EVALUATION OF LABORATORY SAFETY MEASURES AND MANAGEMENT PRACTICES FOR PREVENTING LABORATORY ACCIDENTS AMONG UNDERGRADUATE SCIENCE EDUCATION STUDENTS

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Abstract

Science education relies heavily on laboratory activities to develop students' scientific inquiry skills, making laboratory safety a critical component of effective teaching and learning in undergraduate science programmes. The study investigated safety measures and management practices for preventing laboratory accidents among undergraduate science education students. Five research questions guided this study. A descriptive survey research design was adopted for the study. The study population comprises 682 students from the Department of Science Education at Nnamdi Azikwe University, Awka, Anambra State, Nigeria. A sample of 357 students was selected using a stratified, simple random sampling technique. The instruments used for the study included a researcher-developed, validated questionnaire. A reliability index of 0.89 was obtained using Cronbach's alpha. The mean and standard deviation were used to analyse the data with respect to the research questions. The study revealed that undergraduate science education students have high awareness of laboratory safety protocols. The existing laboratory safety education programmes include web-based training, videos, and quizzes on laboratory safety. The management practices related to laboratory safety include prioritising safety as a core value, involving group leaders in safety initiatives, and enforcing laboratory safety policies and procedures. The challenges affecting effective laboratory safety practices include inadequate training and orientation, insufficient resources and funding, inadequate emergency preparedness and response, poor communication and teamwork, and inadequate incident reporting and investigation. The ways forward to adhering to safety laboratory measures include creating a comprehensive safety manual, providing regular training and orientation on safety measures and emergency procedures, and conducting regular safety inspections to address potential hazards. The study recommends that lecturers promote students' awareness of proper handling, storage, and disposal of hazardous materials and safety signs.

Keywords: laboratory safety, safety awareness, science education, safety management practices, accident prevention

Introduction

Science is a systematic approach to understanding natural phenomena through inquiry, logical reasoning, and empirical investigation (Ministry of National Education, 2018). Nwele (2023) and Klaavuniemi and Siponen (2020) define science as the study of nature and natural events, which calls for a number of methodical techniques and engagement abilities. Science describes and explains natural occurrences through experimentation and observation as a methodical approach to knowledge acquisition and scientific inquiry (Nwafor et al., 2024; Okeke, 2017). Therefore, science is systematic in its approach. This view was supported by Al-Dahhan, Ali, and Yousif (2017) and Hieronymi (2015), who claimed that scientific experimentation is crucial to the advancement of science because laboratory research has enabled several inventions and groundbreaking discoveries. Science education is improved and made more interesting by the study of science, preparing students for success in a world that is becoming more and more scientific and technological.

For any country to develop, science education is crucial. In both formal and informal contexts, it introduces students to science concepts and procedures. The process of teaching and learning about the natural world, comprising the earth and space sciences as well as the physical, biological, and chemical sciences, is known as science education (National Research Council, 1996). According to Bybee (2023), scientific education is an endeavour that aims to prepare students for jobs in science, technology, engineering, and mathematics (STEM) and to help them comprehend and explain the natural world. In Nigerian senior secondary schools, science education consists mostly of three subjects: biology, chemistry, and physics (Aina, 2023). A functional and well-equipped laboratory is expected in every school. Only a small number of secondary schools typically offer separate labs for these three scientific courses. The West African Examination Council (WAEC) and the National Examination Council (NECO) require graduates to possess practical science knowledge and skills in order to pass the Senior School Certificate Examination (SSCE). This is implied by the functions of science laboratories in science teaching and learning (Omiko, 2015). Omiko emphasised that these kids would not have the necessary credentials to enrol in classes such as agricultural science, engineering, medicine, or other science-related fields.

According to Dienye and Gbamanja (2019), a laboratory is a space, structure, or even a period of time designated for conducting experimental research. According to Igwe (2020), a laboratory is a place where people can learn about science and the methods used by scientists. It can take place outside, at riverbanks, in workshops, or beneath a tree, or indoors, in a well-planned and furnished space

available in most schools. The science teacher uses the laboratory as a teaching tool to teach pupils about science and how scientists study their surroundings (Nbina, 2023). For this reason, according to Muhammad (2017), the scientific lab is a unique space where students can practise science. It is a school facility dedicated to scientific research and discoveries. Students can experience and take part in demonstration activities in the laboratory, which provide them the chance to solve problems and gain a grasp of academic and practical topics. Students' talents and skills, such as formulating hypotheses, developing and carrying out scientific experiments, presenting and defending scientific arguments, and posing scientifically orientated questions, are developed through the laboratory inquiry process (Aziaka & Aderonmu, 2016). Through the development of manipulative abilities, the laboratory helps students understand and, to some extent, replicate the function of the scientist. Laboratory experience helps learn key scientific concepts, models, principles, and hypotheses and comprehend their tentative character (Dienye & Gbamanja, 2019). However, chemists and scientists use materials and chemicals that could be hazardous or dangerous to themselves and other people working with them throughout their laboratory work. This fact emphasises how crucial it is to put in place efficient safety procedures and management techniques to guarantee secure laboratory settings, especially for undergraduate students who frequently lack expertise handling dangerous compounds.

Safety is the state of no harm, risk, danger, or loss. It is the ability to avoid or prevent harm, danger, or loss. According to Aziaka and Aderonmu (2016), it can also be viewed as a conscious effort to prevent or lessen risk, make sensible decisions, and actively manage your health. When a laboratory is built with appropriate access and a plan that allows staff to move freely in the event of an emergency, it is deemed safe (Safety, 2024). Adopting neat and orderly habits, following excellent laboratory procedures, maintaining discipline, strictly forbidding unapproved practical work, and teachers' awareness of the risks involved are the cornerstones of laboratory safety. Students and school personnel share responsibilities for laboratory safety. The process of addressing issues using scientific methods to take measures and prevent malfunctions and hazards related to tools, machinery, and equipment is known as laboratory safety. Furthermore, it outlines the risks associated with laboratory-based research (Bayrak & Ağaoğlu, 2019). The dangers connected to procedures like the use, labelling, storage, and waste disposal of chemicals in science classes are covered by laboratory safety in schools, along with the safety measures and practical management techniques that must be implemented in educational settings. Everyone who is exposed to hazardous materials and the risks associated with routine laboratory equipment operation must

take safety into account. Much work has been done to enhance safety education in order to prevent accidents (Wu et al., 2020). Thus, students' comprehension, application, and adherence to laboratory safety measures are directly impacted by the quality of safety management in science education programs.

Other elements that impact laboratory safety include glassware and equipment, electrical and fire mishaps, and biological risks. Among the steps to take before possible incidents happen include wearing personal protection equipment and being aware of first aid. According to Ottander and Grelsson (2016), one goal of a science lab is to foster interest in science and the growth of analytical and critical thinking abilities. Additionally, it disproves the widespread notion that science is a difficult subject of study by encouraging scientific mindsets and the thrill and love of learning. Students are able to comprehend the workings of the natural world around them in more real and useful terms thanks to the knowledge they get from science classes with significant laboratory components.

Statement of the Problem

Laboratory accidents pose a significant threat to the health, well-being, and academic success of science students. Despite the importance of laboratory safety protocols, accidents continue to occur, resulting in injuries, illnesses, and even fatalities. The consequences of laboratory accidents can be severe and long-lasting, underscoring the need for effective safety measures to prevent them.

Undergraduate science students are particularly vulnerable to laboratory accidents due to their limited experience and training in handling hazardous materials and equipment. Inadequate safety measures, insufficient supervision, and a lack of awareness about potential hazards contribute to the risk of accidents in science laboratories. Furthermore, the pressure to complete experiments and meet deadlines can lead to shortcuts and compromises on safety protocols, increasing the likelihood of accidents.

The lack of effective safety measures in science laboratories underscores the need for a comprehensive study to assess current laboratory safety practices and identify strategies to prevent laboratory accidents. This study aims to address safety measures for preventing laboratory accidents among undergraduate science education students by examining current safety protocols, identifying gaps and weaknesses, and recommending effective safety strategies to ensure a safe learning environment.

Research Questions

The following five research questions guided the study:

1. What is the current awareness of laboratory safety protocols among

undergraduate science education students?

2. What are the existing laboratory safety education programmes in promoting safety awareness among science education students?
3. What are the management practices related to laboratory safety within the science education programmes?
4. What are the challenges in current laboratory safety practices for enhancing safety protocols and reducing the incidence of laboratory accidents?
5. What are the ways forward to adhering to safety measures within laboratory settings among undergraduate science education students?

Methodology

A descriptive survey research design was adopted for the study. According to Nworgu (2018), descriptive survey research design is one in which a group of people and items are studied by collecting and analysing data from only a few people, considered representatives of the entire group. A descriptive survey design is appropriate for this study, as respondents were asked to complete a questionnaire. This study was conducted at Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The population of the study comprised all the science education students in the 2023/2024 session of the Faculty of Education, Nnamdi Azikiwe University, Awka. The total population was 682 undergraduate science education students, with a sample size of 357. They were selected from the total population using stratified random sampling. The population was stratified based on programmes within the Departments of Science Education. The respondents were finally selected using a simple random sampling technique by balloting without replacement.

The instrument used for data collection was a researcher-constructed questionnaire titled "Questionnaire on the Awareness, Safety Measures and Prevention of Laboratory Accidents among Undergraduate Science Education Students (QASMPLAUSES)". The instrument was divided into five clusters based on the research questions. The questionnaire items were rated on a four-point Likert scale: Strongly Agree (SA=4), Agree (A=3), Disagree (D=2), and Strongly Disagree (SD=1). The instrument for the study was validated by three experts, two from the Department of Science Education and one from the Department of Educational Foundations (Measurement and Evaluation unit), all in the Faculty of Education, Nnamdi Azikiwe University, Awka. To assess the instrument's reliability, the questionnaire was administered to 30 students randomly selected from Chukwuemeka Odumegwu Ojukwu University, Igbariam, Anambra State. The data obtained from the administered questionnaire were analysed using Cronbach's alpha. The reliability index was 0.89, indicating that the instrument is highly

reliable, according to Nworgu (2018). The researcher went to administer the questionnaire to the respondents on the spot. All completed questionnaires were retrieved immediately from respondents to avoid delays and incomplete returns. In analysing the data collected, the mean and standard deviation were used. The decision rule to determine students' awareness of laboratory safety protocols was a mean of 2.5 and above for high awareness and a mean of 2.49 and below for low awareness. For research questions two to five, any mean score range from 2.50 and above was accepted, while scores from 2.49 and below were rejected.

Results

Research Question One: What is the current awareness of laboratory safety protocols among undergraduate science education students?

Table 1: Mean and standard deviation of the current awareness of laboratory safety protocols among undergraduate science education students

S/N	Statement	Mean	SD	Remark
1.	I am aware of the importance of wearing appropriate PPE, such as gloves, goggles, and lab coats, to prevent exposure to hazardous materials.	2.87	1.26	High
2.	I familiarize myself with the handling, storage, and disposal of chemicals, including understanding Material Safety Data Sheets (MSDS).	2.73	1.18	High
3.	I am aware of the safe operation, maintenance, and troubleshooting of laboratory equipment.	2.87	0.96	High
4.	I am aware of emergency procedures, including evacuation routes, fire extinguishers, and spill response protocols.	2.80	1.11	High
5.	I ensure that all laboratory personnel receive proper training and orientation on laboratory safety protocols.	3.00	1.04	High
6.	I regularly review and update laboratory safety protocols to ensure they remain effective and relevant.	2.38	0.99	Low
	Cluster Mean	**2.78**	**0.84**	**High**

The results in Table 1 show that items 1, 2, 3, 4, and 5 had high awareness, while item 6 had low awareness. Moreover, 2.78 and 0.84 were obtained as the overall mean score and standard deviation, respectively. This indicates that undergraduate science education students have a high awareness of laboratory safety protocols. However, the results showed that undergraduate science education students do not regularly review or update their knowledge of laboratory safety protocols to ensure they remain effective and relevant in their practice.

Research Question Two: What are the existing laboratory safety education programmes in promoting safety awareness among science education students?

Table 2: Mean and standard deviation of the existing laboratory safety education programmes in promoting safety awareness among science education students

S/N	Statement	Mean	SD	Remark
1.	I am involved in hands-on training sessions, lectures, and workshops.	2.40	1.09	Rejected
2.	I undergo web-based training programs, videos, and quizzes on laboratory safety	2.60	1.09	Accepted
3.	I am exposed to written resources outlining laboratory safety protocols.	2.67	0.95	Accepted
4.	I share my laboratory safety experience with new research personnel	2.87	1.03	Accepted
5.	I practice quick response to emergencies, such as spills or fires.	2.73	1.07	Accepted
6.	I do recognize individuals who complete their safety training programs.	2.67	1.14	Accepted

The result in Table 2 shows that items 8, 9, 10, 11 and 12 with mean scores of 2.60, 2.67, 2.87, 2.73 and 2.67 respectively, were all accepted since there mean scores were above the mean cut-off point of 2.50 whereas item 7 with a mean score of 2.40 was rejected because it has a mean score below the mean cut-off point. This indicates that the existing laboratory safety education programs in promoting safety awareness among science education students include undergoing web-based training programs, videos, and quizzes on laboratory safety, being exposed to written resources outlining laboratory safety protocols, sharing laboratory safety experience with new researcher personnel, practicing quick response to

emergencies, such as spills or fires and recognizing individuals who complete their safety training programs.

Research Question Three: What are the management practices related to laboratory safety within the science education programmes?

Table 3: Mean and standard deviation of the management practices related to laboratory safety within the science education programmes

S/N	Statement	Mean	SD	Remark
1.	I prioritise safety as a core value and demonstrate it through leadership commitment and resource allocation.	3.06	1.00	Accepted
2.	The group leaders are actively involved in safety initiatives, setting the tone for a culture of safety.	2.87	0.72	Accepted
3.	I develop and enforce laboratory safety policies and procedures	3.00	0.73	Accepted
4.	I conduct regular safety audits and risk assessments for safety laboratory measures	3.00	0.82	Accepted
5.	I provide training and orientation for new students and staff for their safety in the laboratory	3.13	0.81	Accepted
6.	I implement chemical handling and disposal procedures for the safety laboratory	2.93	1.18	Accepted

The results in Table 3 show that all items 13, 14, 15, 16, 17 and 18 were accepted, as their mean scores were above the mean cut-off point of 2.50. This indicates that the management practices related to laboratory safety within the science education programmes include prioritizing safety as a core value, ensuring that group leaders are actively involved in safety initiatives, setting the tone for a safety-focused culture, developing and enforcing laboratory safety policies and procedures, conducting regular safety audits and risk assessments for safety laboratory measures, providing training and orientation for new students and staff for safety laboratory and implementing chemical handling and disposal procedures for safety laboratory.

Research Question Four: What are the challenges in current laboratory safety practices for enhancing safety protocols and reducing the incidence of laboratory accidents?

Table 4: Mean and standard deviation of the challenges in current laboratory safety practices for enhancing safety protocols and reducing the incidence of laboratory accidents

S/N	Statement	Mean	SD	Remark
1.	Inadequate training and orientation	3.07	1.00	Accepted
2.	Insufficient resources and funding	3.33	0.87	Accepted
3.	Lack of standardization and consistency	3.40	0.49	Accepted
4.	Inadequate emergency preparedness and response	3.27	0.77	Accepted
5.	Poor communication and teamwork	2.87	0.89	Accepted
6.	Inadequate incident reporting and investigation	3.07	0.93	Accepted

The results in Table 4 show that all the items 19, 20, 21, 22, 23, and 24, with mean scores of 3.07, 3.33, 3.40, 3.27, 2.87, and 3.07, respectively, were accepted because their mean scores were above the mean cut-off point of 2.50. This indicates that the challenges in current laboratory safety practices for enhancing safety protocols and reducing the incidence of laboratory accidents include inadequate training and orientation, insufficient resources and funding, lack of standardization and consistency, inadequate emergency preparedness and response, poor communication and teamwork and inadequate incident reporting and investigation.

Research Question Five: What are the ways forward to adhering to safety measures within laboratory settings among undergraduate science education students?

Table 5: Mean and standard deviation of the ways forward to adhering to safety measures within laboratory settings among undergraduate science education students

S/N	Statement	Mean	SD	Remark
1.	I create a comprehensive safety manual outlining laboratory safety policies, procedures, and protocols.	3.02	0.96	Accepted
2.	I provide regular training and orientation sessions for laboratory personnel on safety measures and emergency procedures.	3.03	1.07	Accepted
3.	I conduct regular safety inspections to identify and address potential hazards.	3.13	0.96	Accepted

4.	I ensure the availability and proper use of Personal Protective Equipment (PPE), such as gloves, goggles, and lab coats.	3.08	1.06	Accepted
5.	I develop and regularly practice emergency response plans, including evacuation procedures and spill response protocols.	3.07	1.00	Accepted
6.	I organise safety awareness programs, such as seminars, workshops, and campaigns, to promote safety culture.	3.16	0.99	Accepted

The results in Table 5 show that all items 25, 26, 27, 28, 29, and 30 were accepted, as their mean scores were above the mean cut-off point of 2.50. This indicates that the ways forward to adhering safety measures within laboratory settings among undergraduate science education students include creating a comprehensive safety manual outlining laboratory safety policies, procedures, and protocols, providing regular training and orientation sessions for laboratory personnel on safety measures and emergency procedures, conducting regular safety inspections to identify and address potential hazards, ensuring availability and proper use of Personal Protective Equipment (PPE), such as gloves, goggles, and lab coats, developing regularly practice emergency response plans, including evacuation procedures and spill response protocols and organizing safety awareness programs, such as seminars, workshops, and campaigns, to promote safety culture.

Discussion

The study found that undergraduate science education students have high awareness of laboratory safety protocols. However, the results showed that undergraduate science education students do not regularly review or update their knowledge of laboratory safety protocols to ensure they remain effective and relevant in their practice. The study's findings agree with the findings of Oludipe and Etobro (2018), who found that students demonstrated awareness in their responses to questions relating to good/safe practices, appropriate attire, and emergency procedures. However, the present study revealed two important safety issues where student awareness was alarmingly lacking: clean-up of spills and recognition of laboratory signs/symbols. Conversely, this study's findings differ from those of Ikiroma et al. (2021), who reported low awareness of safety signs.

The findings of the study showed that the existing laboratory safety education programmes in promoting safety awareness among science education students include undergoing web-based training programs, videos, and quizzes on laboratory safety, being exposed to written resources outlining laboratory safety

protocols, sharing laboratory safety experience with new researcher personnel, practicing quick response to emergencies, such as spills or fires and recognizing individuals who complete their safety training programs. This finding is in agreement with the study of Hu et al (2024) which affirmed that implementing these particular procedures (the experiment instructor provides safety instruction related to the experiment's subject matter before each class, and the laboratory teaching assistant gradually increases students' awareness of safety as the class moves forward) had a substantial impact on students' comprehension of laboratory safety standards and heightened their consciousness of laboratory safety. In addition to their findings, Hu et al. (2024) developed a user-friendly, multi-tiered dual-teacher teaching approach that has been of great help in cultivating and enhancing laboratory safety awareness among local higher education students. This method offers practical guidance for incorporating comprehensive safety education into regular laboratory courses, thereby improving college students' safety awareness and practices in teaching laboratories. Similarly, Townsend and Goffe (2022) stressed the need to use online and web-based safety education, including videos and multimodal learning tools and written safety resources, for laboratory safety in remote settings.

The findings of the study showed that the management practices related to laboratory safety within the science education programmes include prioritizing safety as a core value, ensuring that group leaders are actively involved in safety initiatives, setting the tone for a safety-focused culture, developing and enforcing laboratory safety policies and procedures, conducting regular safety audits and risk assessments for safety laboratory measures, providing training and orientation for new students and staff for safety laboratory and implementing chemical handling and disposal procedures for safety laboratory. This is in line with the findings of the National Science Foundation (2020), which asserts that there are significant gaps in laboratory safety management practices within Science Education. Notably, 75% of participants reported inadequate training on laboratory safety procedures, underscoring the need for comprehensive workshops and regular updates. The findings of Ezenwa et al. (2021) also align with those of the present study, as they showed that leadership involvement in laboratory safety, enforcement of procedures and protocols, and promotion of safety audits serve as management practices in academic and industrial chemical laboratories. Moreover, Yazdi (2025) stressed the need for excellent leadership to promote training and a safety-first culture, thereby improving institutional performance.

The findings of the study showed that the challenges in current laboratory

safety practices for enhancing safety protocols and reducing the incidence of laboratory accidents include inadequate training and orientation, insufficient resources and funding, lack of standardisation and consistency, inadequate emergency preparedness and response, poor communication and teamwork and inadequate incident reporting and investigation. This finding is in agreement with the National Science Foundation (2020), which opined that the respondents reported inadequate training on laboratory safety procedures (75%) and limited availability of safety equipment and materials (60%). Additionally, the National Science Foundation emphasises the importance of comprehensive training and resource allocation for laboratory safety. The findings are also consistent with those of Quan (2024), who highlighted the lack of training, insufficient safety awareness, and inadequate safety facilities as challenges to mitigating safety risks in chemical laboratories in universities. Alqahtany et al. (2024) found that challenges to laboratory safety measures include PPE shortages, inadequate training, poor infrastructure, overcrowded spaces, and high workloads.

The findings of the study showed that the ways forward to adhering safety measures within laboratory settings among undergraduate science education students include creating a comprehensive safety manual outlining laboratory safety policies, procedures, and protocols, providing regular training and orientation sessions for laboratory personnel on safety measures and emergency procedures, conducting regular safety inspections to identify and address potential hazards, ensuring availability and proper use of Personal Protective Equipment (PPE), such as gloves, goggles, and lab coats, developing regularly practice emergency response plans, including evacuation procedures and spill response protocols and organizing safety awareness programs, such as seminars, workshops, and campaigns, to promote safety culture. These findings agree with those of Wang et al. (2025) who emphasised the need for comprehensive laboratory safety, the use of PPE, clear safety policies and protocols, risk mitigation and adequate storage procedures. Similarly, Antoniadi et al. (2025) highlighted the need to integrate safety culture into academic institutions, conduct frequent safety drills, ensure emergency preparedness, and ensure the availability of PPE. The findings of this study are also in line with the National Science Foundation (2020), which emphasizes the importance of comprehensive training and resource allocation for laboratory safety.

Conclusion

The study on safety measures to prevent laboratory accidents among undergraduate science education students concludes that implementing comprehensive safety protocols is crucial for minimizing the risk of such accidents.

The findings highlight the importance of integrating laboratory safety training into the science curriculum, providing adequate resources, and fostering a safety-conscious culture within institutions. The study also emphasizes the need for clear safety protocols, regular safety audits, and incentives for reporting safety concerns. Notably, the research reveals that students' attitudes towards laboratory safety significantly improve when they receive comprehensive training and are engaged in safety education. This underscores the value of student-centred approaches in promoting laboratory safety.

The study's conclusions have far-reaching implications for science education policy and practice. Government and institutions must prioritise laboratory safety, allocate sufficient resources, and develop evidence-based safety guidelines to ensure consistency across institutions. Ultimately, the study reaffirms that laboratory safety is a shared responsibility among educators, administrators, policymakers and students. By working together to implement effective safety measures, institutions can protect students and staff, promote scientific inquiry, and foster a culture of safety and responsibility.

Recommendations

Based on the findings of this study, some recommendations were made:

1. Proper awareness of chemical handling, storage, and disposal should be promoted using hands-on and real-life case studies during laboratory instruction.
2. Universities should maintain continuous safety training for both lecturers, students, group leaders, and technologists to maintain competence in management practices, hazard identification and emergency responses.
3. Institutions should ensure a comprehensive laboratory safety education programme to expose students to various forms of safety, including web-based modules, videos, quizzes, and written and safety materials.
4. A strong safety culture should be promoted within science education programmes by developing and enforcing a laboratory safety manual, policies and procedures for both staff and students.
5. Focus must be paid to learning and assessing practical parts of laboratory procedures and first aid techniques during lectures and experimentation.
6. Government and institutions should provide funding to address challenges such as inadequate training, poor communication and insufficient resources in the university laboratories.

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