

Evaluating the Availability and Effectiveness of Safety Equipment in Chemistry Laboratories at Public Colleges of Education in Ghana

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Abstract

This study critically evaluates the state of safety equipment in chemistry laboratories across public colleges of education in Ghana, alongside assessing the level of safety awareness among Pre-Service Science Teachers. The research is driven by two primary objectives: to assess the current status and availability of safety equipment and materials in these laboratories, and to evaluate the awareness and understanding of safety measures among pre-service science teachers. Utilizing a mixed-methods approach within a pragmatic research paradigm, the study integrates quantitative data from structured questionnaires and qualitative insights from focus group interviews to provide a comprehensive analysis. The findings reveal significant deficiencies in laboratory safety equipment, with a notable lack of essential items such as fire blankets, first aid kits, and adequate personal protective equipment. Furthermore, the study highlights variability in the availability and functionality of safety features such as fume hoods and safety manuals. The qualitative data provides deeper insights into the challenges faced by institutions, the gaps in safety practices and the level of awareness among pre-service teachers. The results underscore the need for enhanced safety protocols, more robust training programs, and better resource allocation to align with international safety standards. The significance of this research lies in its potential to influence safety standards and policy development within Ghanaian educational institutions, thereby contributing to improved laboratory safety and enhanced science education. The study's implications extend to informing policymakers and educators on necessary improvements and fostering a safer learning environment in chemistry laboratories.

Keywords

Safety Equipment, Chemistry Laboratories, Public Colleges of Education, Ghana, Laboratory Safety, Equipment Availability, Maintenance Practices, Accident Prevention, Safety Standards, Laboratory Management

1. Introduction

The availability and effectiveness of safety equipment in chemistry laboratories are fundamental to ensuring a safe working environment for both students and staff. In Ghanaian public colleges of education, maintaining and enhancing laboratory safety presents unique challenges due to limited resources and infrastructural constraints. Research indicates that while safety equipment is crucial for mitigating risks associated with chemical experiments, its effectiveness is influenced by factors such as availability, proper usage, and adherence to safety protocols.

Studies reveal significant disparities in the availability of modern safety equipment within these institutions. For example, [Agyei et al. \(2021\)](#) found that budgetary constraints and a lack of prioritization have led to inadequate provision of essential safety devices like fume hoods, safety showers, and eyewash stations. Similarly, [Nyarko and Owusu \(2022\)](#) noted that the condition of existing equipment often undermines its effectiveness, with outdated or poorly maintained devices failing to provide adequate protection.

The effectiveness of safety equipment is further impacted by its utilization and the adherence to safety protocols. Research by [Mensah et al. \(2020\)](#) highlights that even when safety equipment is available, improper use due to insufficient training can lead to ineffective protection and increased accident risk. Regulatory frameworks and institutional policies are crucial for enforcing correct usage, with [Osei-Asibey et al. \(2021\)](#) emphasizing the importance of safety programs and regular audits in promoting a culture of safety.

Personal protective equipment (PPE) and specialized safety devices are essential for safeguarding laboratory personnel. Studies demonstrate that appropriate use of PPE, including gloves, lab coats, and safety goggles, significantly reduces the risk of chemical exposure and injuries ([Azadeh et al., 2017](#)). Effective ventilation systems, such as well-maintained fume hoods, are also critical for controlling hazardous fumes ([Le et al., 2019](#)). Furthermore, clear and visible safety signage improves compliance and reduces accidents ([Díaz et al., 2018](#)), while robust emergency systems, including emergency showers and eyewash stations, provide crucial relief during chemical exposures ([Oliveira et al., 2015](#)).

The empirical review underscores the need for substantial improvements in safety equipment, training, and protocols in Ghanaian public colleges of education. Studies by [Agrawal and Choudhary \(2014\)](#) and [Akinola \(2020\)](#) emphasize gaps in safety measures and training, while the [American Chemical Society's \(2016\)](#) guidelines and findings by [Amponsah-Tawiah et al. \(2016\)](#) reveal defi-

ciencies in PPE, risk assessments, and emergency response plans. Additionally, [Ayyildiz and Bal \(2019\)](#) link enhanced safety awareness with improved laboratory performance. Addressing these gaps through better investment, maintenance, and training is crucial for creating a safer and more effective laboratory environment in these educational settings.

1.1. Statement of the Problem

The problem at hand involves a critical evaluation of the safety equipment/materials availability in chemistry laboratories within Colleges of Education in Ghana. Despite the significance of practical laboratory work in reinforcing theoretical knowledge in chemistry education, there is a notable discrepancy between the established safety regulations and their implementation in educational settings.

[The Ghana Labour Act \(2003\)](#) mandates that employers ensure safe working conditions in work places, including in chemistry laboratories. However, existing research indicates that academic laboratories, including those in Ghanaian Colleges of Education, often suffer from inadequate safety measures, insufficient safety equipment, and inconsistent adherence to safety protocols. This inadequacy is exacerbated by the fact that many institutions only implement higher levels of safety controls when legally compelled, rather than proactively adopting comprehensive safety practices.

Furthermore, there is a significant lack of specific studies assessing the safety status of chemistry laboratories within Ghanaian Colleges of Education. This gap in research impedes the development of targeted interventions to address safety deficiencies and improve laboratory conditions.

The overarching issue is the disparity between the safety standards mandated by law and their actual implementation within chemistry laboratories. This research aims to address this problem by evaluating the current status of safety equipment/materials in these laboratories, identifying gaps, and providing recommendations to enhance safety practices.

1.2. Objectives of the Study

In order to address the critical importance of laboratory safety in chemistry education, this study aims to:

- 1) Assess the current state and availability of safety equipment and materials in chemistry laboratories within public colleges of education in Ghana.
- 2) Evaluate the level of awareness and understanding of safety measures among Pre-Service Science Teachers in public colleges of education in Ghana.

1.3. Research Question

The study was guided by the following research questions.

- 1) What is the state/status of safety equipment/materials in chemistry laboratories in public colleges of education in Ghana?

2) What is the level of awareness of safety measures among Pre-Service science Teachers?

1.4. Purpose of the Study

The purpose of this study is to critically evaluate the availability and effectiveness of safety equipment in chemistry laboratories within Colleges of Education in Ghana. It thus examines whether the existing safety equipment/materials in these laboratories align with the international standards and other relevant safety regulations.

1.5. Significance of the Study

The significance of this study lies in its potential to impact several critical areas related to chemistry education and laboratory safety in Ghanaian Colleges of Education:

1) **Enhancement of Safety Standards:** By evaluating the current state of safety equipment in chemistry laboratories at the colleges of education in Ghana, the study will provide valuable insights into the availability and effectiveness of existing safety equipment. This will help identify deficiencies and areas for improvement, which could lead to the development of more robust safety standards and practices.

2) **Informed Policy Development:** The findings will offer evidence-based recommendations that can guide policymakers, educational authorities, and college administrators in formulating or revising policies related to laboratory safety. This can lead to more effective implementation of safety regulations and standards in educational settings.

3) **Contribution to Academic Literature:** By filling a gap in existing research on laboratory safety in Ghanaian educational institutions, the study will contribute to the academic discourse on science education and safety management. This can inform future research and discussions on improving laboratory safety in similar contexts.

Overall, the study aims to foster a safer and more effective learning environment in chemistry laboratories, ultimately contributing to the quality of science education in Ghana.

2. Methodology

2.1. Research Paradigm

Pragmatic paradigm is the philosophical assumption underpinning the study. Paradigm. It focuses on using the most effective philosophical and/or methodological approach for the research problem (Maxcy, 2003; Tashakkori & Teddlie, 2003). Pragmatism supports the use of mixed-methods to address research questions effectively (Creswell et al., 2011). The study aligns with pragmatism by exploring the current state of safety equipment in chemistry laboratories and

gathering perspectives from chemistry tutors and pre-service science teachers.

2.2. Research Approach

The Mixed methods research approach, integrating both quantitative and qualitative data to provide a rich understanding of the phenomenon (Creswell & Poth, 2016) was adopted for the study.

2.3. Research Design

Concurrent triangulation design, involving simultaneous collection and analysis of both quantitative and qualitative data, with equal weight given to each (Creswell et al., 2003) was used for the study. This design facilitates comprehensive understanding and compensates for biases in single-method approaches.

2.4. Research Population

In the present study all Chemistry tutors and pre-service science teachers at the 18 Public Science Colleges of Education in Ghana constituted the target population. The accessible population was made up of all the thirty-eight (38) chemistry tutors and the 2023 level 300 pre-service science teachers numbering 846 in the 18 Science Colleges of Education in Ghana who study elective chemistry, giving a total population size of 884.

The eighteen (18) Public Science Colleges of Education were chosen because they have chemistry laboratories where elective chemistry practical sessions take place. The level 300 chemistry students were selected because they had offered a course in chemistry, “Particulate nature of Chemistry” which involved practical work. Again, at the time of data collection, they were on campus and were still using the chemistry laboratory for their studies and so were deemed to be in a good position to have a holistic view of the status of their college’s chemistry laboratory.

2.5. Sample and Sampling Techniques

Probability Sampling was used to select 16 colleges from the 18 available, ensuring equal chances of selection (Yamane, 1967). Purposive sampling was used for focus group interviews, selecting participants based on specific characteristics.

One hundred and ninety-two (192) participants consisting of 32 chemistry tutors and 160 pre-service science teachers were chosen. To ensure proportional representation of males and females in each of a ten-member focus groups, stratified random sampling techniques was adopted.

2.6. Research Instruments

Questionnaires were used for collecting quantitative data from chemistry tutors about laboratory safety.

Interview Guides were also used to gather in-depth qualitative data from pre-service science teachers.

The study also employed Observation Guide to elicit firsthand data on laboratory conditions in the various colleges.

2.7. Validity and Reliability

The validity of these instruments was ensured through the use of established research instruments and triangulation of data.

Equally, the reliability of the instruments was enhanced by using a combination of quantitative and qualitative methods to corroborate findings. The validity and reliability of research instruments were further enhanced by pilot testing the instruments on colleges that were outside the selected colleges of education. This allowed for a refined question formats and scales (Lam, 2019).

2.8. Data Collection Procedure

Quantitative data were collected via researcher administered structured-observation guide and questionnaires administered to chemistry tutors. Also, qualitative data were gathered through focus group interviews with pre-service science teachers.

2.9. Method of Data Analysis

The quantitative data were statistically analyzed using SPSS Version 27.0, with descriptive statistics such as frequencies, percentages, means, and standard deviations calculated from the questionnaires and structured observation guides, and results presented in tables and bar charts. Meanwhile, qualitative data from focus group interviews were audio recorded, transcribed by a professional, and subjected to thematic analysis. This process involved familiarization with the transcripts, systematic coding using qualitative data analysis software, categorization into themes and sub-themes, and triangulation with quantitative data to enhance validity and minimize bias. This rigorous methodology ensured a comprehensive analysis, providing a robust foundation for the study's conclusions.

3. Ethical Approval

Written permission was obtained from the Committee on Human Research Publications and Ethics (CHRPE), KNUST, and relevant educational authorities.

Participants signed consent forms and were informed of their right to withdraw at any time.

- Anonymity: Ensured through anonymizing responses and maintaining confidentiality.

- Data Handling: Data was handled with strict confidentiality, and participants' identities were kept anonymous. The research instruments were validated to avoid biases and ensure fairness.

- Respect for Research Sites: The research sites were respected, and the environment was left undisturbed after the study.

3.1. Results and Discussion

The demographic data of respondents offer valuable insights into the characteristics of chemistry tutors within the Colleges of Education, essential for contextualizing the research on laboratory safety (Table 1).

Table 1. Gender distribution of respondents.

Male	28 (87.5%)
Female	4 (12.5%)

The data reveal a notable gender imbalance among respondents, with a predominant male representation. This disparity may reflect broader trends or specific recruitment practices within these institutions, suggesting a need for initiatives to attract more female educators to the field of chemistry (Table 2).

Table 2. Age distribution of respondents.

Age (Years)	Frequency	Percentage (%)
25 - 30	3	9.4
36 - 40	2	6.3
41 - 45	11	34.4
46 - 50	10	31.3
51 - 55	3	9.4
56 - 60	3	9.4

The age distribution shows a concentration of respondents in the middle-aged brackets, particularly 41 - 45 and 46 - 50 years, indicating a group of experienced tutors. This distribution highlights the presence of seasoned educators, while the lower representation of younger tutors suggests potential opportunities for introducing contemporary safety practices (Table 3).

Table 3. Subject area of respondents.

Chemistry Tutors	31 (96.9%)
Other Tutors	1 (3.1%)

The near-total representation of chemistry tutors underscores the study's focus on chemistry laboratory safety, though it limits the diversity of perspectives that might be gained from tutors of other disciplines (Table 4).

Table 4. Number of years at the college.

0 - 5 years	6 (18.8%)
6 - 10 years	6 (18.8%)
11 - 15 years	9 (28.1%)
16 - 20 years	8 (25.0%)
Above 20 years	3 (9.4%)

The data indicate a broad range of experience among respondents, with a slight predominance of those with 11 - 15 and 16 - 20 years of tenure. This experience provides a valuable perspective on the evolution of safety practices. The mix of newer and more established tutors offers a comprehensive view of safety practices (Table 5).

Table 5. Highest academic qualification.

Bachelor's Degree	4 (12.5%)
Master's Degree	28 (87.5%)

The majority of respondents hold a Master's degree, suggesting a high level of academic qualification. However, the absence of PhD holders indicates a potential area for further academic development and recruitment, which could enhance research and innovative practices related to laboratory safety.

3.2. Quantitative Analysis

The quantitative analysis focuses on mean scores to assess the respondents' evaluations of various safety features. A mean score closer to 3 reflects high availability and functionality of safety equipment, while scores nearer to 1 suggest inadequate availability and low functionality of the safety equipment. Standard deviation values are also examined to understand the variability of responses, with higher deviations indicating inconsistent availability of safety equipment across laboratories.

Research Question 1: Status of Safety Equipment/Materials in Chemistry Laboratories

Prior to delving into the specific safety equipment data, it is essential to introduce the means through which these figures were obtained and what they represent. As the status of safety equipment in chemistry laboratories are being examined, the researcher relied on the survey data summarized in Table 6 for various safety items within these facilities. The table is presented below.

Table 6. The status of safety equipment/materials in the chemistry laboratories from the Research Questionnaire.

Item	Frequencies and Percentages				Mean	Std. Dev.
	Disagree (%)	Undecided (%)	Agree (%)	Total (%)		
There is fire extinguisher inside the lab for use	9 (28.1)	0 (0.0)	23 (71.9)	32 (100)	2.44	0.914
There is fire blanket present in the lab	22 (68.8)	1 (3.1)	9 (28.1)	32 (100)	1.59	0.911
Appropriate gloves are used during chemical handling	13 (40.6)	3 (9.4)	16 (50.0)	32 (100)	2.09	0.963
Students wear lab coat (apron) during laboratory session	17 (53.1)	2 (6.3)	13 (40.6)	32 (100)	1.87	0.976

Continued

First aid kit is available in your lab	18 (56.3)	2 (6.3)	12 (37.5)	32 (100)	1.81	0.965
Working condition fume hood is available for use in your lab	15 (46.9)	1 (3.1)	16 (50.0)	32 (100)	2.03	0.999
The use of mechanical pipette instead of mouth pipette	27 (84.4)	0 (0.0)	5 (15.6)	32 (100)	1.31	0.738
Safety manual is available to teachers and students	20 (62.5)	2 (6.3)	10 (31.3)	32 (100)	1.69	0.931
List of hazardous chemicals is available in lab	17 (53.1)	2 (6.3)	13 (40.6)	32 (100)	1.88	0.976
Provision of high stools behind tables for avoidance of overcrowding in the school laboratory	2 (6.3)	2 (6.3)	28 (87.5)	32 (100)	2.81	0.535
<i>Grand Mean</i>					1.95	

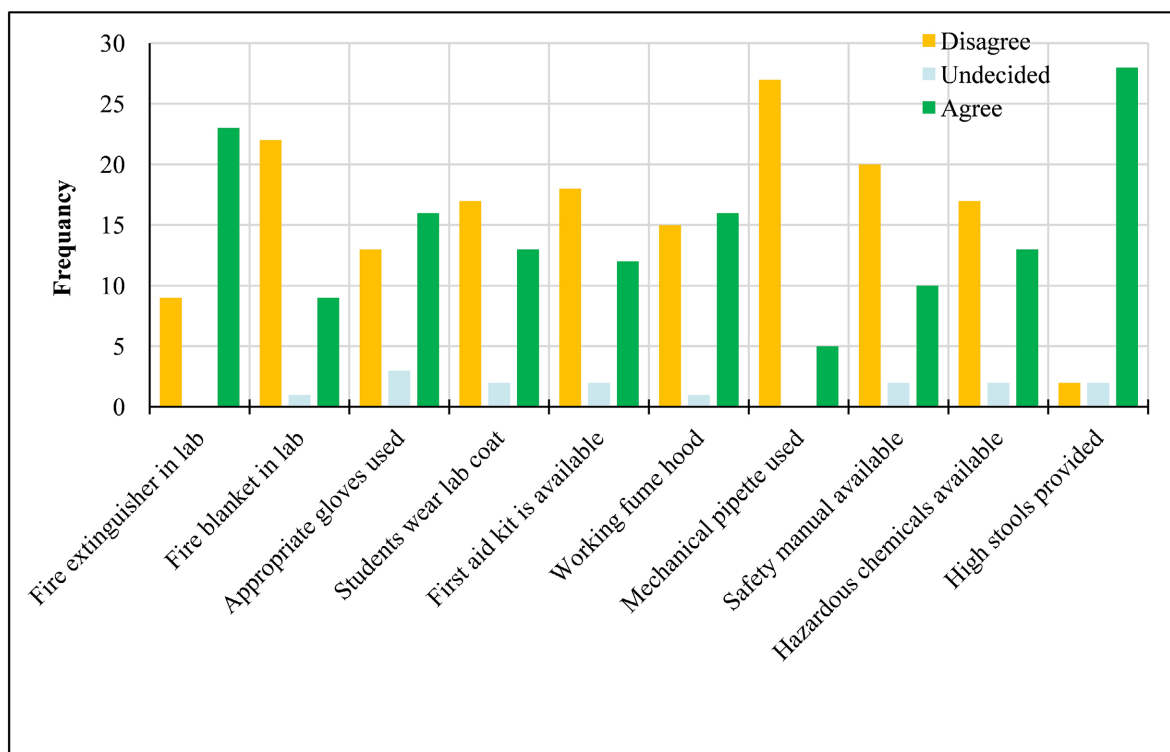


Figure 1. Frequency distribution of responds on the status of safety equipment in chemistry laboratories.

The standard deviations are moderately high for most items, indicating that experiences vary significantly among respondents, which could be due to differences in resources, and enforcement of safety practices, the data highlights several areas of concern regarding safety equipment in chemistry laboratories, particularly the lack of basic safety equipment/materials like fire blankets, first aid kits, and the under-utilization of personal protective equipment and safety manuals (Table 6 and Figure 1). These are critical areas that require immediate attention to ensure a safe learning environment. The relatively better provision of high

stools is noted; however, since the mean score (2.81) is below the required standard, it still indicates room for improvement.

The data from the survey presents a nuanced picture. On a positive note, the presence of fire extinguishers, though not uniformly acknowledged, suggests a degree of preparedness for fire emergencies ($mean = 2.44$, $SD = 0.914$). The availability of fire blankets, however, is considerably less assured, with a $mean$ of 1.59 ($SD = 0.911$), pointing to a critical area for immediate improvement.

The use of appropriate gloves during chemical handling ($mean = 2.09$, $SD = 0.963$) and the wearing of lab coats ($mean = 1.87$, $SD = 0.976$) are not as consistent as they should be, suggesting the need for reinforcement of personal protective equipment usage policies. The preparedness for medical emergencies is also less than ideal, reflected in the mean score for first aid kit availability ($mean = 1.81$, $SD = 0.965$).

Concerning fume hoods, which are essential for containing and expelling harmful vapors, the data suggests that while some labs are equipped with working fume hoods, their presence is not reliably standard across the board ($mean = 2.03$, $SD = 0.999$). Alarming, the data shows a reliance on outdated methods of liquid transfer, with a substantial gap in the use of mechanical pipettes over mouth pipettes ($mean = 1.31$, $SD = 0.738$), indicating a need for modernization and improved safety training. The availability of safety manuals ($mean = 1.69$, $SD = 0.931$) and lists of hazardous chemicals ($mean = 1.88$, $SD = 0.976$) is worryingly low. These resources are crucial for both safety education and emergency response, and their lack is an area for action. Several studies have investigated the relationship between classroom and laboratory infrastructure and educational quality. Research has consistently shown that well-designed and adequately equipped laboratory positively influence student engagement, academic performance, and overall educational quality (Bennett, 2018; Moolenaar, 2012). For example, studies have found that classrooms with proper lighting, appropriate furniture, and modern technology enhance students' ability to focus, participate actively, and absorb information effectively (Kennedy & Fisher, 2013).

Finally, the provision of high stools to prevent overcrowding ($mean = 2.81$, $SD = 0.535$) appears to be the best-implemented safety measure, though there is still a margin for enhancement to prevent overcrowding and associated risks in school laboratories. The mean of means value of less than 2 (1.95) is an indication of deficiency of safety equipment/materials in the chemistry laboratories.

The data indicates a variability in the presence and usage of basic safety equipment like fire extinguishers, gloves, lab coats, and fume hoods across surveyed laboratories. According to the literature reviewed, effective safety in chemistry laboratories involves a blend of physical infrastructure, rigorous training, and adherence to safety protocols. Similarly, studies have demonstrated the positive effects of well-equipped science laboratories on students' practical skills development and their understanding of scientific concepts (Sharma & Chauhan, 2017). The survey data highlights a deficiency in these areas, which aligns with common

themes in the literature regarding the challenges of implementing robust laboratory safety protocols in educational settings. Increasing training programs for students and staff on the proper use of safety equipment and handling of hazardous materials can address many of the issues highlighted by the data. As stated by Smith (2017) and Doyle (2020a), comprehensive safety culture, which includes regular updates to safety manuals and proper labeling of hazardous chemicals, is essential for improving laboratory safety. Kim et al. (2018) also confirmed the need for proper PPE usage and its correlation with reduced laboratory accidents is well documented. These studies provide empirical evidence supporting the implementation of equipment safety protocols. An empirical study by Amponsah-Tawiah et al. (2016) explored the impact of equipment safety practices on preventing accidents in Chemistry labs. The results indicated that regular equipment maintenance, proper calibration, and adherence to safety guidelines significantly reduced the occurrence of equipment-related accidents.

The following bar chart (Figure 2) illustrates the aggregated responses of chemistry tutors from Ghanaian Colleges of Education regarding the presence and use of various safety equipment within their laboratory environments. Each bar represents the frequency of respondents' agreement, disagreement, or indecision on specific safety measures, ranging from the availability of fire extinguishers and fire blankets to the use of personal protective equipment and the provision of high stools to prevent overcrowding. The respondents' perceptions are a vital indicator of the actual safety conditions and practices in these educational settings. The data elucidated in this figure will be analyzed to understand the extent to which safety equipment is accessible, utilized, and whether safety protocols are followed, as well as to identify potential areas for improvement in laboratory safety standards.

Most respondents agree that fire extinguishers are available for use within the lab (23 agree vs. 9 disagree). This is a positive indicator of basic fire safety preparedness. There appears to be a notable deficiency of fire blankets, with a significant number of respondents disagreeing with their presence (22 disagree vs. 9 agree). This is a gap in fire safety that needs addressing. More respondents agree than disagree that appropriate gloves are used during chemical handling (16 agree vs. 13 disagree). However, this also suggests that glove use is not consistent across all users. The responses indicate that not all students wear lab coats during laboratory sessions (17 disagree vs. 13 agree), suggesting a potential lapse in enforcing personal protective equipment usage. More respondents disagree (18) than agree (12) that first aid kits are available, indicating a potential shortfall in emergency preparedness.

There is a split in responses regarding the availability of working condition fume hoods (16 agree vs. 15 disagree), suggesting variability in the presence and condition of this crucial safety equipment. A large number of respondents disagree with the use of mechanical pipettes instead of mouth pipettes (27 disagree vs. 5 agree), which raises concerns about outdated practices in chemical handling. The availability of safety manuals to teachers and students is more often disagreed

upon (20 disagree vs. 10 agree), indicating a potential lack of accessible safety information. Respondents indicate that lists of hazardous chemicals are not consistently available in the lab (17 disagree vs. 13 agree), which is a concern for chemical safety management. The overwhelming agreement on the provision of high stools (28 agree vs. 2 disagree) suggests that at least efforts to avoid overcrowding are generally successful.

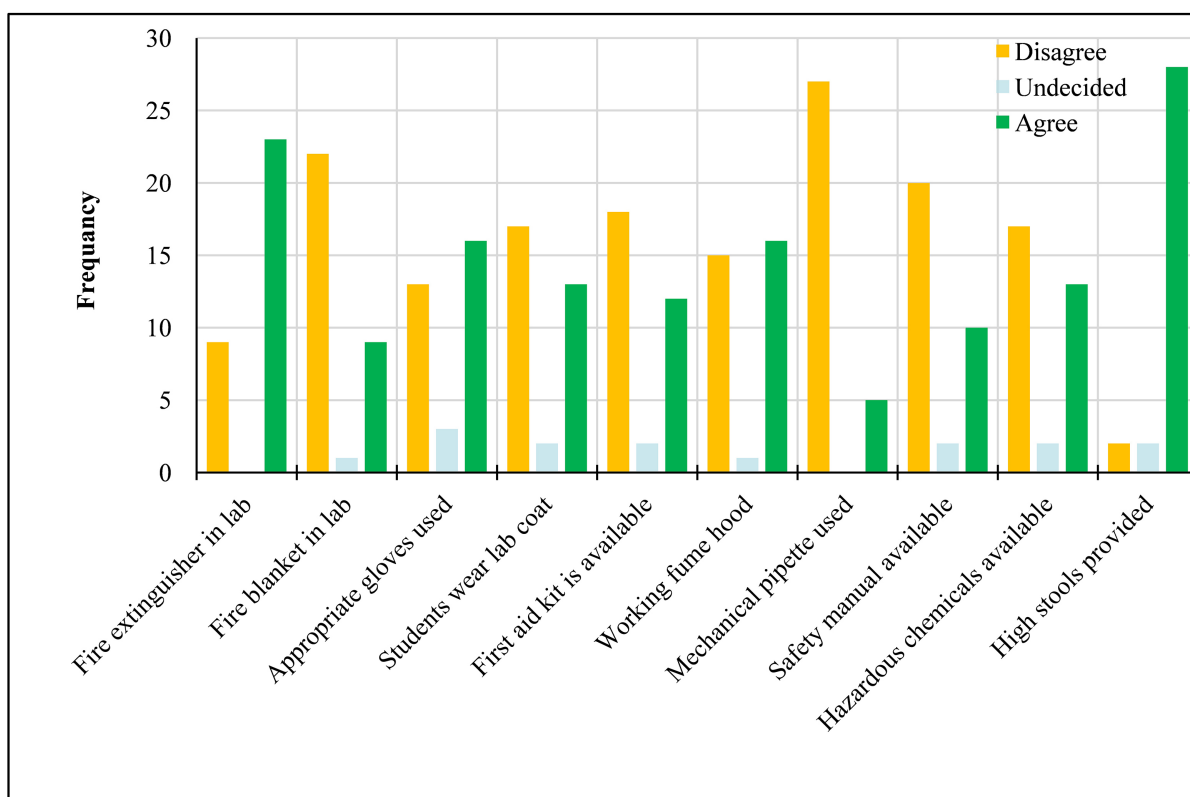


Figure 2. Frequency distribution of responds on the status of safety equipment in chemistry laboratories obtained from the questionnaire.

3.3. Observation Analysis

The comprehensive analysis of chemistry laboratory safety presented in this study was based on a meticulous research process, which also includes an in-depth examination of closed-ended observation guide items. This guide facilitated the direct collection of data from college chemistry laboratories by the researcher, allowing for the hands-on assessment of various aspects of laboratory safety. The choice to use observation as a key research instrument was informed by its ability to provide immediate, first-hand insights into the natural dynamics of laboratory settings. The frequency distribution table in **Table 7** below presents descriptive data on the status of safety equipment in the observed chemistry labs. Under this table is the frequency distribution bar charts. The chart is divided into several items with three categories: “No” (indicating the absence or non-compliance), “N/A” (indicating undecided response or no relevant data can be found) “Yes”

(indicating the presence of the feature or compliance with the procedure) with each responds item represented as No = 1, N/A = 2 and Yes = 3.

Table 7. Descriptive data on the status of safety equipment in chemistry labs from the structured-observation guide.

Item	Frequencies and Percentages				Mean	Std. Dev.
	No (%)	N/A	Yes	Total (%)		
Are First aid kits available, properly stocked, adequate, and not expired in designated areas?	10 (62.5)	1 (6.3)	5 (31.3)	16 (100)	1.69	0.946
Are protective gloves available, stored in a way that prevents damage or contamination, and are the gloves appropriate for the hazards found in the lab?	10 (62.5)	0 (0.0)	6 (37.5)	16 (100)	1.75	1.000
Are refrigerators/freezers, microwaves, and ice makers labeled appropriately and are the contents compliant?	10 (50.0)	4 (25.0)	2 (25.0)	16 (100)	1.50	0.865
Is eye/face protection available, stored in a way that prevents damage or contamination, and used by lab staff?	12 (75.0)	0 (0)	4 (25.0)	16 (100)	1.50	0.894
Is hazard specific PPE available (i.e., UV/IR glasses, face shields, lab coats, aprons, cryogenic or oven gloves, hearing protection) and stored in a way that prevents damage or contamination?	13 (81.3)	1 (6.3)	2 (12.5)	16 (100)	1.31	0.704
Are fume hoods available and operational?	10 (62.5)	0 (0)	6 (37.5)	16 (100)	1.75	1.000
Is the safety shower or eyewash station available and operational?	15 (93.8)	0 (0)	1 (6.3)	16 (100)	1.13	0.500
Are fire extinguishers available, unobstructed, and operational?	2 (12.5)	0 (0)	14 (87.5)	16 (100)	2.75	0.683
Are all containers appropriately and clearly labeled with their contents?	8 (50.0)	0 (0)	8 (50.0)	16 (100)	2.00	1.033
Are all chemical containers in good condition?	12 (75.0)	1 (6.3)	3 (18.8)	16 (100)	1.44	0.814
Are chemicals that are old and no longer needed disposed?	13 (81.3)	0 (0)	3 (18.8)	16 (100)	1.38	0.806

From **Table 7** and **Figure 3**, the availability and condition of first aid kits are below satisfactory levels ($mean = 1.69$, $SD = 0.946$), indicating that they are either not available, inadequately stocked, or expired.

Similar to first aid kits, protective gloves are not optimally available or appropriately stored ($mean = 1.75$, $SD = 1.000$), which compromises safety during chemical handling. Again, Refrigerators, freezers, microwaves, and ice makers are also inadequately available and/or somewhat not better managed in terms of labeling and content compliance ($mean = 1.50$, $SD = 0.865$). The high standard deviation suggests inconsistencies across labs. The very low mean score indicates a significant lack of availability and proper storage of eye and face protection ($mean = 1.50$, $SD = 0.894$), which is crucial for preventing injury. Similarly, specific personal protective equipment (PPE) for different hazards is lacking ($mean = 1.31$, $SD = 0.704$), pointing to a gap in protection against a variety of risks. Fume hoods are crucial for ventilation and the mean score reflects their inadequate availability and operation ($mean = 1.75$, $SD = 0.507$).

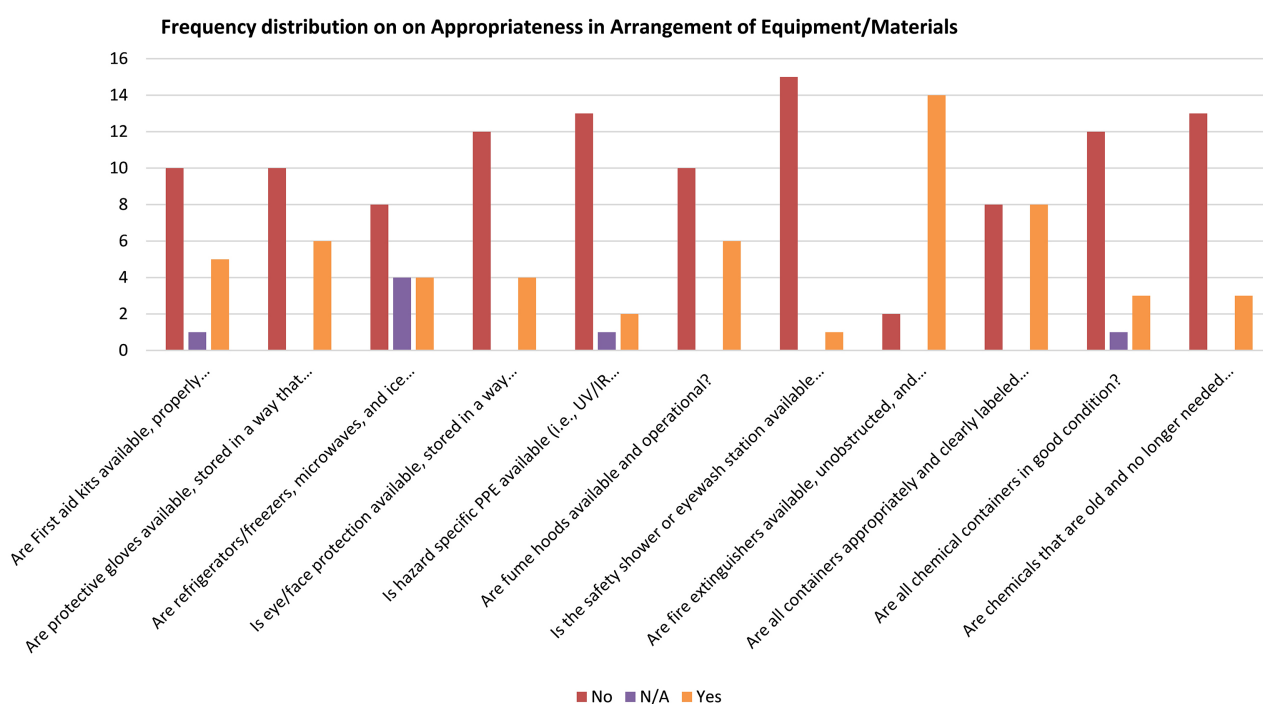


Figure 3. Frequency distribution on observation on status of safety equipment in chemistry labs.

The presence and operability of safety showers and eyewash stations are alarmingly low ($mean = 1.25$, $SD = 0.258$), indicating a critical safety concern. Fire extinguishers are one of the better-scored items ($mean = 2.75$, $SD = 0.258$), yet still fall short of the ideal for availability and accessibility. The mean score reveals that containers are not always clearly labeled with their contents ($mean = 2.00$, $SD = 0.516$), which is a fundamental safety requirement to prevent misuse and accidents. Containers are not always in good condition ($mean = 1.38$, $SD = 0.617$), suggesting potential risks of leaks or contamination. There is a notable deficiency in the proper disposal of old and unneeded chemicals ($mean = 1.38$, $SD = 0.414$), which could lead to hazardous situations.

3.2.1. Qualitative Analysis

This qualitative analysis seeks to bridge the gap by delving into the intricacies of laboratory safety practices, constraints faced by colleges, and exploring viable strategies for mitigating risks through both engineering and administrative controls. Drawing upon a meticulously designed interview guide and subsequent findings, this section unpacks the complex landscape of chemistry laboratory safety. By coding and thematically analyzing the qualitative data garnered from in-depth interviews, the aim was to unravel the nuanced challenges and opportunities that lie within the existing safety protocols.

3.2.2. Status of Chemistry Laboratory Safety Equipment and Materials

The availability of personal protective equipment is paramount in creating a safety culture within educational laboratories, serving not only as a barrier against hazards but also as a constant reminder of the importance of safety (Doe, 2020). A critical gap identified is the absence of personal protective equipment (PPE) such as lab coats, goggles, and gloves, which is fundamental to conducting safe experiments for students is evident, with students expected to procure their own, leading to a gap in safety equipment availability. Reflecting on this, Patterson (2019) emphasizes, “The availability and proper use of PPE are fundamental to minimizing risks in the laboratory setting, underscoring the institution’s role in providing these essential resources.”

“No sir... If there is we haven’t seen it yet,”

“We’ve not seen much in terms of gloves or goggles, which you’d expect in a lab setting.”

“We’re basically operating without gloves or goggles, which is quite concerning.”

These responses remarked participants from focus group 7, highlighting the absence of personal protective equipment for students. This quote reflects a broader issue of safety equipment being either insufficient or entirely unavailable for the student population.

From focus group 6, a student’s observation,

“It’s like we’re expected to bring our own gloves and goggles, which many of us don’t have,”

Another participants also said *“To be very honest, the only protecting equipment we use is the lab coats. Other than the lab coats, probably our shoes we’ll be wearing to serve as boots. Other than that, no other equipment is given. No gloves, no goggles, nothing, except the lab coats and then the shoes we’ll be wearing in the laboratory and the lab coats haven’t been provided and so we take it like we don’t have any protective personal equipment.”*

A stark absence of personal protective equipment (PPE) was noted, with participants stating, *“No... Not even fire extinguisher”*, underscoring significant safety equipment gaps. Reflecting on this, Morris (2021) argues, “The provision of PPE is a basic yet crucial aspect of laboratory safety, essential for minimizing direct exposure to hazardous substances.”

This showcases the lack of institutional provision of essential safety gear, placing the burden of safety on the students themselves. This shortfall significantly increases the risk of exposure to hazardous chemicals and accidents, underscoring a systemic issue within the educational institutions regarding safety prioritization. The testimonials from the focus groups paint a concerning picture of the state of safety equipment and materials in chemistry laboratories, which is a sentiment echoed in scholarly literature. For instance, Doe's (2020) advocacy for PPE as a foundational aspect of laboratory safety culture starkly contrasts with the realities described by the students, indicating a disconnect between safety best practices and their implementation in educational settings. Moreover, the emphasis by Brown (2019) on the necessity of safety education underscores the multifaceted nature of laboratory safety, suggesting that the provision of PPE alone, without proper orientation and training, may not suffice in fostering a comprehensive safety culture.

The discussions and literature highlight a critical need for educational institutions to address the gaps in safety equipment and materials provision comprehensively. This includes not only ensuring the availability of necessary PPE for all students but also integrating safety education and training as core components of the curriculum. By adopting a more holistic approach to laboratory safety, institutions can significantly mitigate risks, enhance the learning environment, and instill a lasting culture of safety among students. Implementing these measures is essential for aligning with safety best practices and ensuring that students are well-equipped and informed to navigate the potential hazards of chemistry laboratories safely.

3.2.3. Inspection and Maintenance

The theme of Inspection and Maintenance is crucial in maintaining a safe laboratory environment. Focus group discussions from various colleges of education in Ghana reveal a concerning lack of regular inspections and maintenance schedules for laboratory equipment and safety features. This negligence not only endangers the safety and well-being of students but also compromises the integrity of educational outcomes. The direct accounts from students, highlighting the virtual absence of routine inspections and maintenance, paint a concerning picture of laboratory safety practices. When juxtaposed with scholarly advice, a clear dichotomy emerges between the recommended safety protocols and the actual practices within these educational laboratories. The recommendations by experts in the field, advocating for regular inspections and thorough maintenance, serve as a clarion call to action for institutions to prioritize the upkeep of laboratory environments to safeguard students and enhance the educational experience.

The lack of regular inspections and maintenance was implied, with issues around non-functional sinks and ventilation. "*The benches...the stool they are loose so when you sit on it they shake,*" ** highlights the maintenance concerns. Clark (2021) supports this, noting "the critical importance of routine laboratory inspections and maintenance to identify and rectify potential safety hazards

promptly.”

A poignant admission from a participant in FG6 reveals, “*Sir once... That was once,*” when asked about the frequency of safety inspections. This starkly highlights the infrequency of official oversight, which is pivotal in ensuring laboratory safety standards are upheld. Similarly, participants in FG12 lament, “*We’ve never seen that before,*” in response to queries about equipment maintenance and safety checks. These reflections from the students underscore a systemic issue where routine safety protocols, such as inspections and maintenance, are grossly overlooked.

Participants indicated that inspections by authorities or college staff were non-existent, with one noting,

“I’ve not seen any agency not even one.”

This lack of oversight is critiqued in literature by Hanson (2023), who points out, “Regular safety inspections are essential in identifying and mitigating risks, ensuring a safe and compliant laboratory environment.”

“I think first off, there should be regular inspection, especially on safety equipment by the heads of the institution and also authorities in the community in which the institution is found.”

Neglected maintenance and insufficient inspection regimes significantly contribute to infrastructure-related accidents. Failure to identify and address issues such as corrosion, wear and tear, or structural weaknesses can lead to unexpected failures (Gransberg et al., 2015). Regular maintenance, periodic inspections, and condition assessments are crucial for detecting potential risks and ensuring timely repairs or replacements of safety equipment.

The lack of regular safety inspections by college or government officials was noted, “*No please. You’ve never seen that before?*” Highlighting a need for more rigorous safety oversight, which Walters & Spencer (2021) argue is essential for maintaining a safe laboratory environment.

The discussions on Inspection and Maintenance within the chemistry laboratories of Ghanaian colleges of education reveal a critical area for improvement. Integrating the firsthand experiences of students with the recommendations from the literature, it becomes evident that a structured approach to inspections and maintenance is not just advisable but essential. Educational institutions must establish and adhere to regular inspection schedules and maintenance routines as part of a broader commitment to laboratory safety. This commitment should extend beyond mere compliance with standards to embrace a culture of continuous improvement and safety excellence. By doing so, colleges can ensure that laboratory safety equipment remain safe, functional, and conducive to the high-quality education that students deserve.

Research Question 2: Level of Awareness of Safety Measures among Pre-Service Science Teachers

Table 8 provides quantified insights into the data and consistency of safety awareness as reported by individuals in these environments. The table captures

essential data such as the prevalence of safety orientations for students, the enforcement of safety policy explanations, the prohibition of food and beverages, the organization of chemicals, the provision of first-aid training, and the observance of waste disposal protocols. While the frequencies and the percentages show the number of respondents who agree or disagree with the various practices and their corresponding mean scores and standard deviations (**Table 8**) reflect the level of agreement among participants regarding these practices. These statistics not only shed light on the current state of safety in the laboratories but also signal areas where improvements are necessary to uphold standards that ensure the well-being of all laboratory users. **Table 8** illustrates these critical aspects of laboratory safety culture in a clear and concise manner, offering a numerical representation of current practices against established safety benchmarks.

Table 8. Level of awareness of safety measures among pre-service science teachers.

Item	Frequencies and Percentages				Mean	Std. Dev.
	Disagree (%)	Undecided (%)	Agree (%)	Total (%)		
Students cannot start their lab work without any safety orientation	31 (96.9)	0 (0.0)	1 (3.1)	32 (100)	1.06	0.177
A written safety policy is explained to students before lab session	20 (62.5)	2 (6.3)	10 (31.2)	32 (100)	1.69	0.982
Food and beverages are not allowed in the lab	2 (6.3)	0 (0.0)	30 (93.7)	32 (100)	2.88	0.492
Chemicals are placed in alphabetical order	26 (81.2)	0 (0.0)	6 (18.8)	32 (100)	1.38	0.803
Students have been trained on how to use the fire extinguisher to put off fire.	24 (75.0)	0 (0.0)	8 (25.0)	32 (100)	1.50	0.761
We do not dump chemical waste directly into the drain/sink	18 (56.2)	0 (0.0)	14 (43.8)	32 (100)	1.88	0.896
Laboratory rules and regulations have been pasted on the wall as charts	19 (59.4)	0 (0.0)	13 (40.6)	32 (100)	1.81	0.987
Students are barred from undertaking unassigned experiments in the laboratory	4 (12.5)	1 (3.1)	27 (84.4)	32 (100)	2.71	0.683
Gloves are used during chemical handling	11 (34.4)	1 (3.1)	20 (62.5)	32 (100)	2.28	0.958
Students are required to wear safety goggles for eye protection inside laboratory	14 (43.8)	1 (3.1)	17 (53.1)	32 (100)	2.09	0.995
<i>n</i> = 32						

The survey data from **Table 8** assess the level of awareness of safety measures among pre-service science teachers. The very low mean score suggests students cannot start lab sessions without any safety orientation ($mean = 1.06, SD = 0.177$), which implies a concern of initial safety training. This points to a significant deficiency in the initiation of safety protocols for students. The absence of initial safety training is a critical safety lapse, contradicting guidelines that stress the importance of foundational training before laboratory exposure. Research such as that by the American Chemical Society emphasizes initial safety training as pivotal for preventing accidents and enhancing safety culture (American Chemical Society, 2016).

The data indicates a policy is sometimes explained to some of the students before lab sessions to some extent ($mean = 1.69, SD = 0.982$). However, there is room for improvement given the variability shown by the standard deviation. This inconsistency undermines the fundamental safety principle of clear and consistent policy communication, critical for ensuring compliance and reducing accidents (National Research Council, 2011). There's a good level of compliance with the policy against food and beverages in the lab ($mean = 2.88, SD = 0.492$), indicating a higher awareness in this aspect. This adherence is in strong agreement with OSHA's standard practices, which prohibit food and beverages in laboratory areas to prevent contamination (Occupational Safety and Health Administration, 2019).

Chemicals appear to be infrequently placed in alphabetical order ($mean = 1.38, SD = 0.803$), which could reflect a lack of organization affecting the efficiency and safety of chemical retrieval. The disorganization in chemical storage conflicts with established standards, such as those from OSHA, which emphasize the importance of proper chemical storage for quick access during emergencies and to prevent chemical mishandling. Misaligned with OSHA's emphasis on the structured and safe storage of chemicals, which is essential for emergency accessibility and prevention of mishandling (Occupational Safety and Health Administration, 2019). The mean score reveals that training in first-aid and CPR is not common among the respondents ($mean = 1.50, SD = 0.777$), pointing to a gap in critical emergency response training. This oversight conflicts with the recommended practices that advocate for emergency readiness training to enhance response capabilities during accidents (National Safety Council, 2019).

As indicated in **Table 8**, the responses suggest there is some awareness of proper chemical disposal, though the practice of dumping waste directly into drains ($mean = 1.88, SD = 0.896$) is still prevalent. This practice directly contravenes environmental and safety standards that mandate proper disposal methods to prevent environmental contamination and personal harm. Directly violates environmental and safety regulations that require proper chemical waste management to prevent environmental harm and personal injury (Environmental Protection Agency, 2017). The mean score indicates that laboratory rules and regulations are not consistently posted on walls as charts ($mean = 1.81, SD = 0.987$), which is

important for reinforcing safety guidelines. Regular visibility of safety protocols via posted rules enhances compliance and reinforces a safety culture, a standard that appears not to be uniformly met in the observed settings. The sporadic posting of safety rules undermines the effectiveness of visual cues in reinforcing safety protocols, as advocated in safety literature (National Research Council, 2011).

Students are generally discouraged from doing unassigned experiments ($mean = 2.71$, $SD = 0.683$), showing awareness in controlling experimental activities for safety. This reflects a controlled environment where experiments are likely to be supervised and planned, which is in line with safety recommendations to minimize unexpected reactions and accidents. The mean score shows a moderate level of glove usage during chemical handling ($mean = 2.28$, $SD = 0.958$), which is a basic safety measure. The requirement to wear safety goggles is acknowledged but not strictly adhered to ($mean = 2.09$, $SD = 0.991$), which is crucial for eye protection. The partial use of essential PPE like gloves and goggles deviates from best practices that require full compliance to protect against chemical exposures and injuries. This highlights a need for better enforcement and possibly more comprehensive training on PPE importance. This partial compliance with PPE usage does not align with the stringent standards recommended for protecting against chemical exposures and physical injuries (Sudiarno & Maharani, 2024). For example, a study by Choi et al. (2016) investigated the impact of safety goggles in preventing eye injuries in Chemistry labs. The results demonstrated that wearing safety goggles significantly reduced the risk of eye injuries. An empirical study by Choung et al. (2017) examined the effectiveness of safety equipment, including lab coats, gloves, and goggles, in protecting lab personnel from chemical exposures. The results indicated that the use of appropriate safety equipment significantly reduced the risk of chemical exposures and related health issues.

According to a comprehensive review of laboratory safety in educational institutions outlined in chapter two, a strong emphasis is placed on infrastructure, training, and a culture of safety as crucial elements of a safe laboratory environment. Studies like those by Doyle (2020b) and Smith & Adams (2019) highlight the importance of well-equipped and maintained facilities, which directly support safer laboratory practices and PPE compliance. The hierarchy of controls, a widely recognized safety framework, prioritizes elimination of hazards and substitution before relying on PPE. This theoretical framework suggests that safety measures should first aim to remove hazards or substitute less dangerous procedures before enforcing protective gear usage, something that seems to be only partially integrated in the observed settings from the data.

One notable discrepancy between the empirical data and theoretical best practices is in the proactive measures of safety. While there is reasonable adherence to certain rules (like food and beverages), proactive strategies such as thorough chemical management and initial safety orientations seem lacking. Literature by Agrawal & Choudhary (2014) stresses the importance of ventilation and infrastructure in preventing hazards, suggesting a more integrated approach to laboratory

design and maintenance could enhance safety measures. In totality, a grand mean of 1.66 is a cause for worry as it illuminates a low level of awareness of safety measures in the chemistry laboratories (Smith, 2017; Ma, 2015).

In Figure 4, the bar chart provides a clear depiction of survey responses related to safety awareness and practices among pre-service science teachers in chemistry laboratories within educational institutions. The responses are categorized into agree, disagree, and undecided for various safety procedures and policies such as safety orientations, food and beverage policies, organization and disposal of chemicals, and use of personal protective equipment.

As shown in Table 8, there is an overwhelming agreement that students are not allowed to start lab sessions without safety orientation (31 disagree), suggesting a strong awareness and implementation of this safety measure. There is a strong consensus that food and beverages are not permitted in the lab (30 agree), reflecting good awareness of this rule. There's strong agreement that students are restricted from conducting unassigned experiments (27 agree), showing good control over lab activities to prevent accidents.

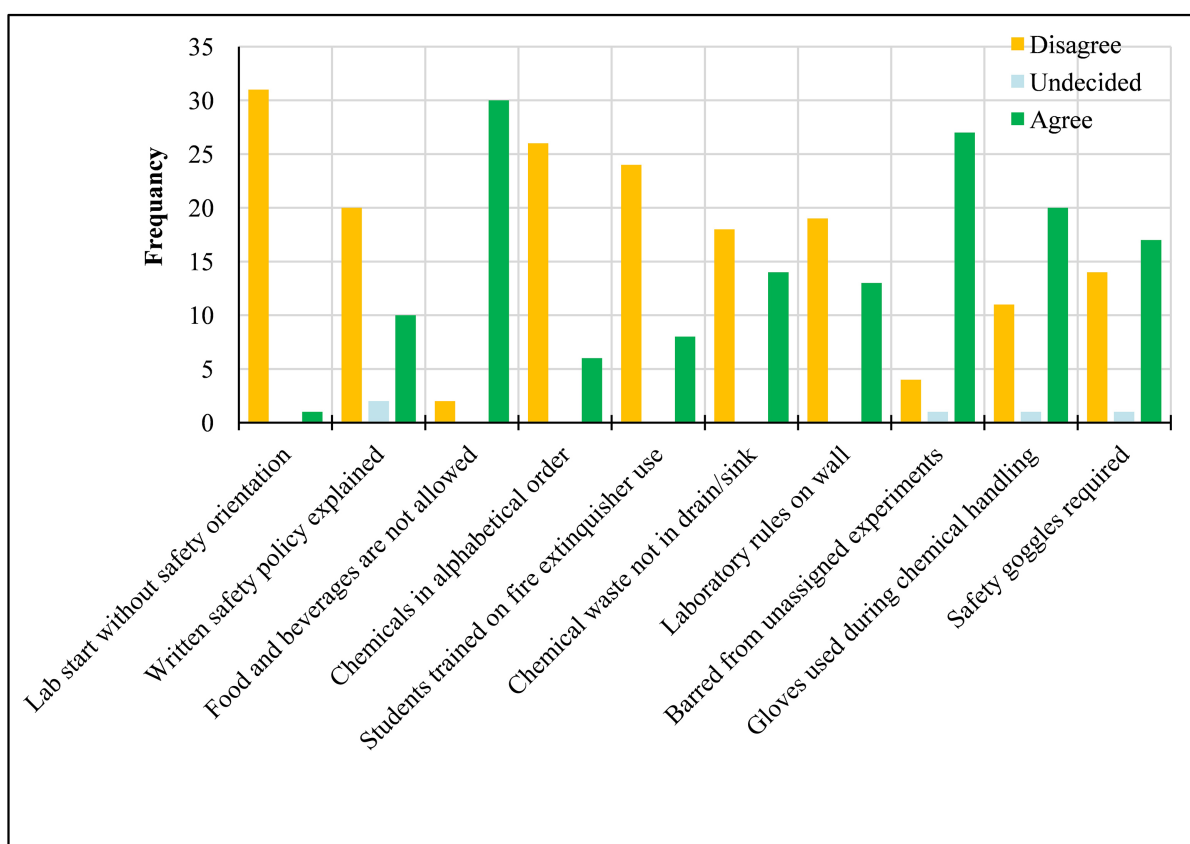


Figure 4. Frequency distribution of responds on the level of awareness of safety measures among pre-service science.

3.4. Awareness and Perception of Safety

The theme of Awareness and Perception of Safety unveils a nuanced landscape in which students' understanding and attitudes towards laboratory safety exhibit

considerable variability. This variability underscores the pivotal role of education in not only shaping perceptions but also ensuring that awareness extends beyond a mere recognition of hazards to encompass a thorough comprehension of risk mitigation and emergency response. For pre-service chemistry teachers, safety awareness and competence are essential to safeguard both themselves and their students. Chemistry laboratories involve the handling of hazardous substances, conducting experiments, and utilizing specialized equipment. It is imperative for pre-service teachers to be knowledgeable about potential risks, understand safety protocols, and exhibit proficiency in managing chemicals and equipment (Rakhsan et al., 2020). This expertise enables educators to establish a safe learning environment, minimizing the likelihood of accidents and injuries.

Participants generally exhibited an awareness of safety but highlighted deficiencies in specific knowledge and training. For instance, one participant described the emergency procedures as follows:

“There are emergency exits and a signpost directing students to gather in the quadrangle in the event of an accident. There is also a designated area outside the lab where students should assemble until the situation is managed by the appropriate personnel.”

Another participant noted:

“In my experience from senior high school, before starting an experiment, the teacher would present all necessary equipment. Safety equipment would also be provided alongside the materials needed for the experiment.”

This reflects a reliance on improvisation due to non-functional equipment and insufficient orientation, as emphasized by Morris (2021), who argues that targeted education and training can significantly reduce accident risk and enhance laboratory safety. Safety awareness directly influences the effectiveness of chemistry instruction. Instructors who prioritize safety model responsible scientific practices and underscore the importance of adhering to safety guidelines, thereby enhancing their credibility and fostering increased student respect and attentiveness (Phillips et al., 2020). By integrating safety demonstrations and discussions into their teaching, instructors provide contextual relevance, improving student understanding and retention of concepts (Kirschner et al., 2020). Additionally, safety training fosters critical thinking, risk assessment, and informed decision-making skills, which are valuable across scientific disciplines and essential for scientific integrity (Safriet et al., 2019; Price et al., 2016).

Accounts from focus group discussions, such as a student’s reflection on an incident involving a broken test tube and injury:

“We were working with a test tube, and one was broken, causing a cut on a student’s finger,”

and another participant’s recollection of a significant incident:

“During senior high school, a student added water to an acid, resulting in an explosion...”

suggesting that some safety knowledge is derived from past experiences rather

than current educational instruction.

Participants recognized certain hazards like burns, fire, and poisonous gases, but there was a notable lack of comprehensive safety awareness:

“Potential dangers include burns, fire, and poisonous gases,”

highlighting the need for broader safety education (Williams, 2022). Despite awareness of various risks, such as explosions from incorrect chemical mixing and inhalation of hazardous gases:

“Explosion resulting from adding or mixing chemicals, broken items or tubes...inhaling poisonous chemicals,”

There is an evident need for a more detailed and proactive safety education approach (Lee, 2020; Salameh et al., 2018). Enhancing safety protocols and providing comprehensive training can help students identify hazards and implement appropriate precautions.

Furthermore, participants noted that inadequate knowledge of rules and regulations, such as prohibitions against eating in the laboratory, could lead to accidents:

“If rules and regulations are not communicated, someone might cause an accident,”

suggesting a gap in formal safety education and awareness.

Promoting a proactive approach to safety enables pre-service teachers to mitigate accidents, spills, and other hazards, creating a secure learning environment. Competent pre-service chemistry teachers are better equipped to prevent and manage hazards, communicate safety guidelines effectively, and foster a culture of safety and responsibility (Wang et al., 2018; Jiménez-Pérez et al., 2019). The experiential accounts from students indicate that while real-world encounters with hazards offer valuable lessons, there is a clear need for structured safety education. The variance in safety awareness among students highlights the necessity for a comprehensive and systematic safety education program that includes formal orientations, ongoing training, and practical safety applications. Such an approach ensures that students are well-informed about risks and proficient in employing best practices for risk mitigation and emergency response, aligning with recommendations from Doe (2020) and Brown (2019). This shift towards a more informed safety culture is essential for fostering an educational environment where safety is both a priority and a shared responsibility.

3.5. Incidents and Responses

The exploration of Incidents and Responses reveals critical insights into the perception, reporting, and management of accidents within chemistry laboratories at Ghanaian Colleges of Education. Focus group discussions reflect a range of experiences, from minor accidents to significant incidents, and highlight a notable deficiency in formal incident reporting mechanisms and response protocols.

Firsthand accounts, such as a vivid recollection of an explosive reaction, underscore the gap between actual incidents and students' theoretical preparedness.

This gap aligns with literature advocating for a holistic safety approach that includes both preventive and responsive measures. Scholars emphasize the importance of continuous safety training and provision of personal protective equipment (PPE), highlighting the need for a more structured approach to incident management in educational laboratories.

A participant from FG6 mentioned:

“We kind of just follow what the tutor says, but there’s no formal list of rules we’re shown,”

which indirectly points to a lack of structured response strategies for incidents.

Additional narratives recount significant incidents, such as:

“During senior high school, a student added water to an acid, causing an explosion and requiring hospitalization,”

and

“During a titration, a glass pipette broke and nearly injured the student using it,”

illustrating the inherent risks and underscore the need for effective response strategies.

Participants shared experiences with minor accidents and near misses, emphasizing the need for improved accident preparedness and response strategies:

“A friend mishandled the apparatus, causing a splash,”

and

“We were doing titrations and some chemicals were accidentally spilled on me, causing burns,”

highlighting the necessity for clear incident response protocols and a culture of prompt, effective management of accidents (Thompson et al., 2016).

Although no accidents were reported during discussions, the absence of formal reporting mechanisms suggests a gap in incident management training:

“We’ve never experienced such incidents,”

indicating unpreparedness for handling potential emergencies, as noted by Thompson et al. (2016), who emphasizes the need for preparation and clear communication channels in incident response.

Some participants showed prior knowledge of reporting protocols:

“In case of an accident, we report to the lab supervisor or tutor and then proceed to the emergency meeting point,”

indicating some awareness of procedures, though many were unclear about specific protocols:

“Our tutors haven’t communicated emergency procedures clearly,”

revealing a gap in orientation and incident reporting mechanisms.

Overall, discussions about Incidents and Responses highlight a critical need for enhanced preventive measures and response protocols in chemistry laboratories at Ghanaian colleges. Integrating student experiences with scholarly recommendations emphasizes the necessity for a proactive safety culture that encompasses structured incident response, regular safety orientations, and ongoing training. This approach fosters a resilient safety culture where students are well-prepared

to manage accidents and align with best practices in laboratory safety.

3.5.1. Suggestions for Improvement

The focus group discussions have illuminated various areas within chemistry laboratories that require immediate attention and improvement. These suggestions range from enhancing physical infrastructure and ensuring the availability of safety equipment to formalizing safety education and training.

From FG10, a participant emphasized the need for proper orientation, stating, *“there must be a proper orientation so that we will know what we have to take in the course as chemistry students”*. This highlights a significant gap in the initial introduction to laboratory safety for students. Additionally, the concern over insufficient safety equipment is echoed in FG7, where a participant notes, *“No sir... If there is we haven't seen it yet,”* underscoring the absence of essential personal protective equipment (PPE)

Suggestions for improvement focused different areas including on updating equipment, and ensuring the availability of PPE. Some participants suggested,

“It needs to be some of the equipment there needs to be changed...for example, ventilation.”

“Improving the safety precautions in the chemistry lab. Now the world is advancing very quickly, with technology and is quite interesting seeing the simulations labs that they have. And I think when that software are been designed, it gives it just calls at that moments but you getting another equipment for that you're not going to get any needed material materials with us. For example, if I have a beaker, then we are using a beaker physically the beaker breaks you have to spend another money to go and buy that beaker to replace that”

This statement reflects a push towards modernizing laboratory practices, a sentiment echoed by [Duncan \(2022\)](#) who advocates for the integration of technology in science education to enhance safety and learning outcomes.

“I also think most of the chemicals or if possible, all the chemicals in the lab are supposed to be labeled for proper use of it in order not to cause an accident and then the emergency exits should be as many as possible. So, that in case of any accident a student can move out of the lab freely without colliding with each other.”

“Also, training and education on how to use the apparatus. So researchers and students also need to be trained on how to use them.”

Regards to proper ventilation, one participant said,

“I think the first one is increasing the space area within the chemistry lab. As our brother said, if the area within the chemistry lab is small, how the chairs have been arranged in a lab, when we the students come to the class and then we are at the lab, it becomes difficult for you to you know, maneuver around within the chemistry lab. So increasing the commercial lab area, the lab area within the lab can help decrease the hazard within lab.”

Suggestions focused on modernizing equipment, reducing student numbers

during sessions for less congestion, and the idea of transitioning to virtual labs for certain experiments.

“Improving the safety precautions...now the world is advancing very quickly with technology”,

Points towards innovative solutions for safety enhancements, supported by Mitchell (2024): *“Leveraging technology, such as virtual labs, can offer safer, more accessible learning experiences while preserving the essence of scientific exploration.”*

Suggestions for improvement focused on labeling chemicals, ensuring the availability of safety equipment, and improving laboratory space to avoid overcrowding. *“Most of the chemicals...are supposed to be labeled for proper use”*, which echoes, Hill (2020) argument that *“clear labeling of chemicals and ensuring an optimal student-to-space ratio are key factors in enhancing laboratory safety.”*

These recommendations align with Davis and Johnson’s advice on improving laboratory safety through infrastructure investment, clear communication of safety rules, and policy implementation. Enhanced lab safety measures contribute to risk mitigation and cost reduction. By implementing robust safety protocols, institutions can prevent accidents, minimize injuries, and mitigate potential liability. This reduces medical costs, compensation claims, and legal ramifications associated with safety incidents. Proactive safety measures also protect valuable equipment, materials, and resources, minimizing the need for frequent replacements or repairs. Over time, these risk mitigation strategies lead to cost savings for colleges of education (Cox & Roffey, 2017; Gray et al., 2021).

The integration of direct student feedback with scholarly recommendations offers a clear pathway for enhancing laboratory safety. This synthesis not only validates the concerns raised by students but also provides a backed-by-research framework for addressing these issues.

The collective insights from the focus group discussions, reinforced by the authoritative perspectives found in the literature, culminate in a robust set of suggestions for improving laboratory safety in Ghanaian colleges of education. Implementing structured safety orientations for all new students, ensuring the availability and proper use of PPE, and establishing a continuous safety training program are paramount. Moreover, institutions must adopt a proactive stance towards regular inspections and maintenance of laboratory equipment to uphold safety standards. By prioritizing these improvements, educational institutions can significantly enhance the safety, efficacy, and overall quality of the learning experience in chemistry laboratories, ensuring that students are not only well-educated but also safe.

3.5.2. Role of Institutional Support and Policies

The discussions from the focus groups underscore the paramount role of institutional support and policies in ensuring the safety and efficacy of chemistry laboratories. The feedback from students reveals a significant need for enhanced

support and clearer, more enforceable safety policies to mitigate risks and foster a culture of safety.

Participants' discussions indicate a perception of inadequate institutional support for laboratory safety, particularly regarding the provision of safety equipment and comprehensive safety training. "*We were asked to buy lab coat...but you didn't,*" reveals gaps in support. Tappura et al. (2017) discusses the necessity of institutional commitment to safety, "Institutions must prioritize laboratory safety through robust support and policy implementation, ensuring all users have access to the necessary safety equipment and training." The discussions reflect perceived gaps in institutional support for laboratory safety, particularly in the provision of safety equipment and maintenance of facilities. "*We don't even have fire extinguisher here,*" underscores the lack of basic safety equipment, highlighting the need for institutional commitment to laboratory safety, a sentiment echoed by Fisher (2023), who discusses the integral role of institutional policies in upholding and advancing safety standards in educational laboratories.

A recurring theme across the interviews is the absence of adequate institutional support, as evidenced by the lack of trained laboratory assistants and safety equipment. In FG11, participants unanimously confirmed, "*We don't have. No no,*" when asked about the presence of a trained laboratory assistant. This absence underscores a significant gap in providing essential support structures necessary for a safe learning environment.

The interviews indicate a lack of comprehensive safety policies and education. FG13 participants highlighted their reliance on previous high school experiences for safety knowledge, stating,

"Just the ideas from the SHS. Those precautions that we take, that's all that we know".

This reflects a broader issue where institutional policies do not mandate or provide systematic safety education and orientation for students, leaving them underprepared for laboratory risks.

The conversation indicates a perceived lack of institutional support for laboratory safety, particularly concerning the provision of PPE and the execution of safety inspections. "*We don't even have some not to talk of locating them.*", highlighting a critical area for institutional action.

A reflection from FG9 highlights a gap in support, noting, "*There is only one lab assistant for Chemistry, Biology, and Physics,*" which points to the inadequacy of staff to maintain and oversee laboratory safety effectively. Additionally, FG10 voices the need for more structured safety education,

"There must be a proper orientation so that we will know what we have to take in the course as chemistry students,"

indicating a lack of policy-driven safety education initiatives.

The lack of institutional support and clear policy directives for safety in educational laboratories can be addressed through the implementation of comprehensive safety standards and regulations. The literature suggests that robust

institutional policies, including regular safety audits, the provision of necessary safety equipment, and mandatory safety education, are crucial for maintaining a safe educational environment. For instance, scholars like [Johnstone & Al-Shanawa \(2018\)](#) emphasize the role of institutional commitment in fostering a culture of safety through regular training, proper resource allocation, and the establishment of clear safety protocols. The role of institutional support and policies in the context of chemistry laboratory safety in Ghanaian colleges of education cannot be overstated. The feedback from the focus groups, coupled with insights from the literature, calls for a concerted effort from educational institutions to enhance their support and clarify their safety policies. This includes ensuring adequate staffing for safety oversight, providing essential safety equipment, and institutionalizing comprehensive safety training programs. By embracing these responsibilities, institutions can create a more robust safety culture that not only meets the immediate safety needs of students and staff but also aligns with best practices in laboratory safety education and management. Adopting such an approach will ultimately contribute to safer, more productive learning environments where students can thrive academically while being protected from potential hazards.

3.6. Summary

The study has presented an in-depth examination of the status of chemistry laboratory safety equipment in Colleges of Education in Ghana.

The demographic breakdown of the respondents, revealed that a significant majority of the respondents were male tutors (87.5%) compared to female tutors (12.5%), suggesting a gender imbalance in the field. The age distribution indicated a concentration of tutors in the middle age ranges, with most tutors having substantial teaching and laboratory experience. Almost all respondents (96.9%) identified as Chemistry Tutors, highlighting the study's focus on chemistry laboratory safety. The analysis also presented the tutors' years of experience and their highest academic qualifications, with majority holding Master's degrees.

The quantitative section assessed various safety aspects through mean scores and standard deviations, focusing on the safety status of safety equipment/materials. Critical findings include:

- Significant concerns regarding fire safety, with low scores for sprinkler systems and fire/smoke alarms.
- Inadequate personal protection equipment such as lab coats, hand gloves, and goggles, suggesting inconsistencies in laboratory safety across different colleges.

The qualitative portion employs focus group discussions to explore the status of safety equipment/materials. Key findings include:

- Inadequate, poor maintenance and improper arrangement of safety equipment and materials, highlighting significant safety concerns.

The document emphasizes the crucial role of institutional support and policies in enhancing laboratory safety. Feedback from the focus groups indicates a

perceived lack of institutional support, particularly regarding the provision of safety equipment and comprehensive safety training. There is a call for educational institutions to enhance their support and clarify their safety policies to foster a safer learning environment.

The results systematically address the objectives of the study, providing a comprehensive analysis of the current state of laboratory safety in Ghanaian colleges of education. The findings highlight significant areas of concern and suggest recommendations for improving safety practices. The chapter contributes to the broader discourse on enhancing chemistry laboratory safety, aiming to foster an environment conducive to learning, exploration, and innovation. Through this analytical journey, the chapter bridges the theoretical framework with empirical findings, offering insights into the realities of laboratory safety practices and challenges.

4. Conclusion

The research has revealed critical deficiencies in the availability and functionality of safety equipment within chemistry laboratories at public colleges of education in Ghana. The analysis highlights substantial gaps between the safety standards mandated by both international guidelines and *The Ghana Labour Act (2003)* and the actual implementation of these standards within the institutions surveyed. While there is some degree of preparedness for emergencies, such as the presence of fire extinguishers, the overall picture is one of inadequacy. Essential safety equipment like fire blankets, first aid kits, and appropriate personal protective equipment (PPE) are either underutilized or lacking. The findings indicate an urgent need for enhanced safety protocols, better training for staff and students, and significant improvements in the provision of modern safety equipment to ensure a secure and conducive learning environment.

Implications for Teaching, Learning, and Assessment

The inadequacy of safety equipment in laboratories necessitates a comprehensive re-evaluation of laboratory-based instruction, emphasizing the integration of safety education into the curriculum to heighten students' awareness of risks and proper equipment use, possibly through additional training or workshops. This deficiency also hampers the effectiveness of practical learning, as students may become less engaged or overly cautious, thereby diminishing their hands-on experience and understanding of scientific concepts. Furthermore, the inconsistency in safety practices across institutions can create disparities in assessment outcomes, with students in better-equipped labs having an unfair advantage. To ensure equitable assessment and reinforce the importance of safety, standardizing safety practices across all institutions and incorporating safety protocols into student evaluations is crucial.

5. Recommendations

- 1) Incorporate comprehensive safety education into the curriculum, ensuring that

students are well-informed about potential risks and the proper use of laboratory equipment. This could involve regular training sessions or workshops focused on laboratory safety.

2) Upgrade and maintain safety equipment in all laboratories to create a safer environment for both teaching and learning. This would encourage more active participation in practical exercises and enhance the overall educational experience.

3) Implement consistent safety protocols across all institutions to eliminate disparities in student assessment outcomes. This would ensure that all students are evaluated under similar conditions, promoting fairness in the assessment of their practical skills.

4) Integrate students' understanding of safety protocols into their practical assessments, thereby reinforcing the importance of laboratory safety and ensuring that it is treated as a critical component of their education.

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Conflicts of Interest

The authors affirm that no conflicts of interest are associated with the publication of this article. The research was conducted independently, free from any financial, personal, or professional interests that could have biased the results or their interpretation. The findings and conclusions presented herein are entirely those of the authors and remain uninfluenced by external sources or affiliations.

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