

MANAGEMENT OF CHEMISTRY LABORATORY RESOURCES FOR EFFECTIVE TEACHING AND LEARNING CHEMISTRY

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Abstract

Effective management of laboratory resources is crucial for enhancing the quality of chemistry education in secondary schools. Well-equipped and properly managed laboratories provide students with hands-on learning experiences that complement theoretical knowledge, foster critical thinking, and improve academic performance. This paper explores the significance of managing laboratory resources for effective chemistry teaching and learning, identifies common challenges faced by schools (including inadequate funding, poor infrastructure, and a lack of skilled personnel), and proposes strategies for overcoming these obstacles. Key recommendations include increasing funding from both government and private sectors, improving laboratory infrastructure, providing professional development for teachers and technicians, enforcing safety standards, and developing efficient inventory management systems. By addressing these challenges, schools can ensure safe, well-equipped laboratories that support high-quality chemistry education and prepare students for future academic and professional success in the sciences.

Keywords: Management, Chemistry, Laboratory resources, Effective teaching, Learning

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Introduction

Teaching chemistry, especially at the secondary school level, is pivotal in shaping students' understanding of the natural world and preparing them for future academic and career opportunities in science and technology. As a subject grounded in both theory and practical application, chemistry relies heavily on laboratory experimentation to help students conceptualize and apply classroom learning. Laboratory work allows students to witness firsthand how chemical principles operate, fostering a deeper and more holistic understanding of abstract concepts such as chemical reactions, molecular structures, and the properties of elements and compounds (Gilewski, 2020).

In most educational systems, particularly in developing countries, chemistry is considered a core science subject, alongside physics and biology. Its curriculum is designed to balance theoretical lessons and practical laboratory sessions. Unfortunately, the effective delivery of chemistry practicals is often hindered by inadequate laboratory resource management. When resources like chemicals, glassware, lab instruments, and safety equipment are unavailable, outdated, or poorly maintained, teachers cannot conduct meaningful experiments. Consequently, learning is restricted to theoretical instruction, negatively impacting students' academic outcomes and diminishing their interest in science-related careers (Hussen Seid *et al.*, 2022).

In developing regions like Nigeria, the importance of efficient laboratory resource management is particularly pronounced. Many secondary schools face severe resource constraints, including a lack of modern equipment and insufficient materials for even basic experiments. This challenge, coupled with inadequate funding, poorly trained laboratory staff, and insufficient maintenance of existing resources, creates a significant barrier to quality chemistry education (Emeka *et al.*, 2021). Effective management,

therefore, is not just about ensuring material availability; it also involves the strategic allocation, use, and preservation of these resources to maximize educational outcomes (Mohzana *et al.*, 2023).

This paper argues that effective laboratory resource management is essential for successful chemistry teaching in secondary schools. Proper management includes adequate funding, ensuring safe and functional laboratory spaces, maintaining up-to-date inventories, providing training for laboratory personnel, and establishing policies for effective resource utilization. Without these practices, chemistry teaching becomes largely theoretical, denying students the opportunity to develop essential practical skills crucial for mastering the subject (Elzagheid, 2023).

Effective laboratory management leads to:

Improved Teaching Efficiency: Well-managed laboratories enable teachers to plan and execute practical lessons efficiently, providing students with hands-on experience with chemical concepts. This reinforces theoretical instruction and improves comprehension.

Enhanced Student Engagement and Learning: Access to fully functional laboratories increases student engagement and motivation. Experiential learning becomes more enjoyable, fostering a deeper understanding of scientific methods and increasing interest in chemistry.

Better Academic Performance: Empirical evidence suggests that students participating in regular laboratory sessions perform better academically in chemistry than those relying solely on textbooks. Practical work develops problem-solving, critical thinking, and analytical skills, crucial for excelling in science.

Long-term Resource Sustainability: Proper management practices, such as regular maintenance and inventory control, ensure sustainable resource use. This reduces waste, prolongs equipment life, and benefits future students.

Conversely, poor laboratory management disrupts learning, compromises safety, creates inefficiencies, and results in poor educational outcomes. Therefore, this paper advocates for systematic improvements in laboratory resource management in secondary schools, particularly for chemistry education.

Purpose and Objectives

This paper advocates for improving laboratory resource management practices in secondary schools to enhance chemistry teaching. By examining current challenges and identifying best practices, this paper aims to:

- i. Highlight the importance of laboratory resources in effective chemistry teaching, demonstrating how hands-on practical lessons complement theoretical learning and contribute to student achievement.
- ii. Evaluate the current state of laboratory resource management in secondary schools, identifying common problems such as resource scarcity, poor maintenance, and a lack of trained personnel that hinder effective chemistry teaching.
- iii. Examine the impact of laboratory resource management on student academic performance, drawing on existing literature and case studies to show the

- correlation between well-managed laboratory resources and improved student outcomes in chemistry.
- iv. Propose strategies for improving laboratory resource management, offering practical solutions to address challenges in resource allocation, inventory control, maintenance, and staff training. These strategies will focus on ensuring laboratory resources are available, functional, and efficiently used in chemistry teaching.

Significance of Practical Learning in Chemistry Education

Chemistry is an experimental science deeply rooted in the interplay of theory and practice. Unlike subjects relying almost exclusively on theoretical instruction, chemistry is unique because its core principles—such as the nature of chemical reactions, atomic structure, and the properties of matter—are best understood through practical experimentation. Laboratory work allows students to visualize and manipulate these abstract concepts, solidifying their understanding and enabling them to apply theoretical knowledge to real-world phenomena (Karch & Sevian, 2022).

Experiential Learning and Conceptual Understanding: Laboratory experiments offer experiential learning, allowing students to actively engage with the material, observe outcomes, and draw conclusions. Research in science education shows that students participating in well-structured laboratory activities develop a better grasp of complex topics, witnessing chemical reaction outcomes firsthand, measuring property changes, and interacting with chemical substances. This hands-on experience bridges the gap between abstract chemistry theory and its practical application, making learning more concrete and accessible (Laverie et al., 2022).

Laboratory work also fosters critical thinking and problem-solving skills. Students design experiments, control variables, observe results, and interpret data—essential aspects of scientific inquiry. This active engagement allows students to test hypotheses, refine understanding, and apply scientific methods. By troubleshooting experimental setups and navigating unexpected results, students build resilience and adaptability, crucial in scientific research and experimentation.

Cognitive and Psychomotor Skills Development: Chemistry laboratory work nurtures cognitive skills (understanding, analyzing, and evaluating information) and psychomotor skills (manipulating tools, precise measurement, and careful observation). Students learn to handle glassware, mix reagents, measure quantities accurately, and follow detailed procedures, promoting discipline and attention to detail. These skills are critical for success in chemistry and transferable to other scientific disciplines and technical fields (Montag, 2024).

Furthermore, laboratory work allows students to visualize chemical phenomena difficult to grasp through lectures alone. Concepts like mole ratios, balancing chemical equations, or energy changes associated with exothermic and endothermic reactions are better understood through experiments where students observe these phenomena in action.

Engagement and Motivation: Laboratory work enhances student engagement and motivation. Practical work often stimulates curiosity and interest by allowing students

to explore the ‘why’ and ‘how’ behind theoretical knowledge. It transforms passive learning into active exploration, encouraging students to question, hypothesize, and experiment. This heightened engagement can lead to greater enthusiasm for chemistry and, in turn, higher academic achievement. Students regularly participating in laboratory activities are more likely to develop a long-term interest in chemistry, potentially leading to increased participation in STEM fields (Yao, 2023).

Impact of Poor Laboratory Resource Management on Chemistry Education

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Benefits of Effective Laboratory Resource Management

Effective management of laboratory resources significantly enhances chemistry teaching and learning. Well-maintained laboratories equipped with up-to-date materials allow teachers to plan and execute curriculum-aligned experiments, providing students with a more comprehensive and engaging educational experience (Chang et al., 2022).

The benefits include:

Increased Availability of Practical Lessons: Well-managed laboratory resources provide students with more frequent opportunities for hands-on learning. Access to a fully stocked and functional laboratory enables teachers to incorporate practical experiments, reinforcing theoretical instruction with real-world applications. This fosters a more active learning environment where students explore chemical concepts through experimentation, leading to better understanding and retention.

Improved Teacher Effectiveness: Teachers with access to well-managed laboratory resources can deliver more dynamic and interactive lessons. With the necessary tools, they can focus on demonstrating chemical principles in action rather than relying on abstract explanations. This improves teaching quality and boosts teacher confidence and job satisfaction, allowing them to fully utilize their skills to engage students in meaningful scientific inquiry.

Enhanced Student Learning Outcomes: Effective laboratory resource management leads to better student outcomes in chemistry. Regular practical activities develop critical thinking, problem-solving, and analytical skills essential for success in chemistry and other scientific disciplines. Well-structured laboratory work allows students to experiment with variables, test hypotheses, and observe outcomes, enhancing their scientific literacy and preparing them for future academic challenges.

Long-Term Sustainability of Laboratory Resources: Proper management ensures the sustainability of laboratory resources. Regular maintenance and inventory control prevent waste and prolong equipment lifespan. By adopting best practices, schools maximize resource use, ensuring future students benefit from well-equipped and functional laboratories.

Challenges in Managing Secondary School Chemistry Laboratory Resources

Managing laboratory resources in secondary schools presents several challenges that can hinder effective chemistry teaching and learning. These challenges, including inadequate funding, poor infrastructure, insufficient technical expertise, lack of teacher training, and ineffective policies, can compromise the quality of students' practical experiences (Chacha et al., 2022). Overcoming these obstacles is crucial for ensuring laboratories are well-equipped, safe, and provide hands-on learning opportunities that enrich students' understanding of chemistry.

Inadequate Funding and Budgetary Constraints: A significant challenge is the lack of adequate funding. Many secondary schools, particularly in developing regions, struggle to allocate sufficient budgets to equip and maintain their laboratories. This limits the availability of essential materials, equipment, and safety infrastructure.

Poor Laboratory Infrastructure and Maintenance: Laboratories require regular maintenance and proper infrastructure. Many schools struggle to maintain laboratories to the required standards due to poor infrastructure, lack of maintenance, and inadequate safety measures.

Insufficient Skilled Personnel and Technical Expertise: Managing laboratory resources requires skilled personnel, including laboratory technicians and trained chemistry teachers, capable of handling the technical aspects of setting up experiments, maintaining equipment, and ensuring safety. Many schools face a shortage of trained professionals with this expertise.

Lack of Laboratory Safety Standards and Compliance: Ensuring safety in chemistry laboratories is paramount, as students work with hazardous chemicals, open flames, and delicate equipment. Many schools struggle to implement and maintain appropriate safety standards due to a lack of resources, inadequate training, and weak enforcement.

Ineffective Inventory Management and Resource Utilization: Effective laboratory resource management depends on proper inventory systems to track materials and equipment. Many schools struggle to maintain organized and up-to-date inventories, leading to wastage, shortages, and inefficient resource use.

Policy and Administrative Challenges: Ineffective policies and administrative practices can also significantly challenge laboratory resource management. School administrators and government agencies play a key role in ensuring laboratories are well-equipped and maintained, but gaps in policy implementation and oversight can hinder this process.

Strategies for Effective Management of Laboratory Resources

Effective management of laboratory resources is crucial for maximizing student learning and engagement in chemistry education. Well-managed laboratories support practical learning, reinforce theoretical concepts, and provide a safe environment for experimentation. This section explores key strategies for improving laboratory resource management in secondary schools, including securing adequate funding, enhancing professional development for laboratory personnel, implementing regular maintenance routines, and establishing robust inventory management systems (Kolil & Achuthan, 2024).

Securing Adequate Funding: A fundamental strategy is ensuring schools receive adequate funding. As discussed previously, insufficient funding leads to poorly equipped laboratories, outdated materials, and limited hands-on learning opportunities. Addressing this requires strategic action from stakeholders, including school administrators, governments, private sector partners, and community organizations.

Professional Development for Laboratory Personnel: Trained and skilled personnel are critical for ensuring laboratory safety, functionality, and effective resource use. This requires ongoing professional development for laboratory technicians and teachers, equipping them with the skills to manage resources efficiently and conduct experiments safely.

Implementing Regular Maintenance and Upkeep: Regular maintenance of laboratory equipment and facilities is essential for maintaining a functional and safe laboratory. A proactive maintenance strategy can prevent equipment deterioration, reduce safety risks, and extend the lifespan of laboratory resources.

Establishing Robust Inventory Management Systems: An efficient inventory management system is critical for tracking resource use, ensuring timely restocking, and preventing misuse or waste. Schools should implement robust inventory management practices to optimize resource availability and utilization.

Promoting Sustainable Use of Resources: Sustainability is increasingly important in laboratory resource management. Schools should adopt practices that minimize waste, reduce environmental impact, and ensure the long-term availability of laboratory materials.

Importance of Effective Management of Laboratory Resources in Chemistry Education

Effective management of laboratory resources is pivotal to chemistry teaching and learning in secondary schools. It directly influences educational quality, depth of student understanding, practical skill development, and overall academic performance. Properly managed laboratory resources not only ensure students are exposed to practical, hands-on experiences but also foster a deeper connection between theoretical knowledge and real-world applications. Kusmawan (2022) highlighted several advantages of well-managed laboratories that enhance teaching and learning, promote safety, foster scientific thinking, and contribute to students' preparedness for future STEM careers:

Enhancing Hands-On Learning and Practical Skills Development: A key advantage is the opportunity for hands-on learning. Practical experience is fundamental to science education, particularly in chemistry, where abstract concepts like chemical reactions,

molecular structures, and stoichiometry are more easily understood when students can observe and manipulate physical substances.

Ensuring Proper Safety Measures: Well-managed laboratories are equipped with necessary safety infrastructure, including fume hoods, fire extinguishers, eyewash stations, and first aid kits. Effective resource management includes implementing safety protocols, such as proper chemical storage and labeling, using personal protective equipment (PPE) like gloves and safety goggles, and regularly inspecting safety devices. A well-organized laboratory ensures safety equipment is readily accessible and students are trained in its use. Teachers and laboratory technicians oversee safety procedures and ensure students understand how to conduct experiments safely. Properly managed laboratories also provide clear instructions on handling accidents, such as chemical spills, burns, or broken glassware, reducing the likelihood of injuries.

Improving Academic Performance and Student Engagement: Effective laboratory resource management directly impacts student engagement and academic performance. Laboratory experiments lead to deeper understanding and better academic outcomes. Hands-on activities make learning more enjoyable and stimulate interest in science, increasing motivation and enthusiasm. Students excelling in laboratory activities are often better prepared for practical examinations. Well-managed laboratories equip students with the skills and knowledge needed to succeed in written and practical exams, improving overall academic performance.

Fostering Scientific Curiosity and Lifelong Learning: A well-managed laboratory fosters an environment where students explore their scientific curiosity and develop a lifelong interest in chemistry. Access to well-organized, well-maintained laboratories makes science seem exciting and dynamic, inviting inquiry and experimentation. Laboratory work encourages students to ask questions, formulate hypotheses, and design experiments. This inquiry-based approach promotes curiosity and critical thinking. In a well-managed laboratory, students explore different aspects of chemistry, fostering a sense of discovery and independent thinking.

Contributing to a Culture of Innovation and Collaboration: Effective laboratory resource management can also contribute to a collaborative and innovative learning environment. In a well-functioning laboratory, students work together on experiments, share ideas, and collaborate on problem-solving. This fosters teamwork, communication, and shared responsibility, essential skills in academic and professional settings.

The importance of effective laboratory resource management in chemistry education cannot be overstated. Well-organized, well-maintained laboratories enhance hands-on learning, promote safety, improve academic performance, foster scientific curiosity, and prepare students for future STEM careers. By prioritizing laboratory resource management, schools create a dynamic and engaging learning environment that encourages innovation, collaboration, and lifelong learning in chemistry.

Conclusion

In conclusion, managing laboratory resources in secondary school chemistry education faces challenges, including inadequate funding, poor infrastructure, insufficient technical expertise, and ineffective safety standards. Addressing these requires a concerted effort by governments, school administrators, teachers, and communities to secure funding, provide professional development, and implement clear policies and oversight. By overcoming these obstacles, schools can create safe, well-equipped

laboratories that enhance students' understanding of chemistry and prepare them for future academic and professional success in the sciences.

Recommendations

Based on the identified challenges in managing laboratory resources for effective chemistry teaching in secondary schools, the following recommendations are proposed to address these issues and enhance chemistry education quality:

1. Governments and educational institutions must prioritize allocating adequate funding specifically for science laboratories.
2. Governments and schools should explore partnerships with private industries, particularly in the chemical, pharmaceutical, and manufacturing sectors, to supplement laboratory funding.
3. Investing in modernizing laboratory infrastructure is essential. Schools should upgrade outdated laboratories to meet safety standards, ensuring adequate ventilation, lighting, workspaces, and appropriate safety equipment.
4. Chemistry teachers and laboratory technicians should receive ongoing professional development to enhance their laboratory management skills, knowledge of safety protocols, and effective resource use.
5. Schools should implement and strictly enforce safety protocols in laboratories to protect students and staff. Regular safety audits by government bodies or third-party inspectors should be conducted to ensure compliance with established standards.
6. Schools should promote sustainable practices in laboratory resource use and management. This includes efficient chemical use, recycling where possible, and minimizing waste.

References

- Asmarany, A. I., Hakim, A. A., Saefudin, A. & Judijanto, L. (2024). Effective Laboratory Management: Efforts to Improve Science Education Management in Islamic Boarding Schools. *Journal Penelitian Pendidikan IPA*, **10** (8): 5673-5680.
- Chacha, J., Onyango, D. & Augustine, S. (2022). Challenges faced by teachers in implementing competence-based chemistry curriculum in public secondary schools in Nyamagana District, Mwanza, Tanzania. *Journal of Research Innovation and Implications in Education*, **6** (1): 346-358.
- Chang, P. S., Lee, S. H. & Wen, M. L. (2022). Developing an inquiry-based laboratory curriculum to engage students in planning investigations and argumentation. *International Journal of Science Education*, **44** (18): 2659-2684.
- Elzagheid, M. (2023). *Chemical Technicians: Good Laboratory Practice and Laboratory Information Management Systems*. Walter de Gruyter GmbH & Co KG.
- Emeka, A., Margaret, A. F., Jacob, O. N. & Olatunde-Aiyedun, T. G. (2021). Problems facing science teachers in public secondary schools in Nigeria and way forward. *International Journal of Discoveries and Innovations in Applied Sciences*, **1**: 118-129.

- Gilewski, A. (2020). *Linking of Chemistry Concepts Using Learner-centered Assessments* (Doctoral dissertation, California State University, Northridge).
- Housni, H., Bendahhou, K., Tahiri, M. & Tahiri Jouti, N. (2023). Evaluation of Chemical Risks Management During Handling Operations and Determination of Storage Conditions in Scientific Laboratories. *Chemistry Africa*, **6** (2): 1087-1101.
- Hussein, B. A. & Shifera, G. (2022). Knowledge, attitude, and practice of teachers and laboratory technicians toward chemistry laboratory safety in secondary schools. *Journal of Chemical Education*, **99** (9): 3096-3103.
- Hussen Seid, M., Assefa, Y., Legas Muhammed, B., Moges, B. T., Tsehay Birhanu, E., Fentaw, Y. & Reshid Ahmed, M. (2022). Students' and Teachers' Perception and Practice towards Laboratory Work in Chemistry Teaching-Learning: Evidence from Secondary Schools in North Wollo Zone, Ethiopia. *Education Research International*, **2022** (1): 7254105.
- Karch, J. M. & Sevian, H. (2022). Development of a framework to capture abstraction in physical chemistry problem solving. *Chemistry Education Research and Practice*, **23** (1): 55-77.
- Kolil, V. K. & Achuthan, K. (2024). Virtual labs in chemistry education: A novel approach for increasing student's laboratory educational consciousness and skills. *Education and Information Technologies*, 1-25.
- Laverie, D. A., Hass, A. & Mitchell, C. (2022). Experiential learning: A study of simulations as a pedagogical tool. *Marketing Education Review*, **32** (1): 3-17.
- Mohzana, M., Murcahyanto, H., Fahrurrozi, M. & Supriadi, Y. N. (2023). Optimization of management of laboratory facilities in the process of learning science at high school. *Jurnal Penelitian Pendidikan IPA*, **9** (10): 8226-8234.
- Montag, S. D. (2024). Transformation of the Organic Chemistry Laboratory: A Movement towards an Inquiry-Based Laboratory Experience. *Online Submission*.
- Shambare, B. & Simuja, C. (2022). A critical review of teaching with virtual lab: A panacea to challenges of conducting practical experiments in science subjects beyond the COVID-19 pandemic in rural schools in South Africa. *Journal of Educational Technology Systems*, **50** (3): 393-408.
- Wynn, S. (2021). The Financial Impact of Manual Inventory Record Errors
- Yao, J. (2023). Exploring Experiential Learning: Enhancing Secondary School Chemistry Education Through Practical Engagement and Innovation. *Journal of Education, Humanities and Social Sciences*, **22**: 475-484.