 2014).
   b. Prevent non-academic activities (e.g., administrative meetings) from interfering with the core function of the laboratory (Riswanto et al., 2019).
3. Enhance Teacher Training and Support

a. Organize regular professional development workshops focusing on experiment-based learning strategies, laboratory safety, and equipment usage (Li, 2024).
b. Reduce administrative burdens on teachers by introducing digital tools for lab report submission and equipment inventory management (Kumar & Sharma, 2016).

4. Optimize School Budget Allocation for Laboratory Development
   a. Advocate for increased funding for laboratory maintenance and personnel recruitment through collaborations with local government programs, private sector funding, or grant proposals(Bennett et al., 2014).
   b. Prioritize essential laboratory needs in annual school budget planning to prevent equipment degradation and resource shortages (Robinson, 1994).
5. Introduce Digital and Hybrid Laboratory Solutions
   a. Implement virtual physics simulations to complement physical experiments, particularly for schools with limited lab accessibility (May, 2023).
   b. Utilize interactive software (e.g., PhET simulations, Arduino-based physics experiments) to enhance student engagement and provide alternative practical experiences (Ismawati et al., 2023)

This study aligns national and international research, confirming that the absence of laboratory assistants, ineffective scheduling, and administrative constraints are major barriers to laboratory utilization. However, studies from other schools that have successfully optimized laboratory use suggest that structured laboratory management, strategic budgeting, and digital integration can significantly enhance laboratory-based learning (May, 2023). Implementing a TQM-based laboratory management framework at SMAN 5 Metro could serve as a sustainable solution to maximize the functionality of the laboratory, ultimately improving student engagement and physics learning outcomes (Rampa, 2010).

CONCLUSION

Based on the data analysis, this study concludes that the utilization of the physics laboratory at SMA Negeri 5 Metro has not been carried out optimally. This is evident from the continued implementation of practicum sessions in the classroom, where teachers bring experimental tools into the class for demonstration rather than conducting experiments in the laboratory. Despite the availability of well-equipped laboratory facilities and qualified physics teachers, poor laboratory management and the absence of dedicated laboratory assistants have hindered the effective use of the laboratory. Additionally, the laboratory is often used for non-academic activities, further limiting its function in supporting physics learning.

Several key factors contribute to the underutilization of the laboratory. The absence of laboratory assistants responsible for maintaining and organizing equipment, managing laboratory schedules, and ensuring compliance with safety protocols has resulted in inefficiencies. Moreover, ineffective laboratory management, including the lack of structured administration such as a tool loan book and inventory tracking system, further restricts its optimal use. Another major limitation is the lack of a structured laboratory schedule, preventing equitable access for all students. To address these challenges, this study

recommends appointing trained laboratory assistants, providing regular training for laboratory staff and teachers, implementing a structured laboratory schedule, improving laboratory infrastructure and administration, and introducing safety awareness programs. These improvements could ensure that the laboratory functions according to its intended purpose and provides students with effective hands-on learning experiences.

This study is limited to a single school (SMA Negeri 5 Metro) and does not include comparative data from other institutions. Additionally, it relies on qualitative methods, primarily through observations, interviews, and student responses, without incorporating quantitative assessments of how laboratory utilization directly impacts student learning outcomes. Future research should expand the scope by conducting comparative studies across multiple schools to identify common trends and best practices in laboratory utilization. Furthermore, quantitative research is needed to measure the impact of laboratory-based learning on student performance in physics, using pre-test and post-test assessments. Additionally, the integration of digital and hybrid laboratory models, such as virtual simulations and remote experiments, should be explored to address limitations in laboratory access. Future research could also investigate the effectiveness of laboratory management frameworks, such as Total Quality Management (TQM) in educational settings, to optimize laboratory efficiency.

By addressing these gaps, future research can contribute to a more comprehensive understanding of laboratory effectiveness and provide evidence-based solutions for improving physics education in high schools. Implementing these strategies will not only enhance the practical learning experience but also foster a more engaging and scientifically enriched educational environment.

REFERENCES

ahmad mujtaba. (2017). Peraturan Menteri Pendidikan Nasional Republik Indonesia Nomor 24 Tahun 2007. *Encyclopedia of Signaling Molecules*. https://doi.org/10.1007/978-3-319-67199-4_100418

Aini, S. N., Kartika, I., & Widayanti. (2020). Analisis Sarana Prasarana dan Intensitas Penggunaan Laboratorium Fisika SMA/MA Negeri di Kabupaten Temanggung. *Prosiding Seminar Nasional Fisika Festival*, *1*, 140–148. https://sunankalijaga.org/prosiding/index.php/fisfest/article/view/756/720

Ayaz, H. (2023). Total Quality Management in Education. *International Journal of Social Science, Innovation and Educational Technologies*, *3*(6), 71–78. https://doi.org/10.54603/iss.185

Bennett, A., Garcia, E., Schulze, M., Bailey, M., Doyle, K., Finn, W., Glenn, D., Blair Holladay, E., Jacobs, J., Kroft, S., Patterson, S., Petersen, J., Tanabe, P., & Zaleski, S. (2014). Building a laboratory workforce to meet the future: ASCP task force on the laboratory professionals workforce. *American Journal of Clinical Pathology*, *141*(2), 154–167. https://doi.org/10.1309/AJCPIV2OG8TEGHHZ

Berte, L. M. (2007). Laboratory Quality Management: A Roadmap. *Clinics in Laboratory Medicine*, *27*(4), 771–790. https://doi.org/10.1016/j.cll.2007.07.008

Feisel, L. D., & Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education*, *94*(1), 121–130. https://doi.org/10.1002/j.2168-9830.2005.tb00833.x

Hendrawan, J., Nurfaika, S., Rahmadayanti, N., Ramadhani, Z., Setiyawan, R., &

Sulaeman, N. F. (2023). Pengelolaan Laboratorium Fisika SMA Di Kota Samarinda Pada Era Digital. *Jurnal Pembelajaran Fisika*, *11*(4), 151–158. https://doi.org/10.19184/jpf.v11i4.36384

Hidayat, W., Sukri, A., & Mirawati, B. (2023). Efektivitas Penggunaan Laboratorium IPA Terhadap Pembelajaran Biologi. *Empiricism Journal*, *4*(1), 163–174. https://doi.org/10.36312/ej.v4i1.1126

Ismawati, R., Widiyatmoko, A., & Cahyono, A. N. (2023). Literature Review of Online Learning Technology in Chemistry Lab Activities. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 751–759. https://doi.org/10.29303/jppipa.v9i10.3635

Kumar, V., & Sharma, D. (2016). Creating Collaborative and Convenient Learning Environment Using Cloud-Based Moodle LMS: An Instructor and Administrator Perspective. *International Journal of Web-Based Learning and Teaching Technologies*, *11*(1), 35–50. https://doi.org/10.4018/IJWLTT.2016010103

Li, Z. (2024). Research on Simulation Experiment Teaching Strategies for High School Physics in Remote Areas. *Open Journal of Social Sciences*, *12*(08), 442–455. https://doi.org/10.4236/jss.2024.128027

May, J. M. (2023). Historical analysis of innovation and research in physics instructional laboratories: Recurring themes and future directions. *Physical Review Physics Education Research*, *19*(2), 20168. https://doi.org/10.1103/PhysRevPhysEducRes.19.020168

Nikmah, S., Hartono, H., & Sujarwata, S. (2017). Kesiapan dan pemanfaatan laboratorium dalam mendukung pembelajaran fisika sma di kabupaten brebes. *UPEJ Unnes Physics Education Journal*, *6*(1), 1–8. https://doi.org/10.15294/upej.v6i1.13928

Nurdyansyah, N. (2018). *Pengembangan Bahan Ajar Modul Ilmu Pengetahuan Alam bagi Siswa Kelas IV Sekolah Dasar*. Universitas Muhammadiyah Sidoarjo. http://eprints.umsida.ac.id/1607/1/Nurdy nahdi.pdf

Permana, A., Purba, H. H., & Rizkiyah, N. D. (2021). A systematic literature review of total quality management (TQM) implementation in the organization. *International Journal of Production Management and Engineering*, *9*(1), 25–36. https://doi.org/10.4995/IJPME.2021.13765

Permen RI. (2007). *Peraturan Menteri Pendidikan Nasional Republik Indonesia Nomor 24 Tahun 2007 tentang Standar Sarana prasarana Sekolah Dasar/Madrasah Ibtidaiyah (SD/MI), Sekolah Menengah Pertama/Madrasah Tsanawiyah (SMA/MTs) dan Sekolah Menengah Atas/ Madrasah Aliyah (SMA* (pp. 1–67).

Purwanti, E., & Fauzi, A. (2020). *Pengelolaan Laboratorium IPA SMA*. UMMPress.

Puspitasari, N. R. N., Shabitna, F. S., Anggraeni, D. K., Wulandari, F. P., Baktiarso, S., & Mahardika, I. K. (2023). Peranan Laboratorium Fisika dalam Menunjang Pembelajaran Fisika di SMA. *Jurnal Fisika Papua*, *2*(1), 6–10. https://doi.org/10.31957/jfp.v2i1.18

Rampa, S. H. (2010). A customised Total Quality Management Framework for schools. *Africa Education Review*, *7*(1), 199–217. https://doi.org/10.1080/18146627.2010.490013

Republik Indonesia. (2005). Peraturan Pemerintah Republik Indonesia

Nomor 19 tahun 2005 tentang standar nasional pendidikan. *Peraturan Pemerintah Republik Indonesia*. https://doi.org/10.1017/CBO9781107415324.004

Riswanto, R., & Dewi, N. A. K. (2017). Peningkatan Keterampilan Proses Sains Melalui Pembelajaran Berbasis Laboratorium Untuk Mewujudkan pembelajaran Berkarakter. *Jurnal Riset Dan Kajian Pendidikan Fisika*, *4*(2), 60. https://doi.org/10.12928/jrkpf.v4i2.8164

Riswanto, Suseno, N., Partono, Harjati, P., & Dedy, H. A. (2019). School Laboratory Management Information System. *Journal of Physics: Conference Series*, *1361*(1). https://doi.org/10.1088/1742-6596/1361/1/012068

Robinson, A. (1994). Rationale for cost-effective laboratory medicine. *Clinical Microbiology Reviews*, *7*(2), 185–199. https://doi.org/10.1128/CMR.7.2.185

Safaryan, N. (2023). Utilizing Virtual Laboratories for Physics Instruction in Secondary Education: a Pedagogical Inquiry. *Main Issues Of Pedagogy And Psychology*, *2*(10), 81–93. https://doi.org/10.24234/miopap.v2i10.10

Sari, W. M., Riswanto, R., & Partono, P. (2019). Validitas Mobile Pocket Book Berbasis Android Menggunakan Adobe Flash Pada Materi Suhu Dan Kalor. *Berkala Ilmiah Pendidikan Fisika*, *7*(1), 35. https://doi.org/10.20527/bipf.v7i1.5728

Sarjono. (2018). Pentingnya Laboratorium Fisika di SMA/MA dalam Menunjang Pembelajaran Fisika. *Jurnal Madaniyah*, *8*(3), 262–271.

Suseno;, R. N. (2017). Sistem Pengelolaan Laboratorium Fisika Untuk Mewujudkan Pelaksanaan Praktikum Yang Efisien. *JPF Jurnal Pendidikan Fisika*, *5*(1), 76–86.

Suseno, N. (2012). Peran praktikum dalam mengembangkan kemampuan dan karakter mahasiswa calon guru fisika pada mata kuliah keahlian program studi (Studi kasus pada perkuliahan elektronika dan listrik magnet). *Membangun Karakter Guru Dan Dosen Untuk Mewujudkan Pendidikan Berkarakter. Paper Presented at Seminar Nasional Pendidikan Ke-1, Universitas Muhammadiyah Metro, Metro*, 132–139.

Suseno, N. dkk. (2014). *Buku Panduan Kepala Laboratorium Sekolah/Madrasah.* Lembaga penelitian um metro press.

Suseno, N., & Riswanto, R. (2017). Program Optimalisasi Peran Laboratorium Fisika SMA di Kota Metro, Lampung. *Jurnal Pengabdian Pada Masyarakat*, *2*(2), 149–158. https://doi.org/10.30653/002.201722.28

Umyati, A., Yanasari, S., Wahyuni, N., & Mariawati, A. S. (2022). Measuring the impact of practicum schedule and mental workload on stress levels in hybrid learning: A case study in Physics practicum. *Journal Industrial Servicess*, *8*(2), 158–163. https://doi.org/10.36055/jiss.v8i2.17312