E-Journal of Humanities, Arts and Social Sciences (EHASS)
ISSN – Online 2720-7722 | Print 2821-8949
Volume 7 Issue 10 2026 pp 3155 - 3169
Available online at: https://noyam.org/journals/ehass/
DOI: https://doi.org/10.38159/ehass.202671016

Check for updates

Enhancing laboratory safety awareness among students: A Constructivist Learning Theory perspective

Vuyokazi Momoti[1]

[1] iYunivesithi Walter Sisulu, South Africa.

ABSTRACT

Laboratory safety is a vital component of science education, essential for protecting learners and ensuring the integrity of experimental procedures. This study investigates students' understanding of laboratory safety through the analysis of test responses across nine key safety categories: Flammable, Safety Shower, Fire Extinguisher, Corrosive, Emergency Exit, Toxic, Electrical Hazard, First Aid, and Assembly Point. Guided by Constructivist Learning Theory, the research explored how students construct safety knowledge, identify prevalent misconceptions, and propose strategies to enhance safety literacy. A document analysis methodology was employed to conduct a quantitative investigation of 41 student responses, drawn from a cohort of 55 enrolled in a science education program. The study focused on patterns of misidentification and conceptual confusion related to laboratory safety signs. Responses were evaluated for frequency, accuracy, and clarity, and visualized using frequency charts to highlight dominant terms and recurring errors. Findings reveal uneven understanding across safety categories, with students demonstrating greater familiarity with visually prominent protocols and less awareness of abstract or infrequently reinforced concepts. The results suggest that text-based instruction alone is insufficient for developing comprehensive safety literacy. To address this, the study recommends the integration of multimodal instructional strategies, including visual aids, infographics, videos, and regular safety drills, to reinforce correct procedures and bridge the gap between theory and practice. This research contributes to the growing body of literature on science education by emphasizing the importance of experiential and visual learning approaches in cultivating a culture of safety within laboratory environments.

Keywords: Laboratory Safety, Constructivist Learning Theory, Safety Literacy Misconceptions, Visual Instructional Strategies

INTRODUCTION

Laboratory environments are integral to science education, offering students valuable opportunities to engage in practical experimentation and inquiry. Yet, these spaces inherently involve risks such as chemical burns, fire hazards, electrical shocks, and exposure to toxic substances. Effective safety education is therefore essential, not only to safeguard learners but also to preserve the integrity of experimental processes. Despite this importance, safety instruction in many tertiary institutions continues to rely heavily on passive information delivery, which often fails to foster deep understanding or long-term behavioral change. In contrast, Constructivist Learning Theory, which emphasizes active

---

CORRESPONDENCE – Vuyokazi Momoti **Email:** vmomoti@wsu.ac.za
PUBLICATION HISTORY - Received: 30th January, 2026 | Accepted: 2nd September, 2026 | Published: 20th November, 2026.
TO CITE THIS ARTICLE – Momoti, Vuyokazi. "Enhancing laboratory safety awareness among students: A Constructivist Learning Theory perspective." *E-Journal of Humanities, Arts and Social Sciences* 7, no.10 (2026): 3155 - 3169. https://doi.org/10.38159/ehass.202671016
COPYRIGHT AND LICENSING - © 2026 The Author(s). Published and Maintained by Noyam Journals.
This is an open access article under the CCBY license (http://creativecommons.org/licenses/by/4.0/).

knowledge construction through experience, collaboration, and reflection, provides a promising framework for rethinking laboratory safety education.

Although laboratory safety protocols are well-documented, limited empirical research has explored how constructivist pedagogical approaches can enhance safety awareness among students in South African tertiary institutions. Existing studies tend to emphasize compliance and procedural knowledge rather than the active engagement of learners in authentic, context-rich safety practices. This gap underscores the need for an analysis that situates laboratory safety within a constructivist paradigm, examining how students construct meaning around safety protocols and identifying misconceptions that hinder effective practice. The objective of this study is to analyze student responses across nine key laboratory safety categories, namely Flammable, Safety Shower, Fire Extinguisher, Corrosive, Emergency Exit, Toxic, Electrical Hazard, First Aid, and Assembly Point, through the lens of Constructivist Learning Theory. By identifying misconceptions and evaluating the effectiveness of constructivist strategies, the study seeks to propose targeted improvements that enhance safety awareness and practice in tertiary science education.

Mayer's principles of visual learning are particularly relevant in multilingual South African classrooms, where the integration of text and visuals helps bridge language gaps and enhances retention.[1] Despite national emphasis on science education and safety compliance, a notable gap remains in the literature regarding students' understanding and interpretation of laboratory safety symbols. This gap underscores the need for localized research that can inform targeted instructional strategies and strengthen safety awareness among learners. Guided by Constructivist Learning Theory, this study seeks to address these challenges by exploring how students engage with laboratory safety concepts, identifying areas of misconception, and proposing pedagogical interventions that foster meaningful understanding.

To achieve this, the study is organized around three interrelated themes that collectively frame the analysis. The first theme, Students' Awareness of Laboratory Safety Categories, explores how experiential, collaborative, and authentic learning activities can foster deeper safety awareness. The second theme, Student Misconceptions in Laboratory Safety, focuses on identifying gaps in knowledge and misunderstandings across the nine categories, thereby highlighting areas where targeted interventions are needed. The third theme, Instructional Strategies to Address Misconceptions and Enhance Retention, examines how safety education can be embedded into science curricula in alignment with constructivist principles, ensuring that safety becomes a natural and continuous part of learning. Together, these themes provide a comprehensive framework for understanding and improving laboratory safety awareness through the lens of Constructivist Learning Theory.

Accordingly, the study is directed by the following research questions:

RQ1: What is the level of student awareness across nine key laboratory safety categories?

RQ2: Which safety concepts are most frequently misunderstood or misrepresented by students?

RQ3: What instructional strategies can address misconceptions and enhance retention of safety protocols?

LITERATURE REVIEW

Student Awareness of Laboratory Safety Categories

Constructivist Learning Theory, as proposed by Jean Piaget and Lev Vygotsky, emphasizes that learners actively construct knowledge through personal experience and social interaction.[2] This paradigm shifts the focus from passive reception of information to active engagement, where learners interpret and internalize new concepts by integrating them with existing cognitive frameworks. In the context of laboratory safety education, this theory offers a robust foundation for understanding how students develop their awareness and application of safety protocols.

Students often build their understanding of laboratory safety through a combination of prior experiences, peer interactions, and instructional cues. However, when prior knowledge is incomplete, informal, or

[1] Richard E. Mayer, *Multimedia Learning* (Cambridge University Press, 2009), https://doi.org/10.1017/CBO9780511811678.

[2] J. Piaget, *The Psychology of the Child* (New York: Basic Books, 1972); Lev S Vygotsky, "Mind in Society: The Development of Higher Psychological Processes" (Harvard university press, 1978).

incorrect, it can interfere with the assimilation of accurate safety practices, leading to persistent misconceptions. For example, a student who has previously handled chemicals without incident may underestimate the importance of wearing personal protective equipment (PPE), despite formal instruction to the contrary.

The importance of practical engagement in science education is underscored by Tindan and Anaba, who, in their systematic literature review, highlight the impact of hands-on scientific activities on academic success and safety awareness.[3] Activities such as safety drills, demonstrations, and guided discovery not only reinforce theoretical knowledge but also allow students to internalize safety procedures through direct experience. These experiential methods align closely with constructivist principles, promoting deeper understanding and long-term retention.

Further evidence of the need for experiential safety instruction is provided by Faulconer and Kam, whose research reveals that student awareness across safety categories is often uneven.[4] While students may be familiar with visible and frequently emphasized protocols such as wearing gloves or lab coats, they often lack understanding of less tangible or less reinforced practices, including proper chemical waste disposal or electrical hazard management. This disparity highlights the necessity of comprehensive, context-rich safety education that addresses all dimensions of laboratory safety.

Yao expands on the role of experiential learning in secondary school chemistry education, noting that traditional, lecture-based methods frequently fail to connect classroom instruction with practical application.[5] Experiential learning, characterized by active participation and hands-on engagement, offers students opportunities to explore scientific concepts, develop critical thinking skills, and apply safety procedures in realistic scenarios.

Complementing constructivist pedagogy, Visual Learning Theory, particularly as articulated by Mayer, emphasizes the cognitive benefits of integrating visual and verbal information to enhance comprehension and retention.[6] Mayer's Cognitive Theory of Multimedia Learning posits that learners process information through two distinct channels, visual/pictorial and auditory/verbal, and that meaningful learning occurs when both channels are engaged in a coordinated and balanced manner.

In laboratory safety education, visual learning strategies are particularly effective in conveying complex or abstract concepts. Safety symbols, pictograms, flowcharts, and instructional diagrams serve as cognitive anchors that help students associate visual cues with specific hazards, procedures, or equipment. These tools are especially valuable in multilingual and linguistically diverse classrooms, where visual aids can bridge language barriers and support inclusive learning environments.

The importance of visual reinforcement is further demonstrated in the study by Sonawane et al., which evaluated the safety knowledge of students at JET's Z. B. Patil College (India) and Concord University (USA).[7] The study found that while most students had basic safety awareness, gaps remained particularly among those who missed safety instruction sessions or exhibited poor attitudes toward safety. The use of visual reminders, such as safety charts and signage, was found to be instrumental in reinforcing correct practices and promoting a culture of safety.

Visual learning not only supports initial comprehension but also facilitates long-term retention and self-directed learning. Strategically placed visual cues in laboratory environments such as posters, labels, and digital displays can serve as immediate reference points during practical activities, reinforcing correct behaviour and reducing the likelihood of accidents. When combined with constructivist, experiential approaches, visual learning enhances the effectiveness of safety education by making abstract concepts tangible and accessible.

---

[3] P. Tindan and A. Anaba, "Hands-on Scientific Activities and Safety Awareness: A Systematic Review," *International Journal of Science Education* 42, no. 10 (2020): 1657–75.

[4] Emily Faulconer and Cheryl Kam, "Safety Competency in an Online Introductory Science Laboratory Course," *Quarterly Review of Distance Education* 24, no. 2 (2023): 1–12.

[5] Junchao Yao, "Exploring Experiential Learning: Enhancing Secondary School Chemistry Education Through Practical Engagement and Innovation," *Journal of Education, Humanities and Social Sciences* 22 (November 26, 2023): 475–84, https://doi.org/10.54097/ehss.v22i.12508.

[6] Mayer, *Multimedia Learning*.

[7] Swapnil L Sonawane, Vikas J Patil, and Rodney A Tigaa, "Evaluating and Promoting Chemical Safety Awareness in the Chemical Sciences," *Journal of Chemical Education* 100, no. 2 (2023): 469–78.

Misunderstood or Misrepresented Safety Concepts

Recent studies have highlighted both progress and persistent gaps in laboratory safety education across various academic contexts. In South Africa, Mugivhisa, Baloyi, and Olowoyo investigated postgraduate students' adherence to safety practices within the departments of Chemistry, Biology, and Biochemistry. Their findings revealed that while the majority of students consistently used personal protective equipment (PPE) such as lab coats and gloves, fewer students engaged in critical safety behaviors, including the use of fume cupboards, proper waste disposal bins, and inspection of chemical containers for hazard warnings. Alarmingly, many students were unable to identify all the warning signs on chemical containers, indicating a gap in hazard recognition and risk assessment.[8]

To address these shortcomings, the authors recommend the implementation of annual emergency safety drills, the installation of informational signage indicating emergency exits, and the placement of safety charts in all laboratories. Furthermore, they advocate for mandatory safety assessments at the beginning of each academic year for all postgraduate students. These assessments would ensure that students possess the requisite safety knowledge and are adequately prepared to work independently in laboratory environments without posing risks to themselves or others.

Complementing these findings, Mtikitiki et al. identified systemic challenges affecting laboratory safety management, including inconsistent hazard reviews, infrequent training, procedural delays, infrastructure limitations, and resource constraints.[9] These factors collectively undermine the ability of institutions to proactively manage health and safety risks. The study also noted that such challenges are not isolated but are echoed across sectors and institutions, often stemming from communication breakdowns, behavioural barriers, and leadership gaps. While the study's scope was limited to a single institution and employed purposive sampling, thus restricting generalizability it nonetheless provides valuable insights into the structural and operational barriers to effective safety education.

These empirical findings align closely with the principles of Constructivist Learning Theory, which posits that learners actively construct knowledge through experience and social interaction. In laboratory safety education, this means that students develop their understanding of safety protocols based on prior experiences, peer interactions, and instructional cues.[10] However, when prior knowledge is incomplete or incorrect, it can lead to persistent misconceptions. For instance, students may erroneously believe that goggles are only necessary during chemical experiments, overlooking the risks posed by biological or mechanical hazards. Vygotsky's emphasis on collaborative learning suggests that peer discussions and group activities can be instrumental in surfacing and correcting such misunderstandings.

To further support the correction of misconceptions, Visual Learning Approaches, particularly those outlined by Mayer, offer valuable pedagogical tools. Mayer's Cognitive Theory of Multimedia Learning demonstrates that combining text with visuals such as infographics, animations, and annotated diagrams can significantly enhance comprehension and retention.[11] In laboratory safety education, visual representations of correct versus incorrect practices can help students internalize appropriate behaviours more effectively than text alone. For example, a side-by-side comparison of proper PPE usage versus common mistakes can clarify expectations and reinforce correct procedures.

In summary, the integration of constructivist and visual learning strategies into laboratory safety education offers a promising pathway to address existing gaps in student knowledge and practice. Empirical evidence underscores the need for structured, experiential, and visually supported instruction, particularly in environments where resource limitations and inconsistent training practices persist. By aligning pedagogical approaches with cognitive and social learning theories, institutions can foster a more robust culture of safety and equip students with the skills necessary to navigate laboratory environments responsibly.

---

[8] L. Mugivhisa, O Baloyi, and J Olowoyo, "Postgraduate Students' Adherence to Laboratory Safety Practices in South African Universities ," 2021.

[9] Ntombenhle Mtikitiki et al., "Occupational Health and Safety Management System of a South African University Setting," *Safety* 11, no. 2 (April 10, 2025): 34, https://doi.org/10.3390/safety11020034.

[10] Vygotsky, "Mind in Society: The Development of Higher Psychological Processes."

[11] Mayer, *Multimedia Learning*.

Instructional Strategies to Address Misconceptions and Enhance Retention

Laboratory exposure plays a pivotal role in enhancing learners' conceptual retention and practical competence in science education. Valiente and Paglinawan underscore the significance of hands-on laboratory experiences in general chemistry, revealing a strong correlation between active engagement and the ability to retain and apply complex scientific concepts.[12] While students demonstrate high levels of engagement and awareness in laboratory settings, the study identifies critical gaps in safety protocol familiarity, troubleshooting skills, and comprehension of challenging topics. These deficiencies highlight the urgent need for comprehensive safety training programs, which should include hands-on practice with safety tools, routine safety drills, and contextual reinforcement of safety procedures.

Addressing these gaps not only enhances learners' confidence but also contributes to a secure and productive learning environment. Moreover, the development of initiative and problem-solving skills requires a pedagogical shift toward inquiry-based and project-based learning strategies. These approaches empower students to take ownership of their learning, collaborate effectively, and cultivate essential leadership and troubleshooting capabilities. The study further emphasizes the importance of connecting theory to practice through contextual learning and real-world applications, advocating for an interdisciplinary approach that makes chemistry more relatable and engaging.

In a related study, Akkuzu and Uyulgan examined the safety knowledge of pre-service teachers and found widespread deficiencies in understanding the chemical properties of substances, hazard classifications, storage protocols, and first aid procedures. Participants frequently misclassified chemicals based on perceived damage rather than actual hazard categories and demonstrated confusion regarding physical, health, and environmental risks. One of the study's key findings was the effectiveness of using real-life accident scenarios to raise awareness and contextualize safety risks.[13] This approach aligns with constructivist principles by situating learning within meaningful, experience-based contexts. To effectively address these challenges, instructional strategies must align with the constructivist view that learning is an active, iterative process.[14] Techniques such as scenario-based learning, peer instruction, and formative assessment allow students to engage dynamically with safety concepts, promoting deeper understanding and long-term retention. These strategies encourage learners to reflect on their experiences, confront misconceptions, and collaboratively construct accurate knowledge frameworks.

Complementing constructivist approaches, Mayer's Cognitive Theory of Multimedia Learning supports the integration of multimedia tools to reinforce safety education. Interactive simulations, visual storytelling, and annotated diagrams help students visualize the consequences of unsafe behavior and the benefits of proper protocol adherence. These tools cater to diverse learning styles and make abstract safety concepts more concrete and accessible.[15] For instance, visual comparisons of correct versus incorrect PPE usage or animated depictions of chemical spill responses can significantly enhance comprehension and behavioural compliance. In conclusion, the integration of experiential learning, constructivist pedagogy, and visual learning strategies offers a robust framework for improving laboratory safety education. By addressing cognitive, behavioural, and contextual dimensions of learning, educators can foster a culture of safety that is both pedagogically sound and practically effective.

THEORETICAL FRAMEWORK

Constructivist Learning Theory

Constructivist Learning Theory, articulated by Piaget and Vygotsky, emphasizes that learners actively construct knowledge through experience, reflection, and social interaction rather than passively absorbing information. Piaget highlighted assimilation and accommodation as mechanisms of cognitive development, while Vygotsky underscored the importance of cultural tools and the Zone of Proximal

[12] Bernadeth A Valiente and James L Paglinawan, "Laboratory Exposure and Learners Conceptual Retention in General Chemistry," *International Journal Of All Research Writings* 6, no. 6 (2024): 131–39.
[13] E Akkuzu Guven and M. A Uyulgan, "Pre-service Teachers' Safety Knowledge and Misconceptions in Chemistry Laboratories ," *Journal of Chemical Education* 1452, no. 1460 (2022): 99–4.
[14] Piaget, *The Psychology of the Child*; Vygotsky, "Mind in Society: The Development of Higher Psychological Processes."
[15] Mayer, *Multimedia Learning*.

Development (ZPD), where learners achieve deeper understanding with appropriate scaffolding.[16] In laboratory education, constructivism explains how misconceptions about safety or scientific processes often arise from incomplete prior experiences. By engaging students in hands-on activities, simulations, and collaborative problem-solving, educators can correct misconceptions and foster meaningful learning. For example, simulated chemical spill responses or guided laboratory demonstrations encourage students to apply protocols, evaluate risks, and reflect on outcomes. Such experiential approaches embed safety and scientific knowledge within authentic contexts, reinforcing retention and transfer across disciplines.

Visual Learning Theory

Complementing constructivist pedagogy, Mayer's Cognitive Theory of Multimedia Learning highlights the cognitive benefits of integrating textual and visual information.[17] Learners process information through dual channels, verbal and visual and meaningful learning occurs when both are engaged in a coordinated manner. In laboratory and science education, visual strategies such as safety symbols, pictograms, flowcharts, and instructional diagrams serve as cognitive anchors, helping students associate visual cues with specific actions or risks. This is particularly valuable in multilingual classrooms, where visual aids bridge language gaps and support inclusivity. Research demonstrates that students recall and apply protocols more effectively when presented in visually enriched formats.[18] For instance, pairing hazard symbols with explanatory text and real-life imagery improves comprehension and reduces misinterpretation. Visual learning also supports self-directed learning, as students can revisit charts, posters, and digital resources as needed. In laboratory environments, strategically placed signage and visual reminders reinforce correct behavior and provide immediate reference points during practical activities.

METHODOLOGY

Research Design

This study adopted a document analysis design with a quantitative orientation, chosen to systematically examine students' exam responses and identify patterns of misidentification related to laboratory safety signs. By focusing on textual extracts rather than observational or experimental data, the design allowed for a structured investigation of misconceptions across predefined safety categories. This approach was appropriate for capturing recurring errors in written assessments, thereby providing insight into students' conceptual frameworks of laboratory safety.

Study Sample and Population

The sample comprised 41 exam extracts from a population of 55 tertiary-level science students enrolled in a South African university program. Although relatively small, the sample size was sufficient to identify recurring misconceptions and patterns of misidentification. The selection was based on convenience sampling, as responses were drawn from students who completed the specific assessment during the study period. While this limits generalizability, the sample provided meaningful insights into laboratory safety awareness within the cohort.

Data Collection

Data were collected from students' written exam responses, focusing on their ability to correctly identify laboratory safety signs. Each student's categorization of safety concepts was captured under nine thematic areas: *Flammable, Safety Shower, Fire Extinguisher, Corrosive, Emergency Exit, Toxic, Electrical Hazard, First Aid, and Assembly Point.*

[16] Piaget, *The Psychology of the Child*; Vygotsky, "Mind in Society: The Development of Higher Psychological Processes."
[17] Mayer, *Multimedia Learning*.
[18] Mayer, *Multimedia Learning*; J. Morgado, P. Silva, and R. Fernandes, "Visual Learning Strategies in Multilingual Science Classrooms: Implications for Laboratory Safety," *Learning and Instruction* 94 (2024): 101999.

Validity and Reliability

To ensure validity, the laboratory safety test was developed in alignment with internationally recognized hazard categories and institutional safety protocols. The assessment instrument underwent expert review by faculty members specializing in science education and laboratory management, ensuring that items accurately reflected safety standards. Reliability was addressed through a coding procedure, where student responses were independently categorized by two researchers. Inter-coder agreement was calculated to confirm consistency, thereby strengthening the reliability of findings.

Justification of Instrument Development

The assessment instrument was designed to evaluate both recognition and categorization of safety signs, reflecting real-world laboratory requirements. Its development was justified by the need to assess not only theoretical knowledge but also practical hazard awareness. By focusing on written exam responses, the instrument provided a standardized measure of students' ability to interpret safety symbols, which is critical for laboratory practice.

Limitations of Methodology

The study analyzed 41 exam responses from a population of 55 students. While sufficient to identify recurring misconceptions, the relatively small sample size limits statistical generalizability. Moreover, the use of convenience sampling, drawing only from students who completed the specific assessment, may introduce bias, as the sample may not fully represent the broader population of tertiary-level science students.

Data collection was restricted to students' written exam responses. Although this provided structured textual evidence of misconceptions, it excluded observational insights into students' practical behaviors during laboratory activities. Consequently, the findings reflect conceptual recognition rather than actual performance in real laboratory contexts.

The laboratory safety test was designed to evaluate recognition of hazard categories. While aligned with institutional safety protocols, the study did not provide detailed justification for the instrument's development or report pilot testing. This raises questions about content validity, particularly whether the items comprehensively captured the range of laboratory safety knowledge required.

Although faculty experts reviewed the instrument, the study did not elaborate on the review process or criteria used. Similarly, while coding of responses was conducted, the reliability of categorization was not quantified through measures such as inter-coder agreement. This omission limits confidence in the consistency of data interpretation.

Data Analysis Procedure

The collected responses were analyzed quantitatively to determine frequency, accuracy, and conceptual clarity. Incorrect identifications were coded and categorized to highlight common misconceptions. A dashboard of frequency charts was generated to visualize dominant terms and recurring patterns across the nine categories. This enabled the identification of areas where students demonstrated strong understanding and where misconceptions were most prevalent.

Ethical Considerations

Ethical principles were observed throughout the study. Student responses were anonymized to protect confidentiality, and no identifying information was included in the analysis. Participation was limited to students already enrolled in the program, and the use of exam extracts was approved within institutional guidelines. The study was conducted with respect for academic integrity and in alignment with ethical standards for educational research.

Question extracted from the Term test
Instruction: Name the following eight (8) standard laboratory safety signs. For each, provide the correct category or hazard it represents.

A Figure 1



B Figure 2



C Figure 3



D Figure 4



E Figure 5



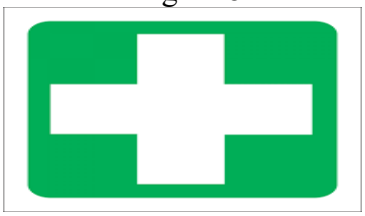
F Figure 6



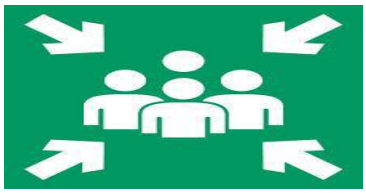
G Figure 7



H Figure 8



I Figure 9



PRESENTATION OF FINDINGS

Figure 10 illustrates the frequency and variation of student responses when identifying laboratory safety signs across nine categories:

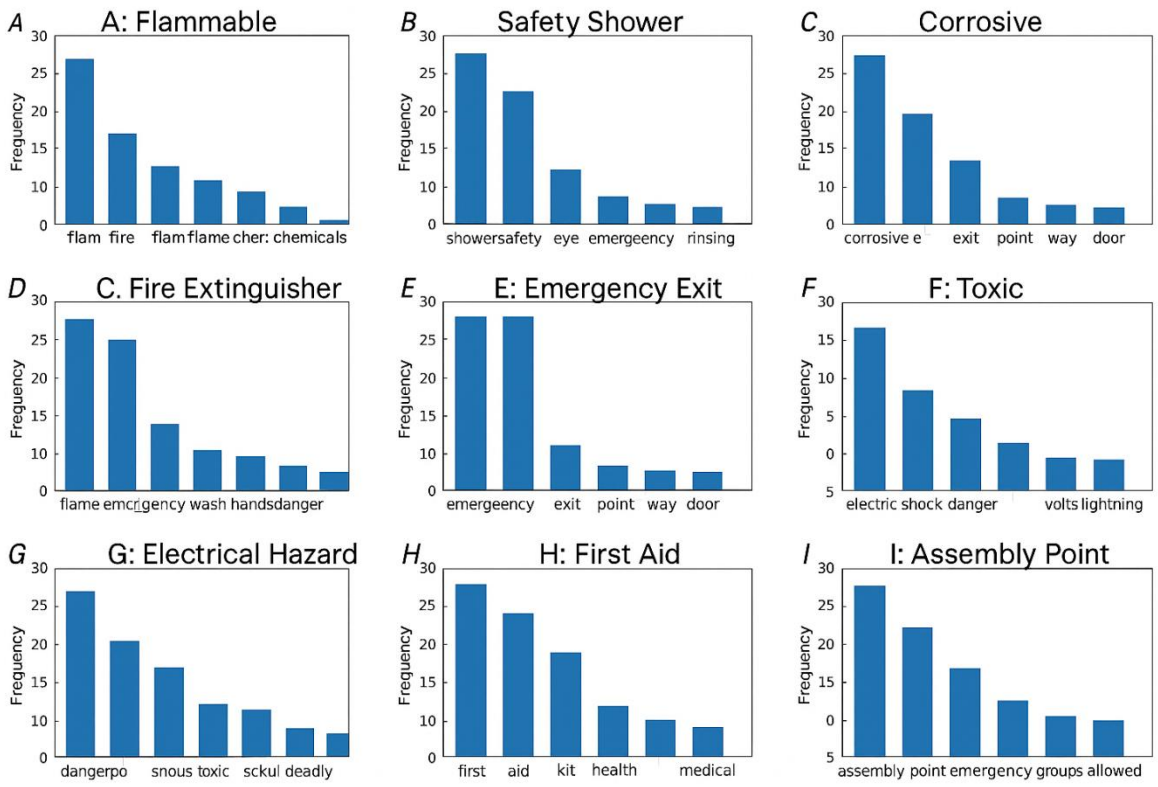


Figure 10: Frequency and variation of student responses

Figure 10 illustrates the frequency and variation of student responses when identifying laboratory safety signs across nine categories:

Flammable: The term flammable was most frequently used, with variants such as fire and highly flammable. This reflects strong awareness of fire hazards, although minor spelling inconsistencies highlight the need for reinforcement of standardized terminology.

Safety Shower: Responses commonly included shower, safety, eye, and emergency. While students recognized the concept, confusion was evident in entries such as bathroom and funner, suggesting partial misunderstanding of the laboratory-specific context.

Fire Extinguisher: The dominant term was fire extinguisher, demonstrating high awareness and proper labeling. This category reflects strong conceptual clarity and recognition of emergency equipment.

Corrosive: Frequent terms included corrosive, chemical, and wash hands. However, unrelated entries such as communication and exit suggest that some students misinterpreted the symbol, indicating gaps in hazard-specific knowledge.

Emergency Exit: Responses were highly consistent, with terms such as emergency exit, exit point, and exit way. This demonstrates strong understanding of evacuation routes and effective recognition of emergency signage.

Toxic: Students frequently used danger, poisonous, toxic, and skull. While hazard recognition was generally strong, irrelevant terms such as skeleton appeared, suggesting occasional misinterpretation of pictorial cues.

Electrical Hazard: Common responses included electric shock, danger, volts, and lightning. Although awareness of electrical risks was evident, vague terms such as danger dominated, indicating limited precision in hazard identification.

First Aid: Responses were clear and accurate, with terms such as first aid kit, health, and medical. This reflects a strong understanding of first aid resources and their role in laboratory safety.

Assembly Point: Students frequently used assembly point, emergency, and groups allowed. While awareness of gathering points was evident, some confusion emerged in unrelated phrases, suggesting that the symbol's meaning was not universally understood.

Analysis of Apparatus Identification

The frequency analysis of student responses reveals notable variation in the accuracy of laboratory apparatus identification (Table 1). Items such as the Bunsen burner, test tube, beaker, and thermometer were identified with high accuracy rates (≥90%), suggesting that students are most familiar with basic and frequently utilized equipment. These results indicate that repeated exposure in both classroom demonstrations and practical sessions reinforces recognition of foundational tools. In contrast, apparatus such as the Erlenmeyer flask (62%), wire gauze (70%), spatula (70%), and safety goggles (71%) were identified with lower accuracy. Errors in these categories were predominantly spelling-related (e.g., "elernmeyer flas," "spatiula," "googles") or involved substitution with everyday terminology (e.g., "sunglasses" for safety goggles, "medicine dropper" for pipette). These findings highlight persistent misconceptions and suggest that less frequently emphasized apparatus are more vulnerable to misidentification.

Moderate accuracy rates (70–80%) were observed for items such as the evaporating dish, wash bottle, funnel, and test tube rack. Here, students demonstrated partial familiarity but also recurring confusion, often conflating terms or relying on approximate descriptors (e.g., "solution wash" for wash bottle, "basin" for evaporating dish). Overall, the dataset demonstrates an average accuracy rate of approximately 75%, with strong recognition of core apparatus but weaker identification of specialized or safety-related items. From a pedagogical perspective, these results underscore the importance of integrating constructivist learning approaches, where students engage in hands-on orientation sessions to reconstruct accurate knowledge, alongside visual learning strategies, such as labeled diagrams and video demonstrations, to reinforce terminology and spelling. The analysis further suggests that curriculum design should prioritize apparatus with low accuracy rates, ensuring that students develop both conceptual clarity and linguistic precision. By embedding repeated exposure, visual reinforcement,

and experiential practice, educators can address misconceptions and strengthen laboratory safety awareness

Table 1: Frequency of Correct vs. Incorrect Identifications

Apparatus Identifications	Correct Identifications	Incorrect/Misspelled	Accuracy Rate
Bunsen burner	40	2 ("bansin burner")	95%
Ring stand	34	6 ("ring stang," "retort stand," "clamp stand")	85%
Evaporating dish/basin	32	10 ("evaporation jar," "evaporating tool," "basin")	76%
Test tube	38	4 ("test tiube," "tset tube," "test tun beem")	90%
Wire gauze	28	12 ("iron gaize," "gauze wire," "metal guizer")	70%
Safety goggles	30	12 ("googles," "goglers," "sunglasses")	71%
Tripod stand	34	6 ("tripod holder," "tripod stand")	85%
Beaker	32	4 ("erymeter beaker," "mixing beaker")	90%
Erlenmeyer flask	38	15 ("elernmeyer flas," "elenmeyer flask," "ernelymer flask")	62%
Stirring rod	34	12 ("string rod," "stick for mixing," "glass tester")	70%
Wash bottle	28	8 ("wasing bottle," "solution wash," "squeeze wash")	80%
Thermometer	32	4 ("erymeter," "beaker thermometer")	90%
Graduated cylinder	30	6 ("grauted," "measuring sylinder," "bunsen cylinder")	85%
Spatula/Scoopula	28	12 ("spatiula," "spacula," "spattula," "scapula")	70%
Funnel	32	8 ("funel," "fanel," "furnel")	80%
Test tube rack/holder	30	10 ("test tube racker," "test tube track," "test tube raskks")	75%

DISCUSSION

Constructivist Orientation

The findings of this study were interpreted through the lens of Constructivist Learning Theory, which posits that learners actively construct knowledge by integrating new information into pre-existing mental schemas.[19] Misconceptions observed among students, such as confusing a "bathroom" with a "safety shower" or labeling electrical hazards simply as "danger", reflect the assimilation of new concepts into flawed or incomplete prior knowledge. This aligns with Mugivhisa, Baloyi, and Olowoyo, who found that postgraduate students struggled to interpret hazard warnings despite consistent use of protective equipment.[20] The persistence of such errors underscores the challenge of correcting entrenched misconceptions when instruction relies primarily on lectures or text-based explanations. Within the constructivist framework, these findings suggest that students' inaccurate mental models must be actively reconstructed through meaningful engagement, rather than passively corrected. The discussion method therefore emphasized the importance of scaffolding, peer mediation, and contextualized learning experiences to reshape students' conceptual frameworks. By situating laboratory safety education within

[19] Piaget, *The Psychology of the Child*; Vygotsky, "Mind in Society: The Development of Higher Psychological Processes."
[20] Mugivhisa, Baloyi, and Olowoyo, "Postgraduate Students' Adherence to Laboratory Safety Practices in South African Universities ."

constructivist principles, the study highlights the need for pedagogical approaches that acknowledge learners' prior knowledge, confront misconceptions directly, and provide opportunities for cognitive restructuring through guided practice and reflection. This orientation ensures that safety education is not merely about transmitting information but about transforming learners' understanding of hazards into accurate, functional knowledge structures.

Experiential and Practical Emphasis

The uneven grasp of laboratory safety categories revealed in this study stronger recognition of visible hazards such as fire extinguishers, but weaker comprehension of abstract hazards like electrical risks demonstrates the limitations of purely theoretical instruction. This finding resonates with Daramola et al., who emphasize the importance of experiential learning methods, including safety drills, demonstrations, and guided discovery, in cultivating hazard recognition skills.[21] Similarly, Faulconer and Kam reported that students often fail to internalize protocols that are not frequently reinforced through practice, particularly those involving electrical hazard management.[22] The discussion method therefore foregrounded the role of hands-on engagement in bridging the gap between theory and practice. By analyzing students' stronger awareness of tangible hazards, the study illustrates how visibility and repeated exposure enhance comprehension, while abstract or less frequently encountered risks remain poorly understood. This interpretation underscores the necessity of integrating practical exercises into laboratory safety education, ensuring that learners not only hear about hazards but also experience and rehearse appropriate responses. Safety drills, scenario-based exercises, and guided demonstrations provide opportunities for learners to reconstruct their mental models through active participation, thereby reinforcing correct procedures for emergency exits, assembly points, and equipment use. Within the constructivist framework, experiential learning serves as a critical mechanism for transforming misconceptions into accurate knowledge, as learners engage directly with the realities of laboratory hazards. The discussion method thus emphasized that practical engagement is not supplementary but essential, positioning experiential strategies as central to effective safety education.

Multimedia Integration

The evidence of conceptual confusion observed in this study further highlights the inadequacy of text-based safety instruction. Students' misinterpretations of safety categories suggest that abstract hazards are difficult to grasp without visual reinforcement. This finding aligns with Mayer's Cognitive Theory of Multimedia Learning, which demonstrates that combining text with visuals enhances comprehension and retention by engaging multiple cognitive channels.[23] The discussion method therefore emphasized the integration of multimedia tools, posters, icons, infographics, and videos as pedagogical strategies to make abstract hazards more tangible. In linguistically diverse classrooms, visual cues serve as inclusive learning tools, reducing barriers to comprehension and ensuring that safety messages are accessible to all learners. This interpretation resonates with Sonawane et al., who found that visual reminders were instrumental in reinforcing correct practices and promoting a culture of safety.[24] By situating the findings within multimedia learning theory, the discussion highlighted how visual reinforcement can correct misconceptions by providing concrete representations of abstract hazards. For example, icons depicting corrosive substances or electrical risks can anchor students' understanding in recognizable imagery, reducing reliance on vague descriptors such as "danger." The discussion method thus underscored the importance of designing laboratory environments that are visually rich, with strategically placed signage and multimedia resources that continuously reinforce safety protocols. This approach not only supports comprehension but also fosters long-term retention, ensuring that learners internalize accurate safety practices. In this way, multimedia integration complements experiential learning, providing both cognitive and practical reinforcement of laboratory safety concepts.

---

[21] Dorcas S Daramola, Jumoke I Oladele, and Mdutshekelwa Ndlovu, "Impact of Technology-Enhanced Experiential Learning on Postgraduate Students' Training in Qualitative Research," *African Perspectives of Research in Teaching and Learning Journal Issue*, no. 8 (2024).

[22] Faulconer and Kam, "Safety Competency in an Online Introductory Science Laboratory Course."

[23] Mayer, *Multimedia Learning*.

[24] Sonawane, Patil, and Tigaa, "Evaluating and Promoting Chemical Safety Awareness in the Chemical Sciences."

Social Mediation and Peer Collaboration

The findings of this study also underscore the role of peer interaction and collaborative learning in correcting misconceptions. Vygotsky's constructivist principle of social mediation suggests that learners reconstruct knowledge through dialogue and shared experiences. The discussion method therefore emphasized collaborative learning strategies, such as peer-led safety audits, group discussions, and scenario-based exercises, as mechanisms for surfacing misunderstandings and facilitating cognitive restructuring. Misconceptions identified in the study, such as mislabeling hazards or confusing safety equipment, were interpreted as opportunities for peer correction, where learners collectively negotiate accurate understandings. This approach is supported by Akkuzu and Uyulgan, who demonstrated that contextualizing safety risks through real-life accident scenarios improved awareness among pre-service teachers.[25] By situating safety education within meaningful, experience-based contexts, collaborative learning ensures that misconceptions are not merely corrected by instructors but actively challenged and reconstructed by peers. The discussion method highlighted how peer interaction fosters accountability and shared responsibility for safety, cultivating a culture where learners support one another in adhering to correct protocols. This interpretation situates laboratory safety education within a broader constructivist framework, where knowledge is socially constructed and reinforced through collective practice. By embedding collaborative strategies into safety instruction, institutions can leverage peer dynamics to enhance comprehension, correct errors, and promote sustained awareness. The discussion method thus emphasized that safety education is most effective when it is not an individual endeavor but a collective process, where learners actively engage in dialogue, reflection, and shared responsibility for safe laboratory practices.

Institutional and Policy-Level Considerations

Beyond pedagogical strategies, the findings of this study reveal systemic challenges that undermine the effectiveness of laboratory safety education. Inconsistent hazard reviews, infrequent training, and resource constraints were identified as institutional barriers that perpetuate misconceptions. The discussion method therefore extended its analysis to the policy level, situating laboratory safety within broader institutional frameworks. This interpretation aligns with Mtikitiki et al., who highlighted how resource limitations and inconsistent training practices compromise safety awareness.[26] Similarly, Mugivhisa et al. recommended mandatory safety assessments and the installation of informational signage as policy interventions to address persistent misconceptions.[27] By connecting the study's findings to these systemic challenges, the discussion method emphasized that pedagogical innovation alone is insufficient without institutional support. Effective safety education requires consistent reinforcement through structured policies, adequate resources, and institutional commitment to hazard management. The discussion highlighted how policy-level interventions such as mandatory safety audits, standardized training schedules, and investment in multimedia resources can create environments where safety education is continuously reinforced. This interpretation situates laboratory safety as both a pedagogical and institutional priority, requiring alignment between classroom practices and organizational policies. By addressing systemic barriers, institutions can ensure that safety education is not undermined by resource constraints or inconsistent practices. The discussion method thus emphasized the need for a holistic approach, integrating pedagogical innovation with institutional accountability to create sustainable improvements in laboratory safety awareness.

Alignment with Global Education Goals

Finally, the discussion method situated the implications of this study within the framework of Sustainable Development Goal 4. SDG 4 emphasizes inclusive, equitable, and effective learning opportunities that equip learners with relevant skills for life and work. Laboratory safety education, when aligned with constructivist, experiential, multimedia, and collaborative strategies, directly contributes to this goal by fostering safe, inclusive, and high-quality learning environments. The findings

[25] Akkuzu and Uyulgan, "Pre-service Teachers' Safety Knowledge and Misconceptions in Chemistry Laboratories ."
[26] Mtikitiki et al., "Occupational Health and Safety Management System of a South African University Setting."
[27] Mugivhisa, Baloyi, and Olowoyo, "Postgraduate Students' Adherence to Laboratory Safety Practices in South African Universities ."

of this study persistent misconceptions, uneven hazard recognition, and systemic challenges were interpreted as indicators of the need to embed safety awareness into curricula as a core component of quality education. By equipping learners with competencies in risk management, problem-solving, and responsible scientific practice, laboratory safety education advances SDG 4's vision of lifelong learning. The discussion method emphasized that safety education is not merely about compliance but about empowering learners with critical skills that extend beyond the laboratory into professional and societal contexts. This interpretation situates laboratory safety as both a pedagogical priority and a policy imperative, ensuring that science education contributes to global goals of equity, inclusivity, and sustainability. By embedding safety awareness into curricula, institutions not only protect students but also prepare them to engage responsibly with scientific practice, thereby advancing the broader agenda of quality education. The discussion method thus highlighted the global significance of laboratory safety, positioning it as a critical dimension of educational quality and a key contributor to the achievement of SDG 4.

RECOMMENDATIONS

Based on the findings and discussion, several practical recommendations can be made to strengthen laboratory safety awareness among students in tertiary institutions. Safety protocols should be embedded into science curricula as core learning outcomes rather than treated as supplementary content. This ensures that safety awareness is continuously reinforced across courses and laboratory activities. Institutions should implement regular safety drills, demonstrations, and scenario-based exercises to provide students with authentic opportunities to practice hazard recognition and emergency responses. Posters, infographics, icons, and multimedia tools should be strategically placed in laboratories and classrooms to reinforce safety concepts and bridge language or comprehension barriers. Collaborative activities such as peer-led safety audits and group discussions can help surface and correct misunderstandings, fostering a shared culture of responsibility. Universities should establish mandatory annual safety assessments, update signage, and ensure consistent hazard reviews. Leadership commitment and resource allocation are essential for sustaining a robust safety culture. By embedding safety education into inclusive, active, and equitable pedagogical practices, institutions contribute to the global goal of providing learners with the knowledge, skills, and confidence to engage in science responsibly and sustainably.

CONCLUSION

This study set out to examine student awareness of laboratory safety categories through the lens of Constructivist Learning Theory, with the purpose of identifying misconceptions and proposing strategies to strengthen safety education in South African tertiary institutions. By analyzing student responses, the research revealed persistent gaps in hazard recognition and conceptual clarity, particularly in categories such as corrosive substances and electrical hazards. These findings underscore the limitations of traditional, text-based instruction and highlight the need for more active, experiential, and visually supported approaches to safety education. The final position of this study is that laboratory safety cannot be effectively taught through rote memorization or passive delivery alone. Instead, safety awareness must be cultivated through meaningful engagement where students actively construct knowledge by participating in drills, demonstrations, scenario-based exercises, and collaborative learning activities. Visual reinforcement, such as charts, icons, and multimedia tools, further enhances comprehension and retention, making safety principles accessible across diverse learning contexts. Ultimately, the study affirms that integrating constructivist and visual learning strategies into laboratory safety education not only addresses misconceptions but also fosters a culture of responsibility and preparedness. By embedding safety protocols into curricula and aligning them with inclusive pedagogical practices, institutions can create safer learning environments and equip students with essential skills for both academic success and professional practice. In doing so, laboratory safety education contributes directly to the broader goal of Quality Education (SDG 4), ensuring that learners are empowered with the knowledge, competencies, and confidence to engage in science responsibly and sustainably.

LIMITATIONS OF THE STUDY

Despite valuable insights, this study has limitations. The sample was restricted to one cohort of prospective science teachers, limiting generalizability. Misconceptions identified, such as confusing a "bathroom" with a "safety shower," may reflect cultural or linguistic influences. Reliance on self-reported data introduces bias, as students may overstate safety awareness. The focus on laboratory safety categories excluded broader dimensions of safety culture, such as institutional accountability and risk attitudes.

DIRECTIONS FOR FUTURE RESEARCH

Future research should broaden laboratory safety studies across diverse student populations and institutions to enhance generalizability and reveal cultural variations in misconceptions. Longitudinal designs are needed to evaluate the durability of interventions such as safety drills, multimedia resources, and peer-led audits, while integrating quantitative measures like standardized safety assessments would strengthen evidence. Investigating institutional policies, including mandatory audits and signage, can address systemic barriers. Studies should also situate safety education within Sustainable Development Goal 4, exploring innovative methodologies such as scenario-based simulations, digital platforms, and virtual reality to foster immersive, constructivist learning experiences.

ACKNOWLEDGEMENT

Copilot was utilized in this study to enhance the fluency and coherence of the text, as the author is a non-native English speaker.

BIBLIOGRAPHY

Akkuzu Guven, E, and M. A Uyulgan. "Pre-service Teachers' Safety Knowledge and Misconceptions in Chemistry Laboratories ." *Journal of Chemical Education* 1452, no. 1460 (2022): 99–4.

Daramola, Dorcas S, Jumoke I Oladele, and Mdutshekelwa Ndlovu. "Impact of Technology-Enhanced Experiential Learning on Postgraduate Students' Training in Qualitative Research." *African Perspectives of Research in Teaching and Learning Journal, Issue*, no. 8 (2024).

Faulconer, Emily, and Cheryl Kam. "Safety Competency in an Online Introductory Science Laboratory Course." *Quarterly Review of Distance Education* 24, no. 2 (2023): 1–12.

Mayer, Richard E. *Multimedia Learning*. Cambridge University Press, 2009. https://doi.org/10.1017/CBO9780511811678.

Morgado, J., P. Silva, and R. Fernandes. "Visual Learning Strategies in Multilingual Science Classrooms: Implications for Laboratory Safety." *Learning and Instruction* 94 (2024): 101999.

Mtikitiki, Ntombenhle, Benett Siyabonga Madonsela, Thabang Maphanga, Karabo Shale, Xolisiwe Sinalo Grangxabe, and Tshidi Mokgatsane Baloyi. "Occupational Health and Safety Management System of a South African University Setting." *Safety* 11, no. 2 (April 10, 2025): 34. https://doi.org/10.3390/safety11020034.

Mugivhisa, L., O. Baloyi, and J. Olowoyo. "Postgraduate Students' Adherence to Laboratory Safety Practices in South African Universities," 2021.

Piaget, J. *The Psychology of the Child*. New York: Basic Books, 1972.

Sonawane, Swapnil L., Vikas J Patil, and Rodney A. Tigaa. "Evaluating and Promoting Chemical Safety Awareness in the Chemical Sciences." *Journal of Chemical Education* 100, no. 2 (2023): 469–78.

Tindan, P., and A. Anaba. "Hands-on Scientific Activities and Safety Awareness: A Systematic Review." *International Journal of Science Education* 42, no. 10 (2020): 1657–75.

Valiente, Bernadeth A., and James L. Paglinawan. "Laboratory Exposure and Learners' Conceptual Retention in General Chemistry." *International Journal of All Research Writings* 6, no. 6 (2024): 131–39.

Vygotsky, Lev S. "Mind in Society: The Development of Higher Psychological Processes." Harvard University Press, 1978.

Yao, Junchao. "Exploring Experiential Learning: Enhancing Secondary School Chemistry Education

Through Practical Engagement and Innovation." *Journal of Education, Humanities and Social Sciences* 22 (November 26, 2023): 475–84. https://doi.org/10.54097/ehss.v22i.12508.

ABOUT AUTHOR

Vuyokazi Momoti is a Life Sciences Lecturer at Walter Sisulu University, South Africa. She is an emerging scholar with developing expertise in Life Sciences education and environmental health, with a particular focus on curriculum development and inclusive pedagogy. Her academic journey includes pursuing a Doctor of Education (Ed.D.), where her research emphasizes equity-driven pedagogy, curriculum alignment, and methodological rigor in Life Sciences Education. She is an active member of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE), engaging with scholarly communities dedicated to advancing science education research across the region.