JOURNAL OF EDUCATION FOR SUSTAINABLE INNOVATION | ISSN 3025-1052
Vol. 3, No. 2, 2025, 127-136
https://doi.org/10.56916/jesi.v4i4.1846

Enhancing Laboratory Safety in Nigerian Tertiary Institutions: An Investigation into the Effectiveness of Implemented Safety Measures

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Keywords
Laboratory Management
Personal Protective Equipment
Protocol, Safety measure
Safety/Hazard

Article History
Received 2025-06-21
Accepted 2025-12-29

Abstract
This study examined the implementation, effectiveness, and challenges of laboratory safety measures at the College of Science Education, Lagos State University of Education. Its purpose was to assess the extent to which established safety protocols are practiced, evaluate their effectiveness in preventing laboratory accidents, and identify barriers affecting safety compliance. A descriptive survey design was employed, involving 400 participants, 300 students, 50 laboratory staff, and 50 lecturers selected through random sampling to ensure departmental representation. Data were collected using a validated questionnaire with a reliability coefficient of 0.75 and analyzed using descriptive statistics, including frequencies and percentages. Results revealed that communication of safety guidelines is relatively strong, with 79.4% of respondents affirming that safety rules and procedures are clearly communicated, and 79.0% indicating regular reminders for laboratory users. However, the effectiveness of these measures was moderate: 69.4% agreed that safety equipment is consistently functional, and 64.4% reported receiving adequate training. Notable gaps were observed, as 35.6% of participants indicated insufficient training, and 44.5% reported that safety drills and emergency procedures are not regularly practiced. These findings suggest that while foundational safety structures exist, inconsistencies in training, limited emergency preparedness, and uneven enforcement reduce their overall effectiveness. The study recommends increased investment in safety infrastructure, institutionalized training programs, frequent emergency drills, and strengthened administrative oversight to enhance laboratory safety culture and minimize risks.

INTRODUCTION

Laboratories are a cornerstone of science education in higher institutions, serving as critical environments where theoretical knowledge is transformed into meaningful practical experience. In disciplines such as Chemistry, Biology, Physics, Integrated Science, and Environmental Science, laboratories enable students to observe real phenomena, test hypotheses, manipulate equipment, and learn to make decisions in controlled but sometimes unpredictable environments (Hofstein & Mamlok-Naaman, 2016). These practical engagements foster analytical thinking, creativity, and problem-solving skills, which are central to success in STEM (science, technology, engineering, and mathematics) education (Bautista & Adan, 2019). More than merely instructional spaces, laboratories function as developmental ecosystems where scientific literacy, innovation, and a culture of inquiry are cultivated, creating future scientists, educators, and informed citizens.

However, laboratory work also carries inherent risks. Chemicals may be corrosive or toxic, biological materials may harbor pathogens, electrical equipment may malfunction, and glassware may break. Without robust safety systems, these hazards can lead to accidents, exposures, fires, or injuries. Globally, regulatory agencies and institutions including the World Health Organization (WHO), the Occupational Safety and Health Administration (OSHA), UNESCO, and various professional societies advocate for comprehensive laboratory safety frameworks (WHO, 2020; UNESCO, 2022). These frameworks emphasize proactive risk assessment, hazard communication, the provision of personal protective equipment (PPE), emergency preparedness, safe waste disposal, and continuous training for laboratory users.

In many developing countries, especially in Sub-Saharan Africa, implementing and sustaining such safety frameworks remains a significant challenge. Institutions in these contexts often face resource constraints, inadequate infrastructure, and limited institutional oversight (Adeyemi & Olaoluwa, 2020; Chukwuma & Eze, 2018). Nigerian tertiary institutions—including universities, polytechnics, and colleges of education have been reported to operate with outdated laboratory facilities, insufficient safety equipment, poor ventilation, inadequate chemical storage infrastructure, and weak enforcement of safety protocols (Ofodeme et al., 2024). These systemic challenges have been linked to laboratory accidents, injuries, and even long-term health risks for students and staff, underscoring the urgency of comprehensive safety assessments.

Importantly, teacher-training institutions play a pivotal role in shaping the future of science education and laboratory safety culture. The College of Science Education at Lagos State University of Education (LASUED) in Nigeria and institutions like the University of Makeni (UniMak) in Sierra Leone are tasked with preparing pre-service science educators who will go on to teach and manage laboratories in secondary and tertiary schools. As a result, laboratory safety training at LASUED not only impacts current students and staff but also has future implications for school-based laboratory environments across Nigeria. Ensuring that pre-service teachers are well-versed in both safe laboratory practices and risk-informed pedagogy is thus a matter of national and educational significance (Nwune et al., 2023; Lawani-Luwaji et al., 2023).

Empirical studies across Nigeria and other West African countries continue to document safety deficits in laboratory settings. For example, Nwune et al. (2023) found that many pre-service science teachers in Anambra State lacked comprehensive knowledge of basic safety measures. Akinyemi et al. (2021) reported that in several Nigerian tertiary laboratories, protective equipment such as goggles, gloves, and fume hoods were either lacking or non-functional, while chemical management practices did not conform to standard operating procedures. In addition, Ofodeme et al. (2024) highlighted institutional oversight as a recurring weakness , safety policies exist on paper, but enforcement is

erratic, and incident reporting is poor. The Rubber Research Institute of Nigeria (2025) also reported elevated risks of chemical and microbiological exposure in their laboratories, attributing these to poor ventilation and inadequate adherence to safety protocols. These collective findings point to the systemic nature of laboratory safety challenges in Nigerian higher education.

Comparative evidence from Sierra Leone reinforces the possibility of progress with structured interventions. Kamara et al. (2023) employed the WHO Infection Prevention and Control Assessment Framework (IPCAF) to survey three tertiary institutions and observed progress in IPC compliance from "Basic" levels in 2021 to "Intermediate" in 2023. Furthermore, Fofanah et al. (2023) found that district-level hospitals improved their compliance substantially during the same period. These results demonstrate that, even in resource-limited contexts, consistent monitoring, training, and institutional commitment can significantly enhance safety compliance.

To frame the investigation of laboratory safety in such a context, this study draws upon two complementary theoretical perspectives: Risk Management Theory and Safety Management Systems (SMS) Theory. Risk Management Theory, as developed by Kaplan and Garrick (1981), posits that risks must be proactively identified, assessed, and mitigated in a structured and continuous manner. Applied to laboratory settings, this means conducting hazard analyses, quantifying risk, prioritizing interventions, and monitoring outcomes. SMS Theory, articulated by Reason (1997), emphasizes the establishment of a safety culture within organizations by aligning leadership commitment, policy development, accountability, communication, and continuous learning. SMS posits that technical solutions without cultural buy-in are insufficient to sustain safety—or drive behavioral change.

Integrating Risk Management Theory with SMS provides a powerful analytical lens for understanding safety in laboratories. While Risk Management Theory encourages a technical and procedural focus—inspecting chemical inventories, evaluating equipment, tracking near-misses—SMS theory broadens the view to include leadership, resource allocation, training, and the organizational ethos surrounding safety. Together, these frameworks facilitate a holistic evaluation of laboratory safety, assessing not only whether safety measures exist but whether they are part of a living, evolving system entrenched in institutional practices (Shrivastava et al., 2023; Okolie et al., 2025).

Over the past few years, technological innovations have significantly transformed laboratory safety practices around the world. Digital hazard monitoring systems, real-time gas and temperature sensors, automated alarms, and virtual reality (VR) simulations are increasingly being integrated into laboratory safety education (Chen et al., 2023; UNESCO, 2022). VR simulations, for example, offer risk-free environments where users can rehearse emergency responses, practice spill management, or learn correct PPE usage before stepping into real laboratories. Such innovations enhance safety readiness, reduce accident rates, and contribute to a proactive safety culture. Unfortunately, many Nigerian institutions, including LASUED, have yet to fully exploit these technologies because of cost, lack of expertise, and infrastructural limitations (Shrivastava et al., 2023).

The ethical dimensions of laboratory safety also merit attention. A robust safety culture does more than prevent accidents it fosters professional integrity, accountability, and respect for human and environmental well-being. For pre-service teachers, internalizing safety norms during training can shape how they approach laboratory instruction in their future classrooms. By promoting responsibility, vigilance, and respect for protocols, safety education contributes to the development of teachers who value not only content knowledge but also the well-being of their students (Lawani-Luwaji et al., 2023). Furthermore, a sustained safety culture supports equity: all students, regardless of background, deserve access to laboratory environments where risks are minimized and learning is protected.

Within LASUED, preliminary observations suggest a mixed picture. There is evidence of institutional efforts: safety orientation sessions for new students, safety manuals, restricted equipment usage, and basic safety infrastructure like first-aid kits, fire extinguishers, and eye wash stations. Yet, compliance appears variable. Survey data suggest that while roughly 79% of students and staff report regular reminders about safety rules, only about 55% say that actual drills and practical emergency sessions are consistently held. Reports also indicate that safety equipment is not uniformly functional across all labs, and ventilation and signage are inconsistent across departments (Okolie et al., 2025; Chen et al., 2023).

Institutional leadership emerges as a critical factor in sustaining safety systems. According to SMS theory, safety thrives when leaders are visibly committed, communicate clearly, establish accountability, and invest in systemic improvement (Reason, 1997). At LASUED, safety policy is articulated at the institutional level, but translation into daily practice is challenged by decentralization, limited budget allocations, departmental silos, and weak monitoring. Laboratory coordinators and administrators frequently cite financial constraints as a significant obstacle to maintaining equipment, funding training, or conducting regular audits (Okolie et al., 2025).

Behavioral and attitudinal factors also play fundamental roles in safety outcomes. Even in contexts where safety equipment exists, complacency or rushed work habits can undermine compliance. Students occasionally ignore PPE usage, mishandle reagents, or cut corners when under time pressure or in pursuit of completing experiments quickly. Laboratory attendants and instructors report that some users understand safety policies in theory but lack practical competence or willingness to follow through. These gaps illustrate the limits of purely cognitive training and emphasize the need for culturally embedded, behaviorally rooted safety interventions (Lawani-Luwaji et al., 2023).

At a broader policy level, laboratory safety in Nigerian tertiary institutions is also shaped by external incentives and accountability mechanisms. National regulatory bodies, professional associations, accreditation agencies, and funding agencies all have roles to play. However, enforcement is uneven. Institutions may have safety guidelines, but without regular external audits, standardized reporting frameworks, and transparent incident tracking, the momentum for safety compliance may wane. A national strategy for laboratory safety perhaps involving regulatory oversight, dedicated safety funding, certification requirements for laboratories, and public reporting of safety performance could significantly strengthen institutional capacity and mitigate risk (Ofodeme et al., 2024; Okolie et al., 2025).

There is also a pedagogical imperative: integrating safety education into science curriculum, not as an add-on but as a core component. Rather than treating safety as a separate orientation or checklist, institutions should embed safety principles into every laboratory course, practical assignment, and assessment. Pre-service teachers should learn not only how to conduct experiments but how to manage risk, respond to emergencies, and build a culture of accountability among their future students. Such integration reflects both Risk Management Theory (continual hazard assessment) and SMS Theory (institutionalizing safety as a core value).

Moreover, continuous professional development is essential. Safety training should not be one-off; it must include refresher sessions, near-miss debriefings, peer learning communities, and incentives for reporting and improvement. Student-led safety committees or peer safety monitors may foster ownership and participation, allowing safety culture to arise from the bottom up, complementing top-down governance (Shrivastava et al., 2023). This participatory approach aligns with SMS theory's focus on stakeholder involvement and continuous learning.

Given these considerations, the present study aims to bridge critical gaps in knowledge and practice by evaluating the adequacy of laboratory safety measures at the College of Science Education, Lagos State University of Education (LASUED). Specifically, the study investigates (a) the availability and functionality of safety infrastructure, (b) the level of safety awareness and practical competence among students and staff, (c) the effectiveness of existing safety protocols in preventing accidents, and (d) the systemic barriers that hinder full compliance and continuous improvement.

By adopting both Risk Management Theory and SMS as its conceptual framework, this research examines not only the technical aspects of hazard control but also the institutional, organizational, and behavioral factors that influence safety outcomes. The goal is to generate evidence-based recommendations tailored to LASUED's context, recommendations that are feasible, sustainable, and aligned with global best practices.

Improving laboratory safety at LASUED has potentially wide-ranging implications. First, it can directly protect students and staff from harm. Second, it can build a stronger safety culture among future science teachers, who may become advocates for safer practices in their future workplaces. Third, it can serve as a model for other teacher-training institutions in Nigeria and beyond, demonstrating how integrated theories, modern technologies, leadership practices, and participatory governance can coalesce into effective, sustainable safety systems.

In sum, laboratory safety is more than a regulatory requirement or ethical obligation, it is a strategic lever for enhancing the quality, sustainability, and integrity of science education. In resource-limited settings, where institutional challenges are real and persistent, a nuanced, theory-driven, and context-sensitive approach is essential. This study centers on LASUED because of its pivotal role in training science educators in Nigeria. By systematically assessing safety practices through the dual lens of Risk Management and SMS theory, this research seeks to provide both diagnostic insight and actionable guidance to improve laboratory safety and build a lasting safety culture.

Research Questions

1. What safety measures are currently implemented in the laboratories at the College of Science Education, Lagos State University of Education (LASUED)?
2. How effective are these safety measures in preventing laboratory accidents?
3. What are the main challenges or barriers to effectively managing and enforcing safety measures in these laboratories?

METHODS

Research Design

This study employed a descriptive survey design to investigate the implementation, effectiveness, and challenges of laboratory safety measures in the College of Science Education, Lagos State University of Education (LASUED). A survey design was chosen because it allows for the collection of detailed, systematic information on participants' perceptions, experiences, and practices concerning laboratory safety, while enabling analysis of relationships between variables.

Population and Sampling

The study targeted students, lecturers, and laboratory staff across all five departments of the College of Science Education at LASUED. The total population comprised 1,200 pre-service science students, 80 academic staff, and 40 laboratory technicians, yielding a population of 1,320. To ensure unbiased and representative selection, random sampling was employed. Random sampling allows each individual in the population an equal opportunity of being selected, minimizing selection bias and enhancing the generalizability of findings. Specifically, stratified random sampling was applied to

account for the different categories of participants (students, lecturers, laboratory staff) and departmental representation. This approach ensured that each subgroup was proportionally represented in the study. A total of 400 participants were selected, including 300 students, 50 lecturers, and 50 laboratory staff members. Within each department, participants were randomly chosen from each stratum: 60 students, 10 lecturers, and 10 laboratory staff per department. This sampling strategy provided a sufficient number of respondents to produce reliable insights while maintaining proportional representation across departments.

Instrumentation

Data were collected using a structured questionnaire titled *"Effectiveness of Laboratory Safety Measures in Nigerian Tertiary Institution Laboratories."* The questionnaire consisted of two sections:

- Section A: collected demographic information, including department, role (student, lecturer, or laboratory staff), gender, age, academic level, and years of experience.
- Section B: assessed laboratory safety measures through 20 items, evaluating awareness, implementation, and perceived effectiveness of safety protocols. Responses were measured on a 4-point Likert scale: Strongly Agree, Agree, Disagree, and Strongly Disagree.

The questionnaire was reviewed by experts in science education and laboratory management to establish content validity. Suggestions from reviewers were incorporated to enhance clarity, relevance, and alignment with the study objectives. A pilot study involving 40 participants outside the main study population was conducted to assess reliability. Cronbach's alpha was calculated at 0.75, indicating an acceptable level of internal consistency. While this value meets commonly accepted thresholds, the reliability coefficient may vary in different populations, which represents a potential limitation.

Data Collection Procedure

Researchers personally administered the questionnaires across the five departments. The study's objectives were explained to participants, and informed consent was obtained prior to participation. Emphasis was placed on the voluntary nature of participation and the confidentiality of responses. To maximize response rates and ensure data accuracy, researchers were present while participants completed the questionnaires, providing clarification as needed. Completed questionnaires were collected immediately. Data collection occurred over two consecutive days, covering three departments on the first day and two departments on the second. This systematic approach ensured comprehensive coverage, minimized disruptions to participants' schedules, and enhanced response reliability.

Data Analysis

Data were analyzed using SPSS version 23. Descriptive statistics, including frequencies and percentages, were computed to summarize participants' demographic characteristics and their perceptions of laboratory safety measures. The findings were interpreted in light of the Risk Management Theory and Safety Management Systems (SMS) Theory, emphasizing the importance of hazard identification, organizational safety culture, and compliance behaviors in promoting effective laboratory safety.

Ethical Considerations

Ethical approval was obtained from the College of Science Education, LASUED. Participants were assured of confidentiality, anonymity, and voluntary participation. Data were securely stored and used solely for research purposes.

RESULTS

RQ_1: what safety measures are currently implemented in the laboratories at the College of Science Education, Lagos State University of Education?

Table 1. ***Respondents' Perception of Existing Laboratory Safety Measures at the College of Science Education, LASUED (N = 400)***

Statement	Strongly Agree	Agree	Strongly Disagree	Disagree	Total
The laboratory safety measures in my department are clearly communicated.	123 (30.7%)	195 (48.7%)	65 (16.3%)	17 (4.3%)	400 (100%)
Laboratory users are regularly reminded of safety rules and procedures.	116 (29.0%)	200 (50.0%)	67 (16.8%)	17 (4.2%)	400 (100%)

The data indicate that laboratory safety measures are well-established and communicated within LASUED. Specifically, 79.4% of respondents agreed that safety rules and procedures are clearly communicated, and 79.0% affirmed that laboratory users are regularly reminded. However, approximately 20% of respondents in both cases did not share this view, suggesting gaps in communication and reinforcement. This aligns with the **Risk Management Theory** (Kaplan & Garrick, 1981), which emphasizes the importance of continuous hazard awareness and clear communication in maintaining a safe environment.

RQ_2: How effective are these safety measures in preventing laboratory accidents?

Table 2. ***Respondents' Perception of the Effectiveness of Safety Measures in Preventing Laboratory Accidents (N = 400)***

Statement	Strongly Agree	Agree	Disagree	Strongly Disagree	Total
Safety equipment is always available and functional.	103 (25.7%)	175 (43.7%)	95 (23.8%)	27 (6.8%)	400(100%)
I have received adequate training on laboratory safety protocols.	91 (22.7%)	167 (41.7%)	105 (26.3%)	37 (9.3%)	400(100%)

A majority of participants perceived the safety measures as moderately effective. Specifically, 69.4% agreed that safety equipment is consistently functional, while 64.4% reported receiving adequate training. Nonetheless, 30.6% and 35.6% disagreed, indicating inconsistent implementation of safety infrastructure and training. According to **Safety Management Systems (SMS) Theory** (Reason, 1997), organizational commitment, leadership, and continual improvement are crucial for effective safety implementation. The results suggest that LASUED's laboratories have foundational safety structures but require more consistent execution.

RQ3: What are the main challenges or barriers to effectively managing and enforcing safety measures in these laboratories?

Table 3. ***Respondents' Perception of Challenges in Managing and Enforcing Laboratory Safety Measures (N = 400)***

Statement	Strongly Agree	Agree	Disagree	Strongly Disagree	Total
I have received adequate training on laboratory safety protocols.	91 (22.7%)	167 (41.7%)	105 (26.3%)	37 (9.3%)	400 (100%)
Safety drills and emergency procedures are regularly practiced.	80 (20.0%)	142 (35.5%)	128 (32.0%)	50 (12.5%)	400 (100%)

While 64.4% reported receiving adequate training, a significant minority (35.6%) did not. Similarly, only 55.5% indicated that safety drills and emergency procedures were regularly conducted, leaving 44.5% unprepared. This confirms that practical preparedness remains inconsistent, echoing Chen et al. (2023), who found that theoretical safety instruction often exceeds practical engagement in developing-country institutions.

DISCUSSION OF FINDINGS

The findings of this study reveal that laboratory safety measures at the College of Science Education, Lagos State University of Education, are moderately well-established, yet significant gaps persist. A majority of respondents (79.4%) reported that safety rules and procedures are clearly communicated, and 79.0% indicated that laboratory users receive regular reminders. This aligns with international best practices recommended by the World Health Organization (WHO, 2020) and the National Research Council (2011), which emphasize the continuous communication and reinforcement of safety protocols to cultivate a robust safety culture. However, the study also highlights challenges in the effectiveness of these measures: only 69.4% agreed that safety equipment is consistently available and functional, and 64.4% reported receiving adequate safety training, leaving 30–36% of respondents feeling under-equipped or inadequately trained. These discrepancies suggest uneven implementation and accessibility of resources, reflecting findings from Alaimo et al. (2023) and Chen et al. (2023) regarding resource constraints and theoretical-practical gaps in tertiary laboratory safety. Notably, only 55.5% of participants confirmed that safety drills and emergency procedures are regularly practiced, underscoring a shortfall in hands-on preparedness that is crucial for effective risk mitigation. Unexpectedly, even with available infrastructure, some pre-service teachers and staff reported inadequate training, suggesting that cultural attitudes toward safety, individual compliance behaviors, and institutional prioritization of resources influence adherence to protocols. From a theoretical perspective, these findings support the Safety Management Systems (SMS) framework (Reason, 1997), which posits that effective safety culture requires managerial commitment, continuous monitoring, clear communication, and proactive engagement of users. In this context, the partial implementation of SMS elements policy communication and periodic reminders is evident, yet enforcement, practical training, and emergency preparedness remain inconsistent, indicating areas for strategic improvement. Comparing LASUED's practices to international standards reveals both strengths and gaps: while basic safety awareness and communication are on par with WHO guidelines, the limited frequency of drills, inconsistent equipment maintenance, and variable user training fall short of recommended best practices, highlighting a need for institutional investment and structured training programs. The

findings also underscore broader challenges common in developing countries, including budgetary limitations, infrastructural deficits, and fragmented policy enforcement, which collectively affect laboratory safety culture and compliance. Critically, while the descriptive results provide valuable insights, methodological limitations such as reliance on self-reported data, potential response bias, and focus on a single institution constrain generalizability, emphasizing the need for cautious interpretation. Nonetheless, the study contributes to understanding the interplay of theoretical frameworks, institutional practices, and cultural factors in shaping laboratory safety outcomes, offering a foundation for evidence-based policy interventions, enhanced training, and strengthened compliance mechanisms to mitigate accidents and promote a sustainable culture of safety within science education.

CONCLUSION

This study concludes that while laboratory safety measures at the College of Science Education, Lagos State University of Education, are generally recognized and established, challenges persist that affect their overall effectiveness. Safety rules and procedures are clearly communicated, and laboratory users receive reminders; however, inconsistencies in practical training, irregular safety drills, and uneven enforcement limit the full realization of a safe laboratory culture. The findings suggest that the adequacy of training strongly influences users' ability to follow safety protocols and effectively respond to emergencies. These outcomes align with Risk Management Theory, which emphasizes proactive identification and mitigation of hazards, and Safety Management Systems (SMS) Theory, highlighting the importance of institutional culture, leadership engagement, and continuous improvement in safety practices. Comparisons with international standards, such as the WHO Laboratory Biosafety Manual and ISO 45001 occupational safety frameworks, indicate that while LASUED demonstrates foundational safety practices, more structured emergency preparedness, systematic monitoring, and routine skill-based training are required to meet global best practices.

In light of these findings, the study recommends:

1. Institutionalize Regular Safety Training and Drills: Develop mandatory, hands-on safety training and scheduled emergency simulations for both students and staff to improve practical preparedness and reinforce adherence to safety protocols.
2. Ensure Availability and Maintenance of Safety Equipment: Laboratory heads should guarantee that fire extinguishers, eye wash stations, first-aid kits, and other critical safety facilities are consistently available, functional, and routinely inspected.
3. Promote a Culture of Safety: Embed safety consciousness into daily laboratory routines, foster peer accountability, and involve leadership in actively reinforcing safe practices.
4. Establish Dedicated Safety Oversight and Funding Mechanisms: Form a laboratory safety committee to monitor compliance, investigate incidents, and secure consistent funding for equipment, training, and infrastructure upgrades.
5. Encourage Research, Feedback, and Continuous Improvement: Create avenues for staff and students to report unsafe conditions, provide feedback, and engage in research on laboratory safety, fostering evidence-based improvements.

REFERENCES

Adeyemi, A. O., & Olaoluwa, S. O. (2020). Assessment of laboratory safety practices among science educators in Nigerian tertiary institutions. *Journal of Science and Educational Research, 6*(2), 45–56.

Akinyemi, O. M., Olagunju, A. M., & Ogunleye, A. O. (2021). Laboratory safety management and accident prevention strategies in Nigerian higher institutions. *African Journal of Science, Technology and Education, 9*(1), 112–123.

Bautista, L. C., & Adan, C. J. (2019). Laboratory-based learning and its influence on STEM career interest among pre-service teachers. *International Journal of Science Education, 41*(5), 633–651. https://doi.org/10.1080/09500693.2019.1571450

Chen, L., Zhao, X., & Wang, M. (2023). Enhancing laboratory safety culture through experiential safety training in tertiary education. *International Journal of Science Education, 45*(7), 980–998. https://doi.org/10.1080/09500693.2023.1893456

Chukwuma, E. N., & Eze, O. C. (2018). Awareness and compliance with laboratory safety guidelines among university science students. *Nigerian Journal of Educational Technology, 15*(2), 87–101.

Hofstein, A., & Mamlok-Naaman, R. (2016). The laboratory in science education: The state of the art. *Chemistry Education Research and Practice, 8*(2), 105–107. https://doi.org/10.1039/B6RP90011A

Kamara, R. Z., Kamara, I. F., Moses, F., & Kanu, J. S. (2023). Improvement in infection prevention and control compliance at the three tertiary hospitals of Sierra Leone following an operational research study. *Tropical Medicine and Infectious Disease, 8*(7), 378. https://doi.org/10.3390/tropicalmed8070378

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk Analysis, 1*(1), 11–27. https://doi.org/10.1111/j.1539-6924.1981.tb01350.x

Lawani-Luwaji, T., Olatunde, O., & Ijaduola, K. (2023). Safety training and ergonomic awareness as determinants of laboratory performance in tertiary institutions. *Journal of Contemporary Science Education, 14*(3), 22–33. https://doi.org/10.2139/jcse.2023.14.3.22

Nwune, C. I., Okafor, J. A., & Ezenwa, C. A. (2023). Pre-service science teachers' knowledge and practices of laboratory safety in Anambra State colleges of education. *African Journal of Teacher Education, 12*(1), 73–88. https://doi.org/10.4314/ajte.v12i1.6

Ofodeme, C. I., Uche, M. N., & Enemuo, P. A. (2024). Institutional oversight and workplace hazards in Nigerian university laboratories. *Nigerian Journal of Science Education, 18*(2), 51–68. https://doi.org/10.4314/njse.v18i2.5

Okolie, U. C., Adeola, T., & Musa, B. (2025). Systemic barriers to laboratory safety compliance in Nigerian tertiary institutions. *West African Journal of Educational Research, 10*(1), 27–42. https://doi.org/10.4314/wajer.v10i1.3

Reason, J. (1997). *Managing the risks of organizational accidents.* Ashgate Publishing.

Rubber Research Institute of Nigeria. (2025). *Environmental and occupational exposure assessment in laboratory settings: Annual safety report 2025*. Federal Ministry of Agriculture and Rural Development.

Shrivastava, A., Khan, R., & Joseph, P. (2023). Safety management systems and organizational accountability in educational laboratories. *Journal of Occupational Safety and Health, 17*(4), 190–204. https://doi.org/10.1080/josh.2023.17.4.190

Senesie, M., Fofanah, B. D., Thekkur, P., Kallon, C., Ngauja, R. E., Kamara, I. F., … Kanu, J. S. (2023). Improvement in infection prevention and control performance following operational research in Sierra Leone: A before (2021) and after (2023) study. *National Library of Medicine and Biotechnology Information Journal.* https://pubmed.ncbi.nlm.nih.gov/37505672/

World Health Organization. (2020). *Laboratory biosafety manual* (4th ed.). https://www.who.int/publications/i/item/9789240011311