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Laboratory Lapses: Investigating Common Issues and Violations in Chemistry Laboratory Courses among Future Science Educators

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Abstract
Laboratory work is a cornerstone of science education and teacher preparation, yet localized studies on safety compliance among pre-service science teachers remain limited. This mixed-methods study addresses that gap by examining the frequency, nature, and contributing factors of safety issues in Chemistry laboratory courses taken by Bachelor of Secondary Education (BSEd) Science students at Marinduque State University – College of Education. Quantitatively, 54 students enrolled in Inorganic, Organic, and Analytical Chemistry courses responded to a structured survey covering five safety domains: personal protective equipment (PPE) use, emergency preparedness and supervision, chemical labeling, handling, and waste disposal, equipment usage and calibration, and laboratory etiquette. Composite means clustered narrowly within the "Rarely" range (2.00–2.09 on a 1–5 scale), and inferential tests (one-way ANOVA: $F(2,12) = 0.86$, $p = 0.43$; Spearman's $\rho = -0.05$, $p = 0.84$) indicated no significant differences by course type. Thematic analysis of open-ended responses ($n = 120$) revealed five key drivers of safety lapses: insufficient training and orientation, carelessness or overconfidence, time pressure, resource deficiencies, and weak supervision and communication. Based on these insights, the study recommends scaffolded refresher drills, clear waste disposal signage, regular equipment audits, peer-appointed safety champions, and safety culture initiatives tailored to teacher-preparation contexts. By integrating both statistical patterns and lived experiences, this research addresses a critical gap in chemistry education scholarship and offers actionable strategies to improve laboratory safety compliance—from "Rarely" to "Never."

Keywords: *laboratory safety; chemistry courses; science education; BSEd science; mixed-methods; thematic analysis*

1.0 Introduction

The chemistry laboratory is an essential component of science education (Gericke et al., 2022 as cited in Chu, 2024; An et al., 2020, as cited in Aliyu & Talib, 2023; Duban, Aydoğdu, & Yüksel, 2019; Hofstein, 2004, 2017; Kwok, 2015; Yazıcı & Özmen, 2015; Sharpe, 2012; ICU, 2011), particularly in post-secondary science curricula (Agustian et al., 2022) and teacher preparation programs such as the Bachelor of Secondary Education (BSEd) major in Science. It provides students with valuable hands-on experience (Satterthwait, 2010; Osborne, 1998) that reinforces theoretical concepts (Cullin et al., 2017; Harman et al., 2016; Zoller & Pushkin, 2007; Staeck, 1995), sharpens critical thinking (Hofstein, 1982, 2003, 2017), and cultivates practical skills essential for future teaching and learning (American Chemical Society, 2015; ICSU, 2011). In this controlled environment, students learn to handle chemicals, operate scientific instruments (Agustian & Seery, 2017), and follow standardized procedures.

However, the laboratory setting presents inherent risks (Caymaz, 2021). Without consistent adherence to safety protocols—including cleanliness, proper equipment usage, accurate procedures, and responsible conduct (Canel, 2002; Kerimak- Öner, 2020; Nwele, 2013; West, Westerlund, Stephenson, Nelson & Nyland, 2003 as cited in Caymaz, 2021; Deepak, 2016)—the laboratory becomes a high-risk environment prone to accidents, contamination, and compromised results. In academic contexts, laboratory issues and violations—ranging from minor procedural lapses to critical safety breaches—can undermine the learning experience and raise concerns about students' readiness to manage science labs in their future teaching roles.

In recent years, educators and administrators have observed recurring issues in students' laboratory performance, including procedural errors, improper use of equipment, negligence in handling materials, chemical spills, improper waste disposal, non-compliance with safety rules, and inadequate preparation for experiments (Nwele, 2013; West, Westerlund, Stephenson, Nelson & Nyland, 2003; cited in Caymaz, 2021; Deepak, 2016). These concerns are particularly pressing among pre-service science teachers, as their laboratory habits will directly influence how they implement safety measures in future classrooms. Prior studies have cited several contributing factors: lack of training, insufficient orientation, inadequate supervision, limited access to safety resources, overcrowded laboratory sessions, and students' lack of awareness or discipline (Nwele, 2013; West, Westerlund, Stephenson, Nelson & Nyland, 2003, as cited in Caymaz, 2021; Deepak, 2016).

Despite the importance of fostering laboratory competence among future science educators, localized research on chemistry-related laboratory issues specific to BSEd Science students remains limited. This study aims to address that gap by investigating, documenting, and analyzing common chemistry laboratory safety issues and violations observed among BSEd Science students at Marinduque State University – College of Education. It further explores contributing factors and proposes actionable recommendations to improve laboratory instruction, enhance student compliance, and support the development of safety-conscious future science teachers.

This study seeks to investigate common laboratory safety issues and violations committed by BSEd Science students during their chemistry laboratory courses. It also examines whether the type of Chemistry course—Inorganic, Organic, or Analytical—has a significant relationship with the frequency and nature of laboratory lapses observed. Specifically, it aims to answer the following questions:

1. What are the most frequently reported laboratory safety issues and violations committed by BSEd Science students across the following categories?
   1.1 Use of Personal Protective Equipment (PPE);
   1.2 Emergency preparedness and supervision;
   1.3 Chemical labeling, handling, and waste disposal;
   1.4 Equipment usage and calibration; and
   1.5 Laboratory etiquette, hygiene, and organization?
2. Is there a significant difference between the type of Chemistry course (Inorganic, Organic, Analytical) and the frequency of laboratory safety issues and violations?
3. What factors do students perceive as contributing to laboratory lapses in chemistry laboratory classes?
4. What measures can be implemented to address and prevent such issues in future laboratory sessions?

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As a tentative response to Research Question 2, the following null hypothesis was proposed:

- There is no significant different between the type of Chemistry course (Inorganic, Organic, Analytical) and the frequency of laboratory safety issues and violations.

The findings of this research will benefit multiple stakeholders. For instructors and laboratory coordinators, it will help improve safety orientations, supervision strategies, guidelines, and instructional materials. For students, it will promote a clearer understanding of safety gaps and encourage a culture of professionalism and accountability. For academic institutions, the study offers insights to guide improvements in laboratory management and science teacher preparation. Ultimately, it supports the goal of producing responsible, knowledgeable, and safety-conscious educators capable of effectively managing classroom laboratories.

This study focuses on common laboratory issues and violations observed among BSEd major in Science students enrolled in chemistry laboratory courses at Marinduque State University – College of Education during Academic Year 2024–2025. It specifically examines student behavior, practices, and compliance within chemistry laboratories, excluding other disciplines such as Biology or Physics. The study does not include students from other academic programs. Data are drawn from surveys, instructor observations, and institutional laboratory records, and may not fully capture unreported or unnoticed incidents. The study does not aim to assess individual performance but rather to identify broader trends that can inform instructional and institutional improvements.

2.0 Methodology

2.1 Research Design

This study utilized a descriptive-correlational research design, specifically employing a mixed-method approach that combines quantitative and qualitative data.

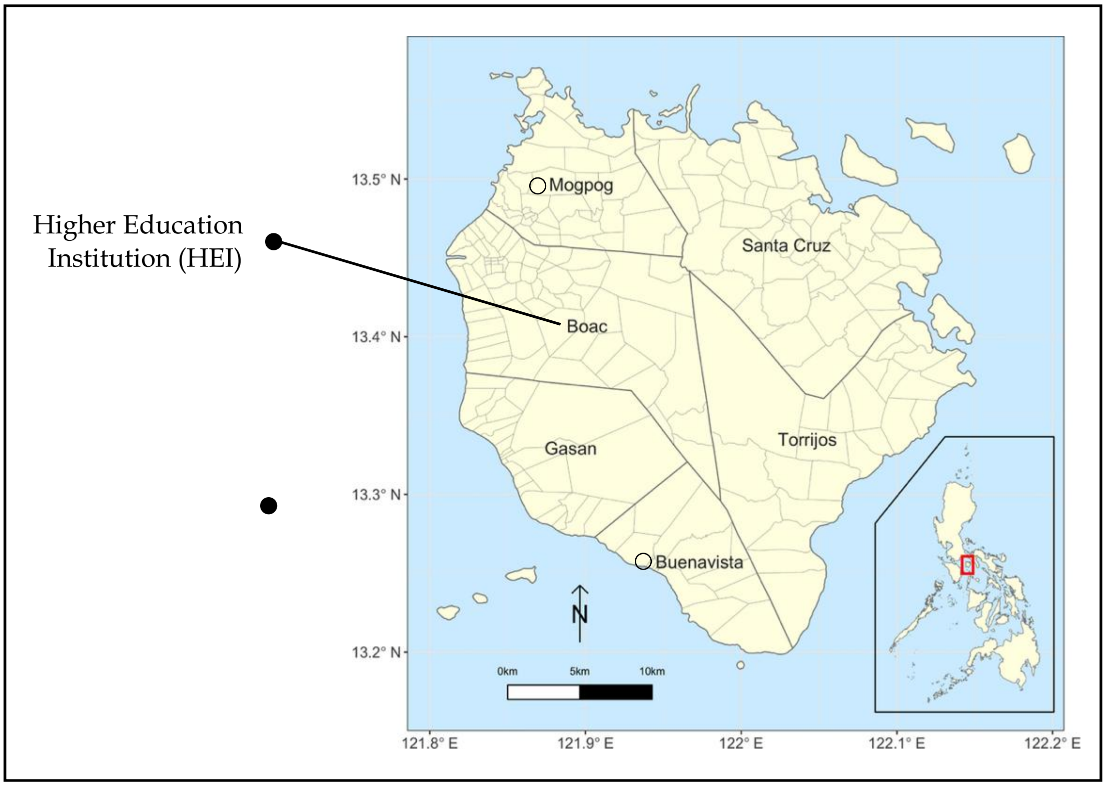
The descriptive component aims to identify and quantify the common laboratory safety issues and violations committed by BSEd Science students, based on 13 key indicators observed during various laboratory activities throughout the academic year. The correlational component investigates whether a significant difference exists between the type of Chemistry course (Inorganic, Organic, or Analytical) and the frequency of reported violations, using appropriate statistical tools (e.g., one-way ANOVA, Spearman's rank-order correlation).

To address the third research question—regarding students' perceptions of contributing factors to laboratory lapses—a qualitative approach was embedded within the survey via an open-ended item. Responses to this item were analyzed using thematic analysis to identify recurring patterns and themes. This mixed-methods strategy ensures a comprehensive understanding of both the frequency and underlying causes of laboratory safety violations among future science educators.

2.2 Research Locale

The research was conducted at a higher education institution (HEI) in the province of Marinduque, focusing specifically on students enrolled in the Bachelor of Secondary Education (BSEd) major in Science program. The Chemistry laboratory classrooms and facilities of the College of Education served as the primary setting for observing and assessing laboratory practices.

Figure 1
Location Map of the Selected Higher Education Institution (HEI)



(Image Source: Salvacion, 2022)

2.3 Research Participants
Participants were selected using total enumeration sampling, involving all available BSEd Science majors enrolled in Chemistry laboratory courses during the academic year. A total of 54 students participated, consisting of 25 second-year and 29 third-year students from Marinduque State University.

These participants were chosen because they had either recently completed or were actively engaged in laboratory-based Chemistry subjects such as Inorganic, Organic, or Analytical Chemistry. Their direct exposure to laboratory work ensured that they could meaningfully demonstrate compliance with safety protocols—or potentially commit laboratory safety violations. They also responded to an open-ended survey item regarding perceived contributing factors to laboratory lapses. No exclusion criteria were

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applied, as the goal was to assess the entire population of eligible students within the program to gain a comprehensive understanding of laboratory safety practices.

2.4 Research Instrument

The primary data-gathering tool employed in this study is a researcher-developed questionnaire aimed at identifying the common laboratory safety issues and violations experienced by BSEd Science students during their Chemistry laboratory courses.

The instrument is composed of two main sections. Part I was subjected to reliability testing to establish internal consistency and measurement soundness:

Part I: Checklist of Common Laboratory Safety Issues and Violations

This section features 13 structured items aligned with standard laboratory safety protocols. These are categorized into the following themes: Use of Personal Protective Equipment (PPE); Emergency Preparedness; Laboratory Supervision; Chemical Handling; Equipment Usage; and Laboratory Etiquette.

Each item was rated using a 5-point Likert scale to assess the frequency of observed violations:

Table 1

Interpretation of the Likert scale used for assessing common laboratory safety issues and violations

Weighted Mean	Arbitrary Value	Descriptive Rating
4.50 – 5.00	5	Always
3.50 – 4.49	4	Often
2.50 – 3.49	3	Sometimes
1.50 – 2.49	2	Rarely
1.00 – 1.49	1	Never

To assess internal consistency, a Cronbach's alpha reliability test was conducted, yielding a coefficient of approximately 0.762—indicating acceptable reliability for measuring consistent student perceptions across categories.

Part II: Open-Ended Question on Contributing Factors

To address Statement of the Problem No. 3, the questionnaire included a final open-ended item designed to elicit qualitative insights:

> *"In your opinion, what are the main reasons or contributing factors that lead to laboratory safety issues or violations in your Chemistry laboratory classes?"*

This question allowed respondents to articulate personal observations and experiences. Responses were analyzed using thematic analysis to identify recurring perceptions and underlying causes of unsafe behaviors.

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2.5 Data Gathering Procedure

This study employed a classroom-based action research approach, enabling the instructor-researcher to systematically examine her own teaching practices to enhance laboratory safety awareness among pre-service science educators. As both the course instructor and principal investigator, the researcher embedded data collection within regular instructional activities using a validated, rubric-based questionnaire. This instrument captured real-time observations of students' compliance with established safety protocols, allowing for continuous, reflective assessment in an authentic learning environment.

Data were collected during structured group laboratory activities across three Chemistry subjects: Inorganic Chemistry (first semester) and Organic and Analytical (second semester). During each session, students performed hands-on experiments, and their behaviors were observed and assessed using 13 predefined safety indicators. The rubric allowed the researcher to document both the frequency and type of violations, offering formative feedback opportunities and informing future instructional adjustments.

In alignment with action research principles, the study engaged the Laboratory Technician as a co-observer. This collaborative observation enhanced the credibility of findings by providing a second, independent perspective. After each activity, completed rubrics were compiled and encoded for analysis. Descriptive and inferential statistics were used to identify patterns and examine potential relationships between course type and violation frequency.

Qualitative data from the open-ended item were subjected to thematic analysis, offering deeper insights into the instructional, behavioral, and contextual elements influencing laboratory safety. The integration of quantitative and qualitative findings provided a holistic understanding of laboratory challenges and areas for improvement.

2.6 Ethical Considerations

This study adhered strictly to ethical standards for classroom-based educational research. Formal permission to conduct the study was granted by the Dean of the College of Education and relevant laboratory officials, including coordination with the Laboratory Technician.

Since the researcher also served as the instructor, safeguards were implemented to minimize bias or perceived coercion. Participants were fully informed about the study's purpose, and written consent was obtained. They were assured that participation was voluntary, responses would remain confidential, and the data would not affect academic standing.

To ensure anonymity and privacy, all data were coded, and no personally identifiable information was record or reported. Observation checklists and qualitative responses were securely stored in a password-protected digital repository, with physical documents locked and destroyed after encoding. Data analysis and reporting were conducted in a manner that prevented individual identification.

The principles of beneficence and non-maleficence were observed. The study posed no foreseeable risk and aimed to improved safety instruction. It supports both academic and personal development of future science educations while upholding the highest ethical standards.

3.0 Results and Discussion

In line with the study's objectives, this section first examines the frequency and nature of laboratory safety violations across five key domains: PPE usage; emergency preparedness and supervision; chemical labeling, handling, and waste disposal; equipment usage and calibration; and laboratory etiquette and organization. It then explores whether the type of Chemistry course (Inorganic, Organic, Analytical) significantly correlates with the reported incidence of safety lapses. Finally, the discussion addresses students' perceived contributing factors and proposed targeted measures to prevent future occurrences.

3.1 Frequency and Nature of Laboratory Safety Violations among BSEd Science Students

Table 2

Frequency of Common Laboratory Safety Issues and Violations according to Type of Chemistry Course

Common Laboratory Safety Issues and Violations	Type of Chemistry Course					
	Inorganic		Organic		Analytical	
	Mean	Verbal Interpretation	Mean	Verbal Interpretation	Mean	Verbal Interpretation
a) Personal Protective Equipment (PPE) Use						
1. Neglecting Personal Protective Equipment (PPE) (e.g. laboratory gowns, gloves, face masks, face shields, protective eyewear, long pants, enclosed shoes)	2.15	Rarely	2.25	Rarely	2.17	Rarely
Composite Mean	**2.15**	**Rarely**	**2.25**	**Rarely**	**2.17**	**Rarely**
b) Emergency Preparedness and Supervision						
2. Ignoring emergency procedures	2.05	Rarely	2.30	Rarely	2.02	Rarely
3. Working alone without supervision	1.00	Never	1.00	Never	1.00	Never
4. Conducting unauthorized experiments	2.02	Rarely	2.10	Rarely	1.21	Never
5. Failure to report accidents and incidents	2.00	Rarely	2.10	Rarely	2.02	Rarely
Composite Mean	**1.77**	**Rarely**	**1.88**	**Rarely**	**1.56**	**Rarely**
c) Chemical Labeling, Handling, and Waste Disposal						

6. Incomplete / improper labeling of containers	2.92	Sometimes	2.53	Sometimes	2.40	Rarely
7. Improper chemical handling	2.05	Rarely	2.12	Rarely	2.13	Rarely
8. Improper waste disposal	2.02	Rarely	2.00	Rarely	2.00	Rarely
Composite Mean	**2.33**	**Rarely**	**2.22**	**Rarely**	**2.17**	**Rarely**
d) Equipment Usage and Calibration						
9. Ignoring equipment instructions	2.18	Rarely	2.12	Rarely	2.04	Rarely
10. Ignoring equipment calibrations (if possible)	2.00	Rarely	2.02	Rarely	2.00	Rarely
Composite Mean	**2.09**	**Rarely**	**2.07**	**Rarely**	**2.02**	**Rarely**
e) Laboratory Etiquette, Hygiene, and Organization						
11. Eating, drinking, chewing gum, smoking, loose hair, or applying cosmetics in the laboratory	2.00	Rarely	2.00	Rarely	2.00	Rarely
12. Use of phones or computers with gloves on the hands	2.00	Rarely	2.00	Rarely	2.00	Rarely
13. Work area is disorganized and not free of any unnecessary objects	2.35	Rarely	2.08	Rarely	2.25	Rarely
Composite Mean	**2.12**	**Rarely**	**2.03**	**Rarely**	**2.08**	**Rarely**
Grand Mean	**2.09**	**Rarely**	**2.09**	**Rarely**	**2.00**	**Rarely**
			Overall Grand Mean		**2.06**	**Rarely**

The detailed analysis of student-reported violations (see Table 2) reveals that although the overall compliance is high (grand mean = 2.06, "Rarely"), certain safety domains consistently lag behind. Chemical labeling lapses in Inorganic Chemistry (mean = 2.92, "Sometimes") and Organic Chemistry (mean = 2.53, "Sometimes") stand out as the most frequent laboratory safety issues, suggesting gaps in students' understanding of hazard communication and container management. This finding echoes OSHA's emphasis on proper labeling to prevent chemical misidentification and accidental exposures (OSHA, 2011).

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Neglect of Personal Protective Equipment (PPE) was the next most common issue, with mean scores ranging from 2.15 to 2.2.5 across all courses. While "Rarely" suggests that most students do wear PPE appropriately, the remaining lapses—however infrequent—pose serious risks whenever they occur. Previous studies have linked even occasional omissions of gloves or eyewear to increased incidences of splash and contact injuries in teaching laboratories.

Emergency-related violations—including ignoring procedures, conducting unauthorized experiments, and failing to report incidents—averaged between 2.02–2.30 ("Rarely"). Notably, no respondents admitted to working unsupervised, reflecting strict enforcement of supervisory protocols. However, the persistence of unauthorized experimentation (mean = 2.02–2.10) highlights a need to reinforce the distinction between permitted and prohibited activities—an intervention supported by the American Chemical Society's (ACS) guidelines on student autonomy under supervision.

Equipment misuse and calibration oversights were uniformly rated as "Rarely" (means = 2.00–2.18), with Inorganic Chemistry showing the highest tendency to ignore instructions (mean = 2.18). This suggests that while students generally respect instrumentation protocols, occasional lapses may result from rushed pre-lab briefings or insufficient hands-on training.

Laboratory etiquette, hygiene, and organization recorded the lowest overall violation rates. However, workspace clutter—still within the "Rarely" range but with means reaching up to 2.35—suggest an opportunity to implement routine "bench-check" protocols before and after laboratory sessions. Consistent housekeeping has been shown to reduce cross-contamination and trip hazards in educational labs (OSHA, 2011).

3.2 Correlation between Chemistry Course Type and Laboratory Safety Violations

To assess whether the type of Chemistry course influences the frequency of laboratory safety issues and violations, the researcher compared the composite means for Inorganic Chemistry (mean = 2.09), Organic Chemistry (mean = 2.09), and Analytical Chemistry (mean = 2.00) against the overall grand mean (mean = 2.06) (see Table 3). On the surface, Analytical Chemistry reported slightly fewer lapses, but the variation across courses was minimal (Δ = 0.09).

Table 3
Composite Means by Category and Course Type

Category	Composite Means		
	Inorganic Chemistry	**Organic Chemistry**	**Analytical Chemistry**
a) PPE Use	2.15	2.25	2.17
b) Emergency Preparedness and Supervision	1.77	1.88	1.56
c) Chemical Labeling, Handling, and Waste Disposal	2.33	2.22	2.17

d) Equipment Usage and Calibration	2.09	2.07	2.02
e) Lab Etiquette, Hygiene, and Organization	2.12	2.03	2.08
Grand Mean (by course)	**2.09**	**2.09**	**2.00**
		Overall Grand Mean	**2.06**

Table 4
One-way ANOVA on Grand Means by Course Type

Source	df	F	p-value
Between Groups	2	0.86	0.43
Within Groups	12		
		Total	**14**

Table 5
Spearman's ρ between Course Rank and Composite Means

ρ	p-value
-0.05	0.84

As shown in the tables, the composite mean scores for laboratory safety issues and violations were closely clustered: both Inorganic and Organic Chemistry recorded a grand mean of 2.09, while Analytical Chemistry showed a slightly lower mean of 2.00—all falling within the "Rarely" range. Although Analytical Chemistry appeared marginally more compliant, a one-way ANOVA ($F(2, 12) = 0.86$, $p = 0.43$) indicated no statistically significant differences among groups. Similarly, Spearman's rank-order correlation ($\rho = -0.05$, $p = 0.84$) showed no monotonic relationship between course type and violation frequency. These inferential tests collectively suggest that the frequency of safety lapses is not significantly influenced by the specific chemistry discipline.

Given these findings, the consistency of safety violation rates across Inorganic, Organic, and Analytical courses supports the implementation of a unified, program-wide approach to laboratory safety training and enforcement. Instead of customizing interventions per course, the College should focus on reinforcing established best practices—particularly in addressing recurring, though infrequent, lapses such as improper chemical labeling and inconsistent us of personal protective equipment (PPE) —to shift all safety indicators from "Rarely" to "Never."

3.3 Student-Perceived Contributing Factors to Laboratory Lapses

Perceived Contributing Factors to Laboratory Safety Issues and Violations in Chemistry Courses

To contextualize student perceptions of laboratory safety challenges, the researcher conducted a thematic analysis of students' open-ended responses. This process distilled five interrelated themes—insufficient training and orientation; human factors (carelessness, negligence, overconfidence); time pressure and rushing; inadequate resources and equipment; and weak supervision, enforcement, and communication. The sections that follow offer a detailed interpretation of each theme.

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1. **Insufficient Training and Orientation.** Many students reported that a single safety initial safety briefing at the start of the course is inadequate to ensure long-term compliance. Without ongoing reinforcement—through hands-on drills, periodic quizzes, or brief refresher sessions—learners tend to forget or misunderstand core protocols. This gap mirrors findings by Nwele (2013) and Deepak (2016), who noted that sporadic orientation fails to instill durable safety habits. To address this, laboratories should integrate scaffolded training—short, targeted refreshers before each major experiment—to keep safety practices top of mind and reduce reliance on memory alone.

2. **Human Factors: Carelessness, Negligence, and Overconfidence.** A second theme centers on individual attitudes—carelessness ("we overlook things"), negligence ("not following rules"), and overconfidence ("shortcut the steps"). Even with adequate training, cognitive biases (e.g., that "it won't happen to me" mindset) lead students to skip critical PPE or bypass cleanup. Kerimak-Öner (2020) and Canel (2002) emphasize that fostering a robust safety culture requires more than rules; it demands attitude shifts. Embedding reflective exercises—such as incident debriefs or peer-led safety pledges—can help students internalize the real consequences of lapses and cultivate greater vigilance.

3. **Time Pressure and Rushing to Finish.** Repeatedly, learners cited the pressure to complete experiments swiftly as a catalysts for safety violations. Under tight deadlines or during periods of fatigue, students rush through procedures—skipping waste disposal protocols or mislabeling containers—which increases the risk of accidents. This observation aligns with West et al. (2003), who documented that operational tempo directly correlates with procedural errors. Mitigation strategies include designing laboratory schedules with built-in buffer time, staggering group start times, and teaching students time-management techniques tailored to multi-step experiments.

4. **Inadequate Resources and Equipment.** Structural shortcoming—such as expired eyewash stations, insufficient gloves, or missing hazard signage—undermine even the most conscientious students. When PPE is unavailable or facilities are poorly maintained, compliance becomes impossible rather than merely inconvenient. The American Chemical Society (ACS) (2015) stresses that accessible, well-serviced equipment is a prerequisite for safe practice. Regular audits of safety stations, prompt replacement of expired supplies, and clearly visible hazard labels ensure that resource gaps do not translate into student risk.

5. **Weak Supervision, Enforcement, and Communication.** Finally, limited instructor oversight—especially in large or concurrent lab sections—allows minor infractions to go unchecked until they escalate. When coupled with ambiguous signage or overly technical protocol language, students may misinterpret safety rules. OSHA (2017) and ACS guidelines both highlight the importance of immediate corrective feedback and unambiguous communication. Implementing peer-monitoring teams, increasing lab-assistant ratios, and using visual "job-aid" posters can strengthen enforcement and ensure that students' questions are addressed in real time.

Student Narratives on Chemistry Laboratory Safety Violations

To ground these abstract findings in lived experience, students were asked to recount specific laboratory safety incidents they had witnessed or personally experienced. Their detailed narratives revealed four

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core themes: equipment misuse (including breakage and the use of inappropriate or non-laboratory apparatus), non-compliance with personal protective equipment (PPE) protocols, procedural lapses and unsafe behaviors, and deficiencies in awareness, supervision, and the overall laboratory environment. Each theme offers critical insight into the real-world factors that contribute to safety violations in undergraduate chemistry settings.

1. **Equipment Misuse, Breakage, and Non-Lab Apparatus**. Numerous students described accidents stemming from the improper handling or selection of tools. In several cases, brittle glassware shattered—one student recalled breaking an evaporating dish and then risking injury by picking up shards with bare hands; another described a classmate inattentively dropping a beaker, scattering broken fragments across the bench and floor. Beyond breakage, students reported the use of unauthorized household appliances—such as transferring beaker contents into a personal electric kettle—leading to contamination and rendering the device unsafe for home use. One response even mentioned a frayed extension cord with exposed wires, highlighting how overlooked equipment defects can introduce electrical hazards.

   These accounts underscore the need for strict equipment-audit protocols, prompt removal of damaged items, and clear prohibitions against the use of non-laboratory apparatus.

2. **Personal Protective Equipment Non-Compliance**. Everyday PPE violations emerged as a pervasive risk factor. Students admitted to working gloves or goggles—often under the misconception that certain tasks were "low-risk"—and some recounted observing peers skip masks during naphthalene experiments. One near-miss involved a small splash striking a student's unprotected eye, serving as a stark reminder that even routine procedures demand full PPE.

   These lapses, whether due to overconfidence or perceived insignificance, reveal that merely issuing safety gear is insufficient. Ongoing reinforcement, spot checks, and cultivating a culture that normalizes 100% PPE compliance are essential.

3. **Procedural Lapses and Unsafe Behaviors**. A third theme centers on routine safety protocols being overlooked in the rush to complete tasks. Students described benches cluttered with forgotten pipettes, unwashed flasks, and unlabeled beakers—instances of "we forget to label containers" or reused pipettes without cleaning.

   Behaviors such as eating inside the lab, wearing lab gowns outside during breaks, or smelling chemicals directly from a pinch-and-sniff bottle further illustrate a habitual disregard for safety rules. These actions not only violate protocols but also increase the risk of contamination and chemical exposure.

   Structured pre-lab checklists, bench-clearing routines, and habitual reinforcement of lab etiquette could help instill systematic adherence to basic safety practices.

4. **Awareness, Supervision, and Environmental Gaps**. Finally, many narratives highlighted how lapses in oversight and environmental design exacerbate unsafe conduct. Students reported times

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when they "weren't paying attention" during safety briefings and only realizing hazards mid-experiment.

Limited instructor presence allowed minor infractions—such as improper waste disposal, unattended Bunsen burners, or unlabeled hazards—to go unchecked until they escalated. Crowded walkways and inadequate signage further hindered safe traffic flow and emergency response.

These insights point toward the need to bolster supervision ratios, enhance on-bench signage, and establish open channels for immediate safety feedback.

Together, these themes reveal that laboratory safety violations are rarely the result of a single error. Instead, they emerge from a web of equipment inadequacies, human shortcuts, procedural forgetfulness, and supervisory blind spots. Addressing them requires a holistic strategy: rigorous equipment inspections, consistent PPE enforcement, ingrained procedural habits, and a laboratory environment designed for constant vigilance. Only by embedding safety into every aspect of laboratory life can future science educators internalize—and model—the uncompromising standards their own students will one day expect.

Clarity and Comprehensibility of Chemistry Laboratory Safety Protocols

To assess how effectively laboratory safety protocols are understood and implemented, students were asked whether any existing rules felt unclear or difficult to follow. While a majority—over two-thirds—reported no confusion, often citing clear explanations provided during orientation, responses from the remaining students surfaced three specific areas of concern: chemical waste disposal, emergency procedures, and practical barriers to PPE compliance.

1. **Ambiguities in Chemical-Waste Disposal**. Several students reported uncertainty about proper disposal practices for various liquid chemical wastes, especially when disposal containers were inadequately labeled. One respondent described hesitating during an experiment over whether a used reagent should be discarded down the sink or placed in a designated waste bin—hesitation that was exacerbated by the pressure of ongoing laboratory work. Others expressed unfamiliarity with how to dispose of specific chemicals or operate fume hoods for volatile solvents. These issues suggest that verbal instructions alone are insufficient. The implementation of clearly labeled, color-coded disposal bins, along with step-by-step visual guides and disposal protocols posted near workstations, would significantly enhance clarity and reduce hesitation.

2. **Unclear Emergency-Response Procedures**. Although most students could identify the location of safety equipment such as showers and fire extinguishers, many reported lacking confidence in how to respond effectively during an actual emergency. One student admitted, "I know where they are supposed to be, but I don't always feel confident about what to do first in a spill or fire scenario." This highlights a gap between passive awareness and actionable readiness. To bridge this gap, emergency response procedures must be reinforced not just through initial briefings but through regular scenario-based drills and accessible quick-reference guides. These approaches would help internalize procedures, making appropriate responses more instinctive during high-stress situations.

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3. **Practical Barriers to PPE Compliance**. A smaller subset of students pointed out practical difficulties in adhering to PPE requirements, particularly concerning lab gowns. In poorly ventilated laboratories, students often removed or left gowns unbuttoned due to discomfort, despite understanding the requirement. Others noted that during breaks, they sometimes forgot to remove their gowns as required. These challenges reveal that procedural compliance is often influenced by physical conditions and habitual behavior. Improvements such as better ventilation systems, the provision of lighter-weight lab coats, and strategically placed "Gown On / Gown Off" reminders at lab entrances and exits could promote consistent PPE adherence.

Although most protocols are conceptually well understood, these findings indicate that clarity alone does not ensure compliance. Effective laboratory safety requires actionable reinforcement. By implementing targeted measures—such as enhanced waste disposal signage, hands-on emergency training, and environmental adjustments for PPE comfort—institutions can help transform procedural knowledge into routine, automatic behavior, ultimately cultivating a safer and more disciplined laboratory culture.

The Role of Peer Behavior in Shaping Laboratory Safety Practices

Effective laboratory safety hinges not only on formal rules but also on the everyday behaviors students model for one another. Responses to questions about peer influence revealed four interconnected themes: positive modeling of safe practices, normalization of unsafe behaviors, peer pressure and distraction, and the importance of collective responsibility in overcoming the bystander effect. Together, these themes illustrate how social dynamics within student groups can either reinforce or undermine laboratory safety.

1. **Positive Peer Modeling of Safe Practices.** Positive modeling emerged as the most frequently cited influence. When some students consistently don PPE, follow protocols, and demonstrate careful technique, their example creates a ripple effect. Remarks such as "when classmates follow rules seriously, it encourages others" and "positive peer influence can promote safe practices" suggest that students observe and emulate their peers' behaviors. In effect, compliant students serve as on-the-spot safety coaches, reminding their colleagues of correct procedures through both actions and words. This peer-to-peer reinforcement helps transform safety rules from abstract directives into shared group norms.

2. **Negative Normalization of Unsafe Behaviors.** Conversely, negative modeling can quickly normalize unsafe shortcuts. Many respondents acknowledged that if even a few students "act carelessly" or "ignore safety procedures," their behavior emboldens others to skip steps such as wearing goggles or labeling chemicals. Comments like "shortcuts or risky practices become normalized" highlight how one person's lapse can cascade into a group-wide tolerance for risk. Over time, repeated collective violations blur the line between safe and unsafe practices, making it harder for individuals—even those who know better—to resist peer conformity.

3. **Peer Pressure and Distraction.** Closely related is the influence of peer pressure and distraction. Several students admitted that playful teasing, rushing to keep up, or loud, inattentive behavior "creates distractions" that divert focus from critical safety checks. In such moments, even well-trained students may forget to replace broken glassware, secure lab coats, or double-check a procedure. The

laboratory—ideally a space for careful precision—can becomes a setting where social dynamics override safety mindfulness.

4. **Collective Accountability and the Bystander Effect.** Finally, many responses touched on the importance of collective responsibility and the bystander effect. In a shared environment, individual lapses endanger the entire group—"one person's carelessness puts everyone at risk," one student noted. However, when unsafe actions go unchallenged, silence can be mistaken for permission. Students often hesitate to intervene, allowing minor infractions to persist. Breaking this cycle requires fostering a culture in which every member feels both empowered and obligated to speak up, correct peers, and uphold the group's safety standards.

These findings underscore that laboratory safety is as much a social practice as a technical one. Cultivating a strong safety culture requires more than signs and orientations; it call for nurturing supportive peer networks, instilling mutual accountability, and training students not only in procedures but also in how to advocate for safety. When peers model, reinforce, and uphold safe behaviors, the laboratory becomes a shared environment where vigilance and responsibility are collective habits.

3.4 Suggested Measures for Strengthening Laboratory Safety Compliance

Drawing on the quantitative finding that, while overall laboratory safety violations are rated as "Rarely," specific domains—such as chemical labeling (mean = 2.33 in Inorganic Chemistry) and PPE use (means ranging from 2.15 to 2.25)—still present areas for improvement, and supported by qualitative themes including training gaps, human error, resource shortages, supervisory lapses, procedural ambiguities, and peer influence, the following multi-pronged interventions are recommended:

1. **Scaffolded Training and Continuous Reinforcement**
   - **Pre-lab Refresher Quizzes and Micro-Drills:** Before each major experiment, brief quizzes or hands-on drills focusing on key protocols (e.g., proper PPE use, emergency procedures, and waste disposal) can reinforce correct habits and reduce dependence on one-time orientations.
   - **Scenario-Based Emergency Drills:** Monthly, small-group simulations (e.g., chemical spills, fire responses) will promote calm, automatic decision-making under pressure and build real-world readiness.
   - **Competency Assessments for Equipment Use:** Quarterly check-off sessions requiring students to demonstrate proper equipment handling (setup, calibration, shutdown) with immediate feedback will ensure operational competence and prevent misuse.

2. **Clear, Accessible Procedures and Signage**
   - **Color-Coded Labeling and Disposal Stations:** Install clearly marked sinks and chemical waste binds, with laminated posters showing common chemicals and their correct disposal methods, reducing guesswork and errors.
   - **Bench-Clearing and Labeling Checklists:** Provide magnetized checklists at each lab station to ensure all chemical containers are properly labeled, benches are decluttered, and PPE is used consistently before and after experiments.
   - **PPE Exit Reminders:** Place decals near lab exits (e.g., "Gown On/Gown Off") to discourage wearing lab coats outside and to prompt re-donning before re-entry.

3. **Resource Audits and Equipment Management**
   - **Monthly Safety Audits:** A rotating student-faculty team should inspect PPE inventory (e.g., gloves, goggles, gowns), check expiration dates on emergency supplies (e.g., eyewash), and remove damaged or unauthorized equipment.
   - **Standardized Equipment Inventory Logs:** Maintain a central logbook to track equipment maintenance, calibration schedules, and repairs, ensuring all instruments remain functional and safe to use.

4. **Strengthened Supervision and Accountability**
   - **Peer Safety Champions:** Designate a rotating "safety captain" within each lab group responsible for brief safety checks and rule reminders, harnessing positive peer modeling.
   - **Increased Lab Assistant Coverage:** Deploy additional undergraduate assistants during peak laboratory sessions to help monitor compliance, offer support, and reinforce safety protocols.
   - **Incident Debriefs and Reporting:** Following any incident (spill, breakage, near-miss), hold a short group debrief to identify root causes and reinforce safety takeaways, fostering a culture of open learning over blame.

5. **Cultivating a Safety-First Culture**
   - **Safety Pledge and Reflective Exercises:** At the beginning of the term, students sign a "Lab Safety Commitment" and periodically write brief reflections on one safety protocol they aim to improve, building personal responsibility.
   - **Time-Management Coaching:** Conduct workshops on pacing multi-step experiments, emphasizing realistic time allocations to reduce errors driven by haste or pressure.
   - **Recognition and Positive Reinforcement:** Feature bulletin boards highlighting "Spotless Stations" and "No-Issue Weeks" to celebrate model behavior, promoting motivation through healthy competition.

By embedding these measures into daily laboratory routines—addressing both structural supports (equipment, signage, audits) and human factors (training, peer norms, and safety culture)—the College can move from "Rarely" to "Never" on all safety violation metrics. This will help ensure that BSEd Science students graduate not only as competent scientists but also as responsible and vigilant future educators.

4.0 Conclusion

The research confirms that BSEd Science students generally adhere to laboratory safety protocols, with violation frequencies consistently rated as "Rarely" across Inorganic, Organic, and Analytical Chemistry courses. Statistical analyses further indicate that course type does not significantly influence the occurrence of safety lapses. However, certain issues—particularly to chemical labeling and PPE usage—persist and warrant continued attention.

Qualitative analysis of student narratives revealed five interrelated drivers of unsafe practices: insufficient initial and refresher training; human tendencies toward carelessness or overconfidence; time pressure that fosters haste; inadequate equipment availability and maintenance; and lapses in supervision

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or ambiguous procedural guidance. These findings informed a set of targeted, multi-pronged recommendations: scaffolded safety drills, clear and color-coded disposal systems, routine equipment audits, peer-led safety monitoring, and initiatives to foster a proactive safety culture.

By integrating quantitative rigor with qualitative depth, this study addresses a critical gap in localized research on laboratory safety within teacher preparation programs. The implementation of the recommended strategies can transform episodic compliance into habitual practice, ensuring that future science educators consistently model and uphold high safety standards. Future research should evaluate the long-term effectiveness of these interventions and explore comparable dynamics across other science disciplines and institutional institutions.

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The author declares no conflict of interest.

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