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Chemical Safety in Laboratories: Awareness, Attitudes and Practices of Higher Education Students

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Acknowledgments

I write the following lines with a sense of mission accomplished. It has been a turbulent two years, full of new challenges but always with the desire to go further, to climb another mountain.

I submit my dissertation, which took a lot of work to complete, but with the support of those around me, it has become a truly meaningful milestone, another satisfying check on my personal goals list.

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It's always for you.

Resumo

As instituições de ensino superior, nomeadamente aquelas que contemplam laboratórios de ensino e investigação nas suas infraestruturas, têm um papel importante na transmissão de conhecimento e atitudes sobre segurança química aos seus estudantes. Como tal, o presente estudo tem como objetivo a avaliação dos conhecimentos e atitudes de estudantes de ensino superior, de diversos ciclos de estudo, em matéria de segurança química em laboratórios.

Foi realizado um estudo transversal, utilizando um questionário adaptado e traduzido para português. O instrumento tinha um total de vinte e sete perguntas e foi distribuído entre estudantes matriculados em cursos que incluem práticas laboratoriais nos seus currículos, entre março e julho de 2025.

Um total de 284 estudantes participou no estudo, divididos entre os diferentes ciclos de estudos do ensino superior (CTeSP= 4.2%; Licenciatura= 70.4%; Mestrado= 21%; Doutoramento= 4.2%). Os resultados demonstraram que, embora haja uma grande percentagem de estudantes com valores altos de conhecimento, as suas atitudes nem sempre são as mais apropriadas, podendo colocar em causa a sua segurança e a de quem os rodeia.

As nossas conclusões revelaram que há margem para ajustes nos currículos. A exposição precoce a conceitos de segurança química e laboratorial tem o potencial de promover o desenvolvimento de estudantes conscientes e futuros profissionais. A integração de módulos de segurança na sua educação poderá aumentar os conhecimentos e as competências necessárias para tomar decisões informadas que possam reduzir acidentes/incidentes num ambiente laboratorial.

Palavras-chave:

Segurança Química; Laboratório; Ensino Superior; Estudantes

Abstract

Higher education institutions, particularly those with teaching and research laboratories in their infrastructure, play an important role in transmitting knowledge and attitudes about chemical safety to their students. As such, this study aims to assess the knowledge and attitudes of higher education students from different study programs regarding chemical safety in laboratories.

A cross-sectional study was carried out, using a questionnaire that was adapted and translated to Portuguese. The instrument had a total of twenty-seven questions and was distributed amongst students enrolled in undergraduate and graduate programs that include laboratory practices in their curricula, through March and July of 2025.

A total of 284 students participated in the study, divided among the different cycles of higher education (CTeSP = 4.2%; Bachelor's degree = 70.4%; Master's degree = 21%; Doctorate = 4.2%). The results showed that, although a large percentage of students have a high level of knowledge, their attitudes are not always the most appropriate, which could jeopardize their safety and that of those around them.

Our findings revealed that there is room for curricula adjustments. Early exposure to chemical and laboratory safety concepts has the potential to promote the development of conscious students and future professionals. By integrating safety modules into their education will potentially increase the knowledge and skills to make informed decisions that can reduce accidents/incidents in a laboratory environment.

Keywords:

Chemical Safety; Laboratory; Higher Education; Students

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List of abbreviations

BN – Bayesian Network

CFA – Confirmatory Factor Analysis

CLASS – Chemistry Laboratory Safety Climate Survey

CLP – Classification, Labelling and Packaging

EFA – Exploratory Factor Analysis

EH&S – Environmental Health & Safety

EU – European Union

GDPR – General Data Protection Regulation

GHS – Global Harmonized System

KMO – Kaiser-Meyer-Olkin

OHSA – Occupational Health and Safety Administration

PFR – Plant and Food Research

PPE – Personal Protection Equipment

PRO – Patient-Reported Outcomes

PSM – Process Safety Management

REACH – Registration, Evaluation, Authorization and Restriction of Chemicals

SDS – Safety Data Sheet

SOFI – Swedish Occupational Fatigue Inventory

TPB – Theory of Planned Behavior

TRAPD – Translation, Review, Adjudication, Pretesting and Documentation

UCLA – University of California in Los Angeles

USA – United States of America

1. Introduction

The laboratory is the foundation on which higher education institutions base their teaching activities, serving as a vital platform for training high-quality talent and building a national innovation system. With the expansion of scientific theory and the development of science and technology, university laboratories are more engaged in cutting-edge research. However, this procedure often involves investigating new materials or methods that may present unknown dangers. These problems constitute substantial impediments to safety management in university laboratories (Zhang et al., 2025). The Occupational Safety and Health Administration (OSHA) has recorded several potential hazards in laboratories, including chemical, biological, physical, and safety hazards.1 Laboratory activities, such as academic and research activities, expose laboratory employees to potential hazards and increase the risk of incidents (Lestari et al., 2019). However, as these teaching and research activities are usually carried out on a small scale or for a limited period of time, people tend to underestimate or even ignore the associated risks (Zhang et al., 2025).

Fires and explosions caused by the use of chemicals are among the incidents that can occur in academic laboratories. The Chemical Safety Board of The United States of America (USA) has recorded several cases of fires and explosions in university laboratories that have resulted in serious injuries (Lestari et al., 2019). Ménard & Trant (2020) described the case of Sheharbano Sangji, a 23-year-old UCLA research assistant who died in 2008 after a pyrophoric chemical ignited her clothes, causing severe burns. The OSHA report revealed that she lacked proper protective equipment, had not received adequate training, and that essential safety protocols and guidelines were absent in the laboratory.

There have been several innovative initiatives at universities and research institutes to improve safety management and prevent laboratory accidents, including a set of safety programs, holding safety meetings, and highlighting unique requirements for chemical management (Murata et al., 2022).

The onion model (Figure 1) comprises seven autonomous but interconnected layers of protection, which together form a comprehensive safety system. From the perspective of accident control sequence, these layers can be categorized into three categories: prevention, control, and emergency response (Zhang et al., 2025). The main function of inherent safety design as an initial layer of protection is to prevent accidents and serve as a preparatory measure. This layer aims to eliminate or reduce potential safety risks primarily through design, such as optimizing equipment selection as well as operational processes and procedures. When considered in conjunction with the onion model of protection layers in the field of chemical safety, reducing the frequency of accidents or mitigating the potential consequences of accidents (from an inherent safety design perspective) is widely regarded as more effective safety management concept than measures taken to reduce the severity of consequences after accidents have occurred.

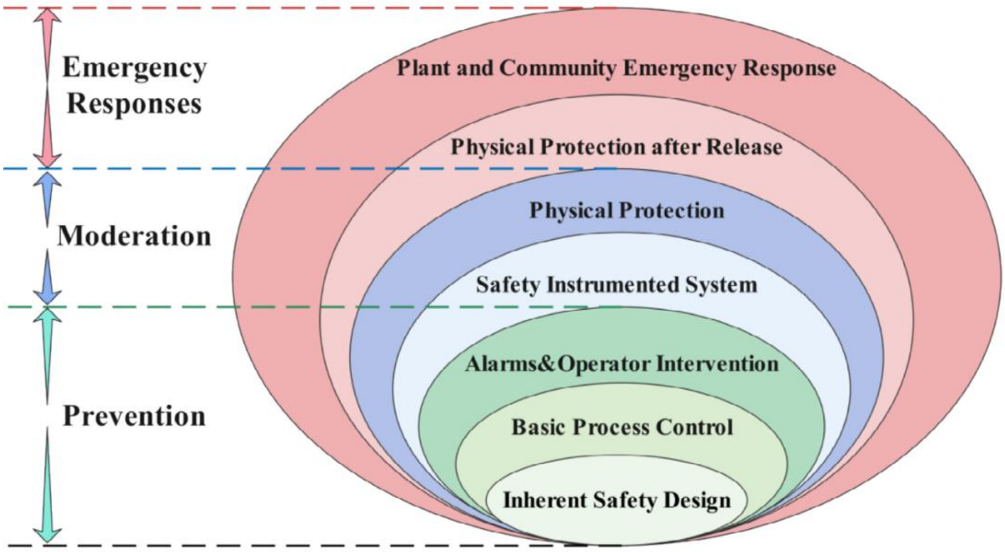

Figure 1 The onion model (adapted from Zhang et al., 2025).

One of the main challenges in ensuring safety in academic laboratories involves their users. Undergraduate students often enter laboratories where their practical experience is limited, and their training in safety procedures is significantly insufficient. Unfortunately, it is common for faculty members and researchers to prioritize research productivity over strict safety compliance, as competition for funding and publications is intense in high-pressure academic environments (Yang et al., 2019).

This study aims to evaluate higher education students' knowledge, attitudes, and practices regarding chemical safety in laboratory environments. Specifically, it seeks to (i) assess students' familiarity with chemical hazard symbols and emergency procedures, (ii) examine their attitudes towards compliance with laboratory safety rules, and (iii) analyze their self-reported safety practices. The findings are expected to identify gaps in safety awareness and behavior, thereby informing the development of targeted training initiatives and institutional strategies to strengthen laboratory safety culture.

1.1. Rationale for the Work

1.1.1. Legal and Regulatory Framework

Chemicals have many uses that benefit society, but they also have the potential to cause harm. For this reason, a regulatory and legislative system has been evolving over the last 50 years to achieve the goal of authorizing and permitting the use of chemical substances for the benefit of society without compromising human health and the environment (Ball et al., 2022). The European chemical industry is one of the sectors with the highest standards in environmental protection, with one of the most important achievements of the European Union (EU) being the creation and implementation of the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) and Classification, Labelling and Packaging (CLP) regulations (Boyanov, 2018). The importance of evaluating students' knowledge, attitudes, and practices regarding chemical safety in laboratories extends beyond academic and research settings, as it reflects broader societal challenges associated with chemical risk communication and management. Within the chemical supply chain, the end users—both professional and consumer—rely heavily on effective communication tools mandated by the European Union regulations REACH and CLP. Through CLP, hazards are communicated via standardized pictograms, hazard statements, precautionary statements, and packaging requirements, which serve as the primary visual alerts to end users.

The CLP regulation came into force in January 2009 and is based on the United Nations' Globally Harmonized System (GHS). The legal document amended the Dangerous Substances Directive (Directive 67/548/EEC), the Dangerous Preparations Directive (Directive 1999/45/EC) and Regulation (EC) nº1907/2006 (REACH) and is, since June 1st, 2015, the only legislation in force in the EU applicable to the classification and labelling of substances and mixtures (ECHA, 2025a).

Its main objective is to ensure that the hazards present by chemical products are recognized and understood by its users. The GHS harmonizes the way hazards of chemicals and mixtures are identified and communicated by providing hazard criteria for the classification of chemicals and mixtures of substances, and hazard communication elements such as pictograms, signal words and hazard statements (Kättström et al., 2025).

One of the main points of CLP regulation is simple communication and consequent easy reading for users of substances or mixtures, and to this end, a series of obligations are presented regarding the content that must be placed on product labels. Therefore, substances or mixtures classified as dangerous contained in packaging must be labelled with the following elements:

a) Name, address and telephone number of the supplier(s) of the substance or mixture;
b) Nominal quantity of the substance or mixture in the packaging made available to the general public, unless this quantity is specified elsewhere in the packaging;
c) Product identifiers;
d) Where appropriate, hazard pictograms;

e) Where appropriate, signal words;
f) Where appropriate, hazard statements;
g) Where applicable, appropriate precautionary statements;
h) Where appropriate, a supplementary information section;
i) The label shall be written in the official language of the Member State in which the substance or mixture is placed on the market.

Complementarily, REACH ensures the transfer of detailed hazard and safety information across the supply chain, particularly through Safety Data Sheets (SDSs). While SDSs are mainly targeted at workplace users, consumers can also request them for specific hazardous substances. Moreover, REACH establishes the consumer's right to know in cases where articles contain substances of very high concern (SVHCs) above the 0.1% threshold. The REACH regulation came into force in 2007, after a decade of negotiations. The purpose of REACH is to ensure a high level of human and environmental protection, including the promotion of alternative methods for the assessment of hazards of substances as well as the free circulation of substances in the European internal market (Macmillan et al., 2024). The regulation applies to all chemical substances, not just those used in industrial processes, so it has an impact not just on the industrial sector but on all sectors that use chemical products such as construction, textiles, computing and educational institutions (including universities and polytechnics) (Boyanov, 2018).

With this in mind, REACH defines a set of processes and obligations (namely registration, evaluation, authorization and restriction), which aim to ensure that there is an adequate and high quality information on substances placed on the market, the evaluation and management of the risk of these substances, as well as the identification of substances of very high concern, or whose manufacture/use poses an unacceptable risk to human health or the environment. It also defines the obligation to communicate the associated dangers and risks, as well as the appropriate management measures, in order to guarantee safe use (ECHA, 2025b).

Article 31 of the REACH regulation sets out the requirements for SDS, a document that must be provided to the users by the supplier of a substance or mixture of substances. The SDS is an essential element in the circulation of information through the supply chain, which includes the end user; it contains information on the properties of the substance or mixture, its hazards, instructions for handling, disposal, and transport, as well as measures for first aid, firefighting, and exposure control (APA, 2021). Appendix

1 shows all the information that must be included in each of the 16 sections, required by the REACH regulation, in an SDS.

In Portugal, national legislation further underscores the importance of chemical safety and exposure. Decreto-Lei n.º 24/2012 (and respective alterations), which consolidates minimum safety requirements and transposes EU directives on chemical risk, mandates that employers evaluate risks from chemical agents, provide proper preventive and protective measures, and guarantee worker access to Safety Data Sheets (SDSs) and relevant training. Although university students are not formally classified as workers (they can be, in case, for example of internships), their frequent laboratory exposure places them in analogous risk contexts.

Despite these regulatory frameworks, studies have shown that users—especially students and young professionals entering the workforce—often have limited understanding of chemical hazard symbols, risk statements, and the practical implications of SDS information (Ho & Tenkate, 2024; Kularatne, 2025). This gap undermines the effectiveness of regulatory communication tools and increases the risk of unsafe handling and exposure throughout the supply chain.

Therefore, assessing students' chemical safety literacy is essential not only for improving laboratory safety practices but also for preparing informed future professionals and consumers. Such studies provide evidence on current weaknesses in hazard communication uptake and help identify targeted interventions to reinforce the link between regulatory communication (REACH and CLP) and actual end-user understanding and behavior. Ultimately, this contributes to strengthening both occupational safety and public health protection within the chemical supply chain.

1.1.2. State of the Art: Chemical Safety in University Laboratories

Guaranteeing chemical safety in university laboratories is a key priority for educational institutions. Strong safety protocols, comprehensive training and effective evaluation techniques are now more important than ever due to the increasing use of hazardous materials in research and teaching laboratories. Students are particularly vulnerable to accidents brought on by a lack of safety awareness or a misperception of chemical risks since they often have little experience in laboratory setting (Kim et al., 2024; Omer, 2024).

To understand the way academic research has addressed this issue, a thorough bibliometric analysis of laboratory safety in higher education is presented by Yang et al., (2019). The study states that, although there has been an increase in the number of publications on safety in university laboratories since the early 2010s, this field is still underdeveloped in research areas, and there is still room and possibility to establish new research.

University laboratory safety is a multidisciplinary research area that covers more than 70 categories, the most common topics being environment, occupational health, chemistry or chemical education, education, and engineering. The authors also highlight the changes that have occurred in the topics in focus of the investigation, since some have shipped from "laboratory safety training and practice", "accident survey and hazard identification", "occupational health work environment", to "laboratory risk assessment and management" and to "safety culture". According to them, most of the literature currently in publication rarely addresses training using rigorous, data-driven methodologies or theoretical frameworks drawn from educational psychology or behavioral science, often falling short of providing more than descriptive accounts.

Although new areas of research have emerged in the last decade, the Yang et al., (2019) suggest that it's necessary for researchers to come up with innovative ideas, new themes and methodologies in this area, for example related to resilience, risk perception, safety communication, human error, or emergency response, which are significant areas of safety.

This bibliometric perspective is enhanced by empirical assessments of students' safety awareness, which provide insights into the current challenges faced in university laboratories. With that, a thorough cross-sectional evaluation of laboratory safety awareness among Kunming University of Science and Technology undergraduate students including chemical, biological, physical and medical safety domains was conducted by Wu et al., (2023). They assessed participants' understanding of emergency equipment and procedures, safety attitudes, practical safety behaviors, and familiarity with GHS pictograms using carefully crafted questionnaire that was filled out by 335 students, with a response rate of 95.7%. This multipronged strategy made it possible to conduct a thorough, quantitative evaluation of awareness levels across disciplines.

The findings show clear gaps in safety awareness: a significant 63.6% of respondents did not receive a "excellent" safety awareness rating, with specific deficiencies found in the ability to recognize GHS and comprehend emergency protocols. There is a significant behavioral safety gap, as evidenced by the startling admissions of 1.8% to 6.3% of students that they have never followed any of the recommended safety procedures. Additionally, the authors found several important characteristics with odds ratios ranging from 5.38 to 8.04 and revealed statistically significant connections with key survey measures ($p<0.05$), especially depending in academic major and prior safety training experience.

Based on the results, Wu et al. (2023) suggest focused interventions for a range of stakeholders, supporting major-specific safety modules, institutionally standardized emergency training and curriculum-integrated safety education. They provide a strong empirical foundation for systematic improvements in laboratory safety awareness by highlighting the necessity of policy reforms by university administrators and suggestions for governmental oversight.

This study provides strong support for future research by emphasizing students' ongoing cognitive and practical safety deficiencies, the importance of individualized, discipline-sensitive educational interventions and the big impact of structured training and curriculum.

Simultaneously, an examination of the safety protocols of research specialists offer a different perspective on organizational culture and behavior. Papadopoli et al., (2020) carried out a robust cross-sectional survey on 237 research laboratory staff members from different Italian institutions to investigate their exposure to hazardous chemicals, awareness and perceptions of chemical risks, self-reported practices and the factors influencing these outcomes, with a response rate of 81.7%. the complexity and severity of chemical exposure in research settings are highlighted by the fact that the participating workers handled more than 90 different hazardous substances. The purpose of the study was to determine organizational and individual factors that affect safety adherence, as well as to assess how well practical behaviors and cognitive awareness of chemical hazards align.

Significant gaps in knowledge and practice are revealed by the results: researchers with more years of laboratory training, younger researchers and researchers who work with a wider range of hazardous chemicals showed greater understanding of chemical risks. Safe handling procedures were not always followed, even though 54.4% of respondents said they felt "very exposed" to chemical hazards. Notably, those who felt their coworkers adhered to safety regulations, felt they had received sufficient training in accident management and first aid, and perceived lower chemical exposure but higher biological risks were more likely to follow proper procedures. These results endorse the thought of safety behaviors being shaped by perception and organizational culture rather than just knowledge.

To improve risk awareness and preventive actions, the authors highlighted persistent gaps in their findings regarding awareness and preparedness and recommended that the research team undergo further occupational training. According to the report, institutional support for safety protocols should include regular leadership participation and systematic oversight of safety standards by principal investigators and supervision.

While research like Wu et al. (2023) and Papadopoli et al. (2020) highlight statistical gaps in knowledge and practice, Brewster et al. (2023) highlight the organizational and social dynamics that are commonly ignored by traditional assessments.

At Plant & Food Research (PFR), a multidisciplinary biological research company in New Zealand where handling chemicals is commonplace, Brewster et al. (2023) investigate risk perceptions and laboratory safety protocols. A "survey-small group meeting" model for interaction with users of chemicals was developed and rolled out across PFR. Survey responses were received from 346 respondents who reported their usage of laboratory chemicals, and this was followed by interactive small group meetings with 38 biology-focused research teams located across 12 sites. While the survey provided a generally positive view of practice and perceptions of risk, the team visits provided more site-specific, granular, and informative insights into the handling of chemicals and functioning of laboratories.

The authors offer an illustration of how collaborative inquiry can be applied as a tool for both diagnosis and intervention. By involving researchers directly in survey discussions, the study promoted communication across hierarchical barriers, enhanced safety awareness, and fostered mutual learning. This participatory approach offers a promising supplement to conventional safety audits by highlighting contextual barriers, social effects, and tacit knowledge that are typically obscured from quantitative measurements. As a result, this study provides a scalable, community-centered method for incorporating reflective safety measures into research culture in addition to expanding our understanding of how academic labs view micro-level risks.

"Safety climate" is a term that describes the collective perceptions and attitudes that an organization or setting holds about safety (Luo, 2020). Marin et al., (2019) created the Chemistry Laboratory Safety Climate Survey (CLASS) as an assessment instrument to evaluate this construct in students. Their research showed that students' views on the seriousness with which their peers and instructors regard safety greatly affect their own adherence to regulations. The authors created a preliminary 40-item questionnaire to assess various aspects of safety climate, including leadership commitment, peer norms, risk communication, and risk recognition, based on theoretical frameworks related to organizational safety culture. They acknowledge that academic laboratories can pose risks thar are comparable to those found in industrial settings and decided to improve the instrument to a 15-item scale structured into four latent dimensions using rigorous psychometric techniques (Confirmatory Factor Analysis (CFA) and internal consistency tastings), obtaining Cronbach's α values between 0.695 and 0.842 and robust fit indices.

The authors confirmed the refined CLASS's multidimensional validity and reliability after distributing it to a second independent sample (n=357), obtaining overall safety-climate scores that, although "slightly high", nevertheless showed notable room for improvement. These results highlight the existence of latent cultural and structural safety issues, which may not be apparent without specific measurement tools, even in situations where students believe thar laboratory settings are generally safe.

The Theory of Planned Behavior (TPB) is used by Abdullah & Aziz, (2020) to examine the variables affecting undergraduates' laboratory safety behavior at five public universities in Malaysia. To investigate the proposed connections among safety knowledge, safety motivation, safety commitment and safety behavior, the authors employed a quantitatively rigorous design, gathered responses from 361 randomly chosen students and used Partial Least Squares Structural Equation Modeling (PLS-SEM). Their main goals were to evaluate the mediating function of safety commitment as well as the direct effects of knowledge and motivation on safety behavior.

The results show that safety motivation (β= 0.15, p= 0.02) and safety knowledge (β= 0.30, p<.001) have statistically significant direct effects on self-reported safety behavior in the laboratory. Importantly, safety commitment was found to be a strong mediator, transferring the impact of both motivation (β= 0.17, p<.001) and knowledge (β= 0.13, p<.001) to behavioral outcomes. The significance of intention and normative pressures in influencing safety-related behavior is highlighted by these findings, which are consistent with TPB constructs.

The study's theoretical implications are noteworthy because it demonstrated the critical role thar safety commitment plays in promoting desired behavior and validates the use of TPB in academic laboratory settings. The authors advise university administrations to improve safety governance by creating policies that strengthen student dedication, like incorporating student representative councils in the creation of safety policies and implementing TPB-based instructional initiatives.

Using a survey of 438 students from public higher education institutions in Northwestern Mexico, Salazar-Escoboza et al., (2020) created and validated a questionnaire to look into the connection between laboratory accidents and institutional safety climate. Strong psychometric qualities were demonstrated by the tool, which captured elements of leadership commitment, safety communication, peer safety standards, and danger awareness. The authors collected the samples using the non-probabilistic convenience sampling method.

The safety scale, based on safety perceptions, was validated through three factors: F1 - Compliance with Safety Regulations and Training; F2 – Institutional Attitudes of workers Towards Safety; F3 – Common Use of Equipment, Materials and Substances in laboratories. Overall, the results of the questionnaire showed that students consider that the information they have on laboratory safety was obtained mainly through practical examples given by teachers during laboratory classes. This study helped to understand that when teachers, researchers or laboratory technicians from educational institutions are interested and committed to safety and act accordance with protocols, students perceive these attitudes and tend to follow these examples.

With the sample results for the first factor, it's demonstrated that higher education institutions should promote and intensify training actions around laboratory safety. Regarding the second factor, the study states that from students' perspectives, workers at higher education institutions have good safety attitudes, for example, students state that teachers frequently check and comply with the safety rules established for the use of academic laboratories. An interesting point in the study, and reported by the authors, is that students state that they understand better the safety measures they should take if they're put into action in practical cases, rather than just learning in theory. Through the third factor, it was possible to verify that students understand that the use of specialized equipment, dangerous substances and materials can entail risks for users and consequently cause accidents. However, Salazar-Escoboza et al., (2020) make a correction, because although the students understand the risks that surround them and are able to identify them, they did not see themselves as active risk agents. The authors suggest institutional changes based on their results, including increasing leadership participation, integrating safety training into organizational protocols, and establishing psychosocial environments that encourage protective conduct.

Training is an essential process for imparting proficiency and attitude towards chemical safety among learners. Viitaharju et al., (2021) examined the impact of online training modules and found that interactive elements such as video simulations and scenario-based quizzes improved learners' retention and confidence. The study also warned that the impact of such training diminishes over time without regular reinforcement.

In additional, Sonawane et al., (2023) conducted an online survey during the 2020-2021 academic year to gauge the level of chemical safety awareness among chemistry undergraduates at Jai Hind Educational Trust's Z.B. Pati College in India and Concord University in the United States. Twenty measures covering three domains- safety practices, knowledge and attitudes, and hazards symbol identification – were included in the instrument, which had 221 participants. The authors found that many students had trouble correctly identifying typical GHS hazard signals, and that important safety precautions (including wearing laboratory coats, goggles, and closed-toe shoes) were not always followed, even though the vast majority (97%) had received official safety instructions.

Using comparison analysis, the study found statistically significant institutional differences in safety attitudes and actions between the Indian and U.S cohorts. The authors emphasize that in addition to individual knowledge, these discrepancies appear to have their origins in institutional policy and instructional influence. Their findings indicate that gaps in protective laboratory behavior are associated with inadequacies in instructor attitudes and safety procedure adherence.

The authors recommend the following specific interventions to fill the gaps they have identified: stricter enforcement of Personal Protection Equipment (PPE) use, institutional policy changes that encourage long-term safety consciousness, and enhanced training that prioritizes chemical waste management and hazard symbol recognition. They situate their research within the broader global discourses on chemical safety and education and offer guidance to domestic and international educators and policymakers on how to apply these findings to create and implement evidence-based strategies to enhance laboratory safety culture. As a result, the work provides a useful theoretical and empirical basis for research projects that attempt to increase awareness of chemical safety through curricular and organizational changes.

Instruments such as questionnaires and survey tools have been developed as essential measures to assess security awareness and behavior. Zhao et al.,(2023) provide a mixed-methods risk-assessment approach that integrates survey data with Bayesian Network (BN) analysis to evaluate laboratory safety at 60 Chinese colleges. In order to collect the associated safe/unsafe condition probability for 16 variables pertaining to human, equipment and materials, environment, and management elements, graduate students were given questionnaires to fill out. Using fuzzy triangle theory and expert elicitation, the authors created conditional probabilities from four basic domains: management, environment, equipment/material, and human. This made it possible to create a comprehensive BN model that could determine causal linkages and assess overall risk.

The study framework is shown in Figure 2.

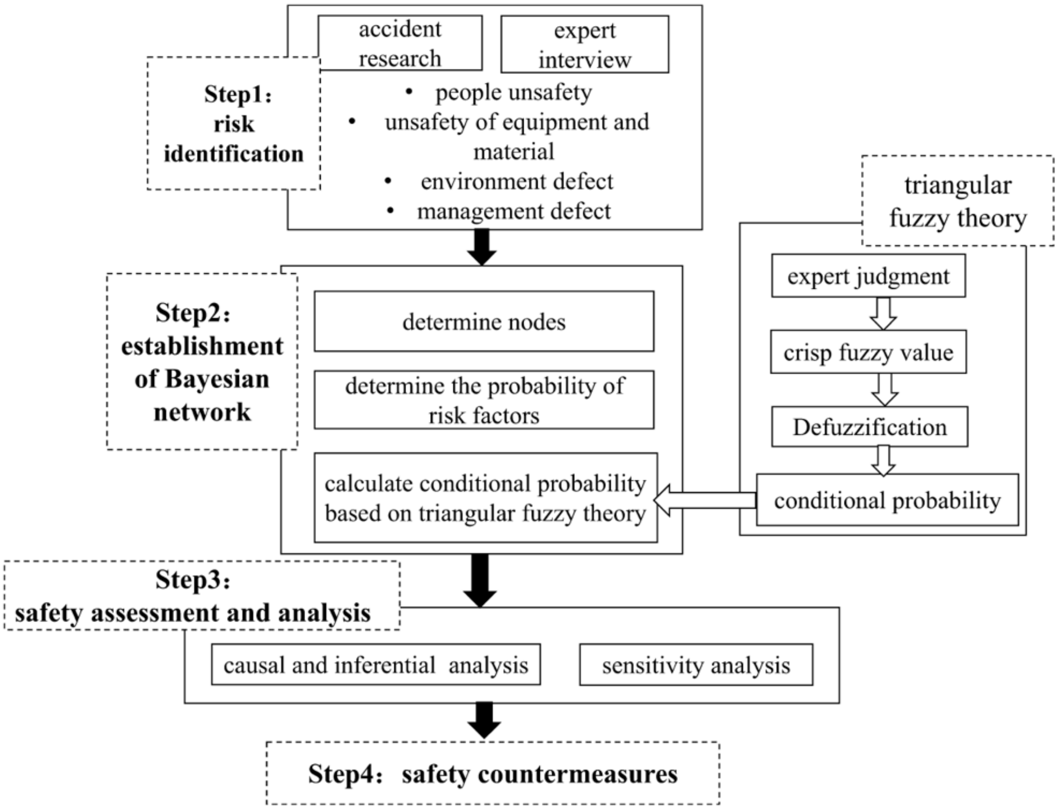

Figure 2 Framework for risk analysis of university laboratory safety used by Zhao et al. (2023)

The first step is to identify risks, using data collected from the questionnaire, which reveals potential factors that influence laboratory safety. The second step is to establish the BN, where the probability of the sixteen risk factors is determined based on the results of the questionnaire and the probabilistic conditions of the four key factors (human, equipment and material, environment, management), using the triangular fuzzy theory. The third step is to analyze the BN results (causal, inferential and sensitivity analysis). In the final step, corresponding safety countermeasures are proposed for the improvement of university laboratory safety. The main conclusion that can be drawn from the work carried out by (Zhao et al., 2023) are: (1) incorrect operation is prominent in the personnel aspect; (2) failure of experimental equipment occurs frequently because of non-standardized customization and poor maintenance; (3) mixed use of offices and laboratories and multiple experiments conducted simultaneously in one room are most critical in the environment factor; (4) the lack of effective training is responsible for the unsafe laboratory state in the management aspect. According to the results, there is also a worrying probability of hazardous conditions (65.2%), with the human factor exerting the greatest influence, followed by equipment and material failures.

Based on the analysis they carried out, the authors proposed some measures, such as: formulate operation procedures for specific scientific research experiments and invite relevant graduate students to participate in its formulation to ensure the practicality of the procedure; conduct compulsory training courses before all new experiments; evaluate the management personnel regularly and encourage their communications with counterparts at other universities to improve their professional level.

Lestari et al., (2016) conducted a comprehensive baseline study that examined the implementation of chemical safety, health, and safety programs in 51 laboratories within Universitas Indonesia's health faculties. The researchers used a systematic Chemical Health, Safety, and Security checklist that was based on recognized standards such as the Security Vulnerability Checklist and Safety Audit/Inspection Manual of the American Chemical Society, in addition to the university's own laboratory safety protocols. Systematic observations and direct inspections were used to collect data, which allowed for the assessment of compliance in several areas, such as emergency preparedness, hazard management, and physical protections.

The results of the check-list application demonstrated some divergences between universities: although some higher education institutions meet the criteria and follow good safety practices, others present significant flaws. The areas with the greatest deficiencies are those directly related to chemical safety measures, such as the storage of volatile compounds, emergency signaling, and training personnel to respond to These findings demonstrated that, despite partial adherence to safety regulations, considerable advancements were needed to ensure uniform protection across all sites.

The authors suggest several corrective measures to improve safety systems in underperforming laboratories considering the disparities they have observed. These include better training, more frequent audits, and institutional policy reinforcement.

Olewski & Snakard (2017) analyzed, through a more critical view, the fallacy that academic laboratories involve fewer risks and are less dangerous compared to industrial laboratories. Although lower quantities of chemicals are handled in university laboratories, the frequency of accidents, some of them resulting in fatalities, highlights how insufficient risk management is now in these institutions. Through the examination of parallels between experimental occurrences and thoroughly record large-scale calamities in industry, the authors present a strong argument that educational environments must not underestimate these dangers.

The authors are in favor of implementing Process Safety Management (PSM) principles in university laboratories, which were previously employed in process industries. This means clarifying basic concepts like risk and hazard and implementing many levels of control to reduce what is left. However, implementing PSM models in academic contexts presents some difficulties and constraints, such as the lack of commitment on the part of institutions, insufficient safety leadership, little training in risk management and insufficient supervision of safety procedures.

Despite the difficulties, the authors provide practical ways to facilitate PSM implementation in academic laboratories. It is recommended that safety leadership be incorporated into university governance, that staff and students receive organized risk assessment and management training and that a culture of near miss reporting, and continuous learning be promoted to address the resource constraints of university environments.

This study contributes to the discourse on laboratory safety by integrating industrial engineering risk management frameworks into academic practices and outlining the institutional and behavioral adjustments required to bridge the gap between policy and practice.

According to Saleh et al., (2025), the Universities of Zakho and Koya in the Kurdistan Region of Iraq developed, implemented and assessed a dual-focused chemical safety and security curriculum. In collaboration with local educators and safety specialists, the module handbook featured examples that were contextualized within the local culture and theoretical foundations that aligned with Sandia National Laboratories' requirements. Second-year chemistry students were given organized content through formative and summative assessments during the six-week trial program, which was in line with Bologna. The topics covered included risk assessment, incident reporting, hazard identification and chemical labeling.

Surveys conducted before and after the intervention revealed statistically significant improvements in the behavioral, affective, and cognitive areas of 68 students' knowledge of chemical safety. Notably, understanding the distinction between safety and security rose from 18.8% to 42.6%; interest in learning more about chemical safety rose from 35% to 50%; and general knowledge of safety concepts grew by 57.4%. These increases were validated using Wilcoxon paired-samples analysis ($p \leq 0.05$), demonstrating that the curriculum is successful in generating measurable advances even in a setting with limited resources and cultural differences.

In similar transitional academic systems, the authors emphasize that this pilot intervention offers a replicable model for incorporating chemical safety and security education into university curricula. With iterative feedback and the integration of globally recognized standards with locally relevant content, the study offers evidence-based support for curriculum initiatives that can bridge existing gaps in risk perception and procedural behavior. By promoting the broader adoption and iterative improvement of such integrated modules, particularly in settings where formal chemical safety and security instruction is lacking or in its infancy, Saleh et al. support the objective of your study, which is to develop contextually relevant, evidence-driven educational interventions in laboratory safety.

1.1.3. Translation, Adaptation and Cultural Validation of Questionnaires

In recent years, the importance of using validated instruments has been underscored increasingly whitin health, educations, as well as safety research, especially whenever diverse linguistic and cultural settings witness the application of these tools (Wild et al., 2005). The task of developing a new questionnaire or translating an existing questionnaire into a different language can be exhausting, with one of the biggest challenges being to create a questionnaire that is psychometrically sound and efficient for use in clinical and research settings (Tsang et al., 2017).

It is essential to identify the concept to be assessed with the questionnaire, as the domain of interest will determine what the questionnaire will measure. The next question is: how will the concept be operationalized? In other words, what type of behavior will be indicative of the domain of interest? Several approaches have been suggested to assist in this process, such as content analysis, research review, critical incidents, direct observations, expert judgment, and instruction. Once the construct of interest has been determined, it is important to conduct a literature review to identify whether a previously validated questionnaire exists. A validated questionnaire refers to a scale that has been developed to be administered among the intender respondents. Validation processes must have been completed using a representative sample, demonstrating adequate reliability and validity (Tsang et al., 2017). One of the questionnaire development and translation process is shown in Figure 3.

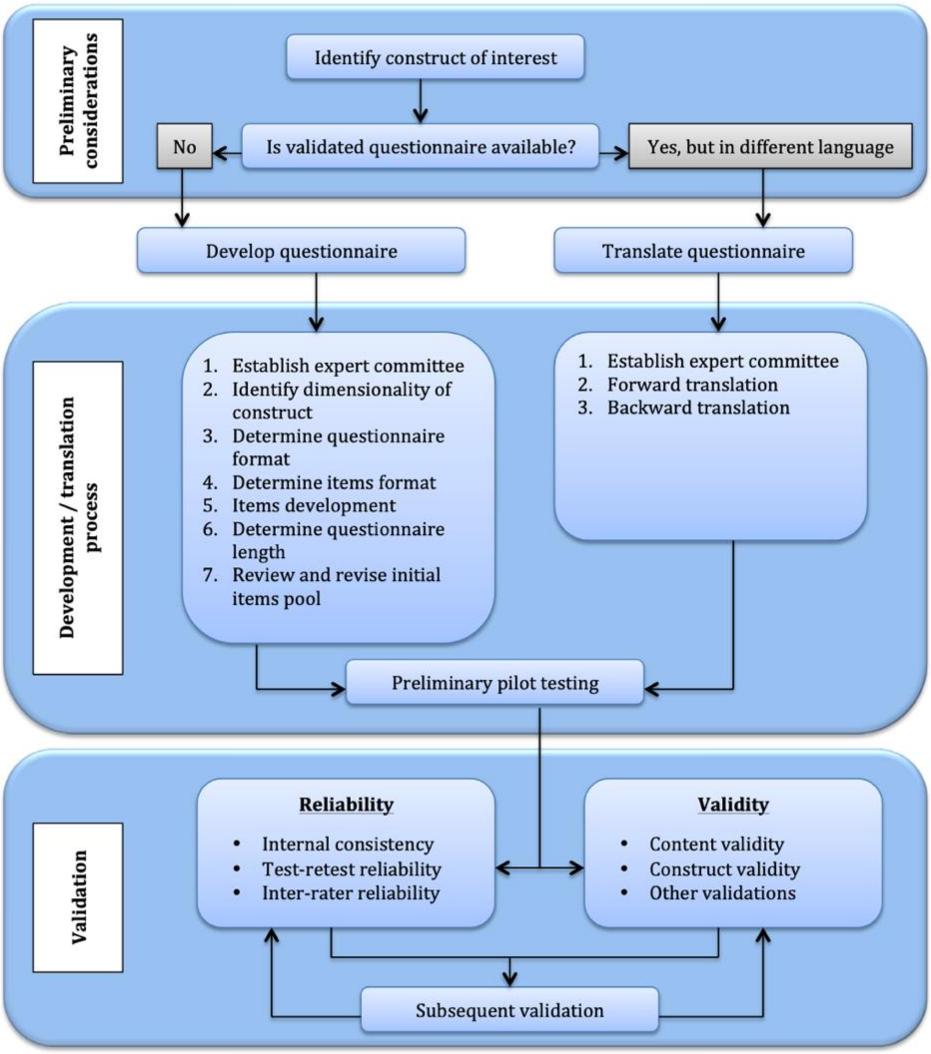

Figure 3 Questionnaire development and translation processes (adapted from Tsang et al., 2017).

With the increase in the number of multinational and multicultural research projects, the need to adapt health status measures for use in languages other than the original one has also grown rapidly.

Most questionnaires were developed in English-speaking countries and, the cross-cultural adaptation of a self-administered health status questionnaire for use in a new country, culture or language requires the use of a unique method in order to achieve equivalence between the original and target versions of the questionnaire. It is now recognized that for measures to be used across cultures, items must not only be well translated linguistically, but also culturally adapted to maintain the content validity of the instrument at a conceptual level across cultures (Beaton et al., 2000).

Intercultural adaptations must be considered for various scenarios and in some cases. In one of Beaton articles, he refers to studies that suggest five different examples (Figure 4) of when attention should be paid to this adaptation, comparing the language and culture of the destination (where it will be used) and the origin (where it was developed). The first scenario is one which will be used in the same language and culture which was developed. No adaptation is necessary. The last scenario is the opposite extreme, the application of a questionnaire in a different culture, language, and country (Beaton et al., 2000).

Wanting to use a questionnaire in a new population described as follows:		Results in a Change in . . .			Adaptation Required	
		Culture	Language	Country of Use	Translation	Cultural Adaptation
A	Use in same population. No change in culture, language, or country from source	—	—	—	—	—
B	Use in established immigrants in source country	✔	—	—	—	✔
C	Use in other country, same language	✔	—	✔	—	✔
D	Use in new immigrants, not English-speaking, but in same source country	✔	✔	—	✔	✔
E	Use in another country and another language	✔	✔	✔	✔	✔

Adapted from Guillemin et al.[4]

Figure 4 Possible Scenarios Where Some Form of Cross-Cultural Adaptation is Required (Beaton et al., 2000)

The development and translation of a questionnaire require researchers to carefully consider issues related to the format of the questionnaire and the meaning and appropriateness of the items. Once the development or translation phase is complete, it is important to conduct a pilot teste to ensure that the items can be understood and interpreted correctly by the intended respondents. The validation phase is crucial to ensure that the questionnaire is psychometrically valid. Although developing and translating a questionnaire is not an easy task, there are multiple articles where researchers can obtain efficient and effective information (Tsang et al., 2017).

When transferring psychometric tools across linguistic and cultural boundaries, cultural adaptation and validation are essential. This is especially important when conducting research with a global population or when applying well-established instruments in diverse cultural contexts, such as with international college students. With a particular focus on the health, behavioral and educational context, this section looks at the main techniques, norms and procedures used in the translation and cultural adaptation of questionnaires.

To ensure equal semantic, idiomatic, experiential and conceptual validity across target cultures, Beaton et al., (2000) provided a thorough six-stage approach in their groundbreaking publication to help researchers adapt self-report instruments across cultural boundaries (Figure 5). The steps include: forward translation by two separate bilingual translators; combining these translations into a single version; back-translation to the source language by two native speakers who are not familiar with the original measure; review by an expert committee to resolve differences and guarantee equivalency; pre-testing with 30 to 40 members of the target population to assess clarity and relevance; submitting the documental procedure for evaluation by the original instrument's creators.

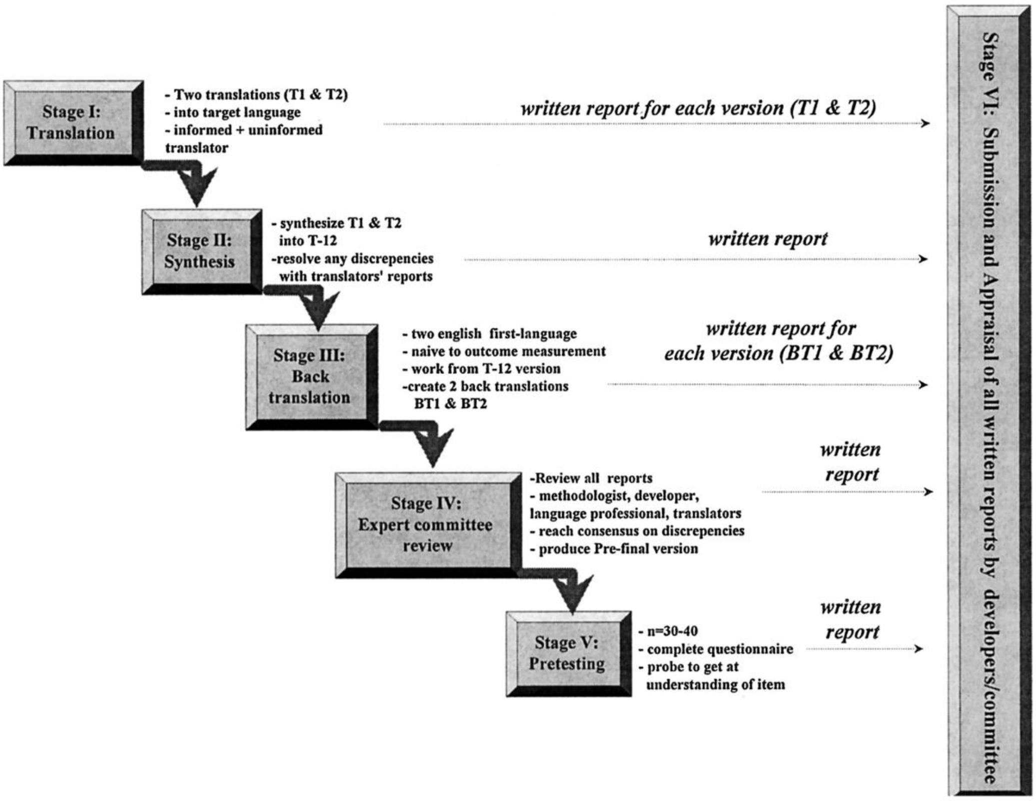

Figure 5 Graphic representation of the stages of cross-cultural adaptation recommended (Beaton et al., 2000)

Importantly, the authors stress that meaningful adaptation requires more than just semantic consistency. In order to guarantee that translated materials are identifiable and significant within the target population's cultural context, the procedure must also take experience and conceptual equivalency into consideration. In addition to identifying unclear or problematic phrasing, the pre-testing stage encourages prospective users to consider each item's interpretative accuracy (a process known as cognitive pre-validation).

Despite being one of the most extensively used recommendations in health and social science research, competing frameworks differ in terminology and methodology. Although there isn't a universally required protocol, a recent review reveals that many excellent cross-cultural adaptations use similar approaches, especially multilingual translation, expert committees, and pre-testing, thorough psychometric resting is advised as a separate, later step. These recommendations offer a strong methodological basis for future studies, guaranteeing that any self-reported tool researchers employ is linguistically and culturally sensitive to their target audience, improving validity and reliability.

Alongside these fundamental methods, more recent guidelines have surfaced that seek to combine psychometric rigor with cultural awareness.

Likewise, the ITC Guidelines for Translating and Adapting Test, set global benchmarks for the translation of tests and surveys, emphasizing the importance of cooperative, iterative methods that incorporate cultural awareness and psychometric assessment (Tsang et al., 2017). The authors of the guideline stress that ensuring psychometric robustness (that is, proving validity, reliability, and practical utility) is the most important challenge, whether creating a new questionnaire or modifying an existing one for new population. To accomplish this, their article offers a clear road map thar combines qualitative and quantitative methods.

Building on Beaton's procedural approach, the authors offer crucial methodological steps that reinforce the relationship between language and statistical validity.

From conceptualization and item construction to forward-backward translation when adapting to new languages, expert committee review, and iterative pre-testing with cognitive debriefing to confirm semantic and experiential equivalency, the authors outlined important methodological phases. The framework then suggests thorough statistical validation, which includes evaluations of test-retest reliability, construct validity using exploratory and CFA, responsiveness, and internal consistency (such as Cronbach's α). For researchers, a flowchart that summarizes the steps offers a useful visual aid.

These principles show that, in the context of cross-cultural adaptation, it is as important to preserve the conceptual intentionality of the instrument as it is to ensure the accuracy of the measurement (both aspects being as important as the linguistic itself).

Furthermore, Tsang et al., (2017) warn that effective cross-cultural adaptation calls for more than just linguistic translation, emphasizing the significance of guaranteeing conceptual and contextual validity to make sure the final tool speaks to the target population's experiences and frames of reference. Additionally, they point out that in order to ensure stability and applicability across various cohorts, full validation necessitates both initial scale testing and continuous psychometric evaluation.

Additionally, conceptual equivalence and meticulous procedures are highly valued in Patient-Reported Outcomes (PRO) guidelines.

Under the direction of the ISPOR Task Force for Translations and Cultural Adaptation, Wild et al. (2005) provided a thorough set of best-practice guidelines for the translation and cultural adaptation of PRO instruments. The authors outlined a multi-step procedure intended to ensure validity at every level, understanding that PRO measures need to preserve conceptual equivalency rather than just semantic accuracy, across various linguistic and cultural contexts. Important stages also include the ones reported by Beaton et al. (2000), as back-translation into the original language, reconciliation into a single version, forward translation by a minimum of two separate translators, and expert review to address inconsistencies.

The purpose of this repeated process is to guarantee that materials are clear, relevant to the culture, and preserve the original aim of the tool by involving both experts in the field and everyday representatives from the specific culture. This approach emphasizes the significance of qualitative feedback during each phase of the adaptation.

Cognitive debriefing involving individuals from the target demographic is an essential element of the Task Force's suggestions. This qualitative phase assesses participants' understanding of each element to uncover any possible misinterpretations or content that may not be culturally suitable. The thorough method, as stated by the authors, enhances both face and content validity, while also delivering a linguistically and culturally consistent rendition of the PRO measure, thereby facilitating additional psychometric assessments such as CFA and tests for measurement invariance.

The report wraps up by emphasizing the importance of maintaining precise records at all stages, which includes detailed logs of translation decisions, adjustments, and outcomes of discussions. This kind of documentation aids in making future revisions or changes easier and enhances the ability to conduct audits. Although these frameworks direct the general organization of translation, scale development techniques that guarantee psychometric rigor are used in conjunction with them.

A succinct but thorough introduction to eh creation and psychometric validation of scales in the social, behavioral and health sciences is provided by Boateng et al., (2018). Based on their vast scale design experience and best practices, the authors present a nine-step, three-phase process: In Phase 1 – Item Generation and Content Validity, domain constructs are defined, literature is reviewed, experts are consulted, a large item pool is drafted and content validity metrics are assesses; In Phase 2 – Scale Construction, pretesting items, administering surveys, reducing items using theoretical and statistical arguments and investigating factors structure are all includes; In Phase 3 – Scale Evaluation and Validation, comprises testing construct, convergent and discriminant validity, assessing reliability and evaluating dimensionality using CFA.

The authors stress the use of parallel item reduction strategies that combine statistical criteria and theoretical alignment, as well as rigorous pretesting using cognitive interviews to evaluate clarity and contextual relevance. Additionally, they support the use of string factor analysis methods to determine the structural validity of the instrument, moving from exploratory to confirmatory analysis. Lastly, they emphasize the significance of maintaining transparency in the development process and disclosing psychometric indices (such as Cronbach's alpha and composite reliability).

Whereas (Boateng et al., 2018) focus on multi-item instruments, others have addressed the value of brevity through single-item tools.

Allen et al. (2022) contested the widespread skepticism surrounding single-item measures by providing a strong argument for their valid application in psychological studies. Historically, journal editors have preferred multi-item tools over single-item scales, which are often perceived as lacking validity and dependability. Nevertheless, the authors share new findings that demonstrate that for unidimensional and specifically defined categories, single-item measures can achieve psychometric characteristics like those found in multi-item measures.

It is suggested that single-item assessments are particularly useful in various disciplines or extensive panel surveys where measuring many aspects is essential. The benefits of those assessments comprise less redundancy, conciseness, and a lighter response load, while also noting that multi-item scales might still be necessary for adequate representation and modeling of complex and diverse variables.

Importantly, Allen et al., (2022) advocate for careful construct selection and validation. They encourage researchers to ensure that their focus construct is conceptually clear and to assess validity by examining test-retest reliability, converge with known instruments, and predictive correlations if they are employing single-item measures. The authors promote rigorous empirical evaluation over rigorous adherence to scale length in order to provide a paradigm for the appropriate use of single-item tools.

Similarly, examples of best practices in Portuguese adaption offer specific procedural insights.

The translation and cultural adaptation procedure employed by Santos et al., (2017) in their validation of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) serves as a methodological benchmark for researchers wishing to adapt psychometric instruments for use in linguistically and culturally diverse contexts. Their approach adheres to internationally accepted best practices and provides a replicable model that ensures cultural relevance and semantic correctness, two essential components of maintaining the integrity of constructs when tools are used with populations other than the ones for which they were intended.

It is interesting to note that using two separate forward translations and then synthesis reduces the bias of each translator and ensures that language subtleties are adequately conveyed. The resulting back-translation process, which is performed by translators' blind to the original version, allows researchers to detect and correct subtle changes in meaning that may compromise the validity of the scale. The expert committee assessment further improves the adaptation by including diverse perspectives that assess not only language equivalence but also conceptual and experience congruence with the target group.

Pre-testing with members of the intended user group is crucial to confirming that the context-appropriate and comprehensible update items exist. This multi-step, repetitive process lessens the probability of measurement inaccuracies resulting from cultural disparities while also enhancing both the instrument's surface validity and its content.

An approach that is both brief and extensive for verifying health outcome scales is presented by Martins Mesquita (2023), emphasizing scientific accuracy and transparency in documenting procedures. He recommends starting with a detailed description of the concept to be measured and then thoroughly analyzing the required sample size, emphasizing the importance of representativeness and consistency in validation studies. The manual highlights the use of test-retest reliability measures when temporal stability is crucial and emphasizes the use of internal consistency analysis to assess the coherence of scale items. The author recommends both exploratory and CFA to determine the dimensional structure of the instrument, highlighting the importance of construct validity in addition to reliability. In addition, he highlights the importance of criterion-related validity and suggests, when feasible, comparisons with objective health outcomes or validated instruments. The guidance also addresses responsiveness and urges researchers to evaluate the scale's ability to detect changes over time in clinical or behavioral settings to ensure sensitivity and practical applicability. Martins Mesquita (2023) also encourages detailed and clear reports covering methodological choices, psychometric measures, and limitations, with the aim of improving reproducibility and promoting critical evaluation.

Lastly, a more comprehensive taxonomy of translation frameworks emphasizes how important it is to match translation techniques with research design.

(Valdez et al., 2021) presented a categorization of translation models and techniques for creating questionnaires, especially for health surveys involving multiple languages. They stated that a correct relationship between translation methods and questionnaire design is crucial, especially in significantly diverse population settings. Their criticism offered instruction on the selection of translation processes like committee consensus or decentered procedures, according to research objectives and population characteristics. Their work adds to the literature through the presentation of how translation paradigms affect the validity of cross-cultural research.

The core of the recommendation is the use of team-based structures supported by committees, especially Translation, Review, Assessment, Pre-testing, and Documentation (TRAPD). This method includes iterative rounds of review, assessment, and pre-testing, as well as multiple translators and interdisciplinary experts, including subject matter experts. In addition to linguistic accuracy, this type of collaboration ensures cultural and experiential appropriateness for the target audience. The authors also emphasize the importance of cognitive interviews and small-scale pilot tests during instrument development to detect and correct cultural misunderstandings early in the process.

In conclusion, Valdez et al. (2021) advocate for transparency in reporting, arguing that researchers should openly disclose the translation structures and questionnaire design strategies they employ to allow for critical review and replication. Their taxonomy, which chooses committee-based, parallel, or decentralized techniques based on the scale of the research, cultural complexity, and available resources, ensures conceptual validity, and facilitates the collection of high-quality data in multiple languages.

1.2. Relevance to Current Study

The reviewed literature underscores the crucial importance of safety perception, awareness and behavior in promoting a secure academic laboratory setting. Evidence from cross-sectional surveys and Bayensian modeling endorses a comprehensive strategy for laboratory safety, integrating education, evaluation and organizational dedication.

These results directly contribute to one of the central aims of this thesis, namely the translation, adaptation, and cultural validation of a survey questionnaire to assess chemical safety perceptions among Portuguese higher education students, representing, to our knowledge, the first study specifically addressing chemical laboratory safety in this context in Portugal. Emerging themes – such as the persistent gap between knowledge and action, the influence of safety climate, and the importance of customized safety training – further highlight the need for a context-sensitive and culturally appropriate evaluation instrument.

In this context, the discussed methodological guidelines and empirical examples provided a sound basis for the translation and validation process. This process must be systematic and evidence based, with a view to linguistic accuracy, cultural relevance and psychometric soundness. Bringing the above principles to the laboratory safety context guarantees that the adaped questionnaire will be relevant to the local academic setting and statistically feasible, and ultimately improve the quality of data obtained and the efficacy of safety practice.

2. Methods

2.1. Description of the Study Area

The study was conducted in several Portuguese higher education institutions, both universities and polytechnics, in courses that include practical laboratory classes, in any of the areas (chemistry, biology, histology, among others).

There is no evidence that laboratory safety training is mandatory for students in the various study programs. However, it is morally necessary that students, teachers, and researchers who attend academic laboratories know and understand the rules for using them.

2.2. The Study Population and Sample Size

A convenience sampling strategy was applied, with all students enrolled in undergraduate and graduate programs that include laboratory practices in their curricula. This non-probabilistic approach was deemed appropriate given the exploratory nature of this study and the practical constraints of reaching a broad cross-sectional sample.

2.3. Survey Instrument

The questionnaire was adapted from the original survey conducted by Al-Zyoud et al., (2019), composed by 27 questions organized into five sections. The first section consisted of five demographic questions including different variables: sex, age group, study cycle and academic year and previous training on laboratory safety. The second included nine different pictograms that were needed to match with the corresponding hazard it represents. In the third section, the responses to statements used a five-point Likert scale and the attitude score was calculated by assigning a score of 1 to "strongly disagree", 2 for "disagree", 3 for "neutral", 4 for "agree" and 5 for "strongly agree".

The fourth consists of four questions, three of them were on the Likert scale, where "never" was assigned with 1, "sometimes" with 2 and "always" with 3, and one was a multiple choice. This section was designed to assess students' practices in the laboratory. In the fifth section we had five multiple choice questions that assess students' knowledge and familiarity with emergency equipment and procedures (Al-Zyoud et al., 2019).

2.4. Translation procedure and cultural adaptation

To ensure the "Perceptions of Chemical Safety in Laboratories" a questionnaire created by Al-Zyoud et al., (2019) (Appendix 2) was linguistically and culturally appropriate for Portuguese higher education students, a comprehensive translation and adaptation process was undertaken. The methodology applied is similar to that used in other studies on translation and cultural adaptation, including forward and backward translation, to maintain semantic and conceptual equivalence.

After obtaining authorization for the use of the questionnaire for its translations, adaptation and cultural validation – given by one of its authors – we followed the guidelines proposed by (Beaton et al., 2000).

We started with two translations of the original questionnaire into Portuguese. This step was carried out by two translators from different professional backgrounds, who were unaware of the questionnaire and therefore the objectives of the work, thus creating two independent translations.

Next, we compared the two translations, by a committee of experts formed by 2 PhDs in the field of Occupational Safety and Health, 1 PhD in Chemistry and 2 Health and Safety Practitioners. This process aimed to ensure that the instrument would be conceptually equivalent, culturally appropriate, and suitable for practical application.

From the analysis of the differences found between the two translations, a single consensual version was formed. Consequently, this version, adapted for Portuguese culture, was sent to a third person, who was also fluent in English and has not taken part in the initial translation, so had no knowledge of the questionnaire. The document was then translated back into its original language – English.

To finish the process, this translation (Appendix 3) was analyzed by the committee and compared with the original version to see if there were any significant differences that would jeopardize this study.

2.5. Data Collection and Analysis

This study was developed in two main phases. The first consisted of the translation, adaptation and cultural validation of the questionnaire created by Al-Zyoud et al. (2019), originally developed in English, with the aim of assessing the perception, knowledge, and practices of higher education students regarding chemical risk in the laboratory environment.

The second phase involved administering the questionnaire to higher education students to analyze the psychometric structure of the instrument, its adaptation to the national academic context and the students' perceptions about chemical safety.

The instrument was then reviewed for content validity by the same committee of experts of the translation process. Before its final application, a pre-test was conducted with 10 students from different study programs to ensure the clarity of the instructions, the understanding of the items, and the adequacy of the response time. Based on this feedback, minor adjustments were made to the language used. The final version of the questionnaire was made available anonymously online, The study was approved by the Ethics Committee of the School of Health from Polytechnic of Porto (Reference CE0018F), complying with all ethical and legal standards applicable to research involving human subjects.

In accordance with the General Data Protection Regulation (GDPR), all ethical issues were duly safeguarded: participation was voluntary, informed, and confidential, and no personal or identifiable data was collected.

After collecting the responses, statistical processing was performed using IMB SPSS Statistic 29.0.2.0 software. The analysis was structured in three main stages: descriptive statistics, normality analysis, and application of inferential tests appropriate to the nature of the data collected.

In the first phase, a descriptive analysis of the sociodemographic and academic variables of the sample was performed, namely gender, age, study cycle, academic year, and previous training in laboratory safety. Absolute and relative frequencies were calculated for these variables.

Next, the normality of the continuous variables and the scores created from the questionnaire was assessed. For this purpose, and because we have an $n>50$, the Kolmogorov-Smirnov test was used. Since most variables did not show a normal distribution ($p<.05$), nonparametric statistical tests were used in the subsequent inferential analyses.

The Knowledge Score variable, constructed from the sum of correct answers to the nine items in Section 2 of the questionnaire, was treated as a discrete quantitative variable. To examine association between variables, Spearman's correlation coefficient was used, which is appropriate for ordinal and continuous variables that are not normally distributed. This analysis allowed us to assess the relationship between visual knowledge and other dimensions of the questionnaire, such as risk perception, attitudes, and practices.

In comparing groups, the Mann-Whitney U test was used (when comparing two independent groups) and the Kruskal-Wallis test (when comparing three or more groups). These tests do not require assumptions of normality or homogeneity of variances and are appropriate for the type of data collected.

In addition, boxplots were generated to visually illustrate the distribution of scores among the different groups, allowing the median, dispersion and presence of outliers to be identified clearly and objectively.

For the section on attitudes toward chemical safety in laboratories, an Exploratory Factor Analysis (EFA) was performed to explore its latent structure. Tests such as Kaiser-Meyer-Olkin (KMO) and Bartlett's, as well as Cronbach's alpha, were performed to assess the internal consistency of the scale. If the $\alpha > 0.7$ or higher is considered acceptable, indicating that the instrument has good internal consistency. A value between 0.6 and 0.7 may be deemed acceptable in exploratory research, and $\alpha < 0.6$ suggest poor internal consistency , indicating that the items may not be measuring the same underlying construct and need revision (Adeniran, 2025; Tavakol & Dennick, 2011).

Factorial validity was assessed by the analysis of factorial weights of the items (λ). If all the items of a dimension have $\lambda \geq 0.5$, it is assumed that the dimension has factorial validity; if $\lambda^2 \geq 0.25$ is an indicator of an appropriate individual reliability of the item (Marôco, 2010).

For the last section, a descriptive analysis of the responses was carried out, using frequency distribution, percentages, and graphical representation, with the aim of characterizing students' knowledge and practice regarding emergency equipment, as well as accident/incident situations.

3. Results and Discussion

3.1. Demographic Data

The sample for this study consists of n=284 higher education students from different study programs and scientific fields. The sociodemographic and academic characterization of the participants (Table 1) allows for a deeper understanding of the respondents' profile and the context in which the perception of chemical risk in the laboratory environment occurs.

In terms of gender, there is a clear predominance of the female one, representing 72.9% of the sample, while 25.3% of participants identified themselves as male. Only 1% reported another gender and 0.7% chose not to disclose this information.

In terms of age, most students were in the 21–25 (45%) and 18–20 (38%) age groups, reflecting a predominantly young sample in the early years of their academic career. The older age groups, 26–29 years, and 30 years or older, represented 5.3% and 11.6%, respectively.

As for the cycle of studies, most participants were enrolled in polytechnic (50.7%) and university (19.7) bachelor's degree programs. Master's students (polytechnic: 10.2%; university: 7%) and higher professional technical courses (4.2%) were also represented. Only 4.2% were enrolled in university doctoral programs.

The distribution by academic year showed a higher concentration in the first three years of training: 28.1% in the 1st year, 27.1% in the 2nd year, and 24.6% in the 3rd year. The fourth year was represented by 19% of students, while the more advanced years, such as the fifth and sixth, were practically residual (1% and 0%, respectively).

Finally, regarding previous training in laboratory safety (including content covered in course units or thematic modules) 80.6% of participants stated that they had already had contact with this type of training, while 19.4% indicated that they had no previous experience in this field.

This characterization shows a sample with predominantly young, female, enrolled in polytechnic education cycles and with a high rate of previous exposures to content related to laboratory safety. This composition is relevant for the interpretation of the perceptions studied, as it contextualizes the students' level of familiarity with the risks associated with laboratory practices.

Table 1 Frequency distribution of students by demographics

Variable	Frequency	Percent
Gender		
Male	72	25.3
Female	207	72.9
Other	3	1.0
Prefer not to say	2	0.7
Age Group		
18-20	108	38.0
21-25	128	45.0
26-29	15	5.3
+30	33	11.6
Study Program		
CTesp	12	4.2
Bachelor's degree (University higher education)	56	19.7
Bachelor's degree (Polytechnic higher education)	144	50.7
Master's degree (University higher education)	20	7.0
Master's degree (Polytechnic higher education)	29	10.2
Integrated master's degree (University Higher Education)	11	3.8
Doctorate (University Higher Education)	12	4.2
Doctorate (Polytechnic higher education)	0	0
Academic Year		
Year 1	80	28.1
Year 2	77	27.1
Year 3	70	24.6
Year 4	54	19.0
Year 5	3	1.0
Year 6	0	0.0
Have you ever had training on laboratory safety procedures? (Including modules/classes on the subject as part of a Curricular Unit of your course)		
Yes	229	80.6
No	55	19.4

3.2. Assessment of Students' Familiarity and Understanding of Chemical Hazards Warning Signs

Section 2 of the instrument aimed to assess students' ability to recognize nine pictograms found in the GHS. Each correct answer was assigned to a value of 1 and incorrect answers a value of 0. Adding up all the correct answers resulted in the variable Knowledge_Score, with possible values between 0 and 9.

Table 2 shows the descriptive statistic for each of the pictograms evaluated. The sample mean is 7.56 (sd=1.74), indicating a high overall level of familiarity with hazard pictograms. However, there is a variation between 0 (minimum possible) and 9 (maximum possible), noting that some students were unable to correctly identify any symbol. This finding raises questions regarding the safety of users in the laboratory.

Table 2 Descriptive Statistic for Correct Identification of Hazard Pictograms and Total Knowledge Score

Statistics

		Q6 Correct	Q7 Correct	Q8 Correct	Q9 Correct	Q10 Correct	Q11 Correct	Q12 Correct	Q13 Correct	Q14 Correct	Knowledge_ Score
N	Valid	284	284	284	284	284	284	284	284	284	284
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		.76	.94	.82	.95	.89	.55	.87	.77	.99	7.5563
Std. Deviation		.425	.231	.385	.209	.312	.498	.337	.421	.102	1.73521
Minimum		0	0	0	0	0	0	0	0	0	.00
Maximum		1	1	1	1	1	1	1	1	1	9.00

Figure 6 shows the distribution of total scores for knowledge of hazard pictograms among the 284 participants. Most students were able to correctly identify between 7 and 9 hazard pictograms, reflecting a high level of knowledge. However, the presence of lower scores highlights the existence of asymmetries in visual safety literacy.

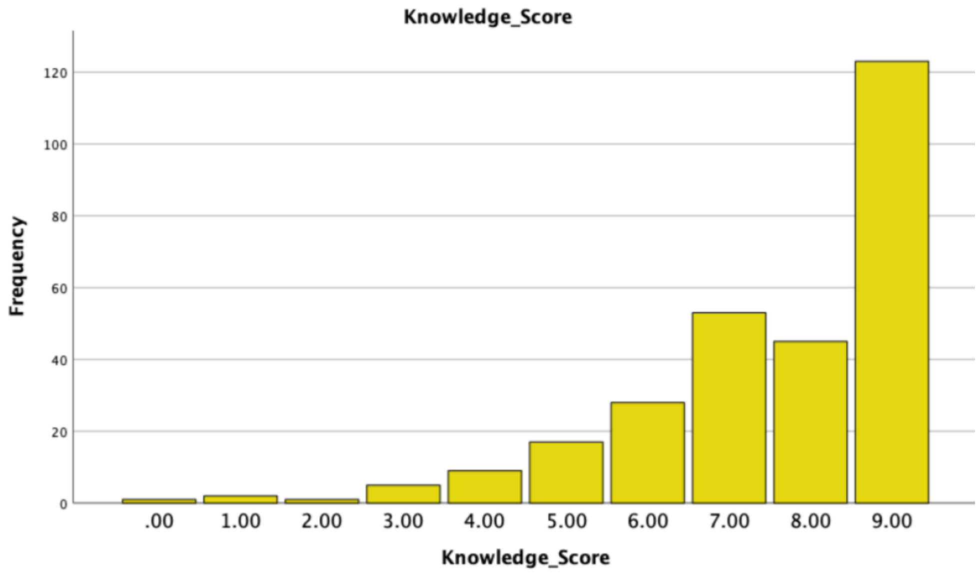

Figure 6 Distribution of Students' Total Knowledge Scores on Hazard Pictogram Identification

With regard knowledge of individual pictograms, the symbol that was most correctly identified was Toxic (Q14), with an accuracy rate of 99%, followed by Corrosive (Q)) with 95% and Irritant (Q7) with 94%. On the other hand, the pictogram with the highest identification error rate was Comburent (Q11), with about 55% correct answers.

These data help to understand which pictograms are most frequently recognized and consequently used in the laboratory environment.

The normality of the Knowledge_Score variable was assessed using the Kolmogorov-Smirnov test (Table 3), which revealed a distribution significantly different from normal (p<.001). therefore, nonparametric tests were used in subsequent analyses.

Table 3 Normality Assessment of the Knowledge Score

	Kolmogorov-Smirnov[a]		
	Statistic	Df	Sig.
Knowledge_Score	.230	284	<.001

With the objective to assess whether were statistically significant differences in the level of visual knowledge depending on the cycle of studies attended, the nonparametric Kruskal-Wallis test was applied, given that the dependent variable (Knowledge Score) did not have a normal distribution,

Initially, the variable "Study Cycle" included seven distinct categories, distinguishing academic degrees according to the nature of the institution (university vs. polytechnic). However, for the purposes of this analysis, equivalent categories were merged, integrating the same academic cycles (e.g., bachelor's or master's degree), regardless of the type of institution. After this reclassification, students were grouped into four categories: CTeSP, bachelor's degree, master's degree, and doctorate.

In Table 4 it is possible to understand that the Kruskal-Wallis test indicated thar there were no statistically significant differences in visual knowledge scores between the groups ($\chi^2(3) = 2.274$, p=.518). These results suggest that academic degree that participants were attending does not significantly influence students' performance in correctly identifying chemical hazard symbols.

Table 4 Kruskal-Wallis Test Comparing Knowledge Scores Across Study Cycles

Test Statistics[a,b]	
	Knowledge_Score
Kruskal-Wallis H	2.274
Df	3
Asymp. Sig.	.518

a. Kruskal Wallis Test

b. Grouping Variable: Study_Cycle

Following this line of thought, we also applied the same nonparametric test to assess whether the level of visual knowledge differed according to the academic year attended. The analysis included the first five years of the academic course, with the sixth year being excluded because it had no participants.

The results (Table 5) indicated that there were no statistically significant differences between the groups ($\chi^2(4) = 4.246$, p=.374). Nevertheless, an upward trend was observed in the average scores between the 1st (128.69), 2nd (143.05) and 3rd years (154.24), with a slight decrease in the 4th year (146.50) and stable values in the 5th year (150.67), although the latter group consisted of only three participants.

Table 5 Kruskal-Wallis Test Comparing Knowledge Score and Academic Years

Test Statistics[a,b]	
	Knowledge_Score
Kruskal-Wallis H	4.246
Df	4
Asymp. Sig.	.374

a. Kruskal Wallis Test

b. Grouping Variable: Year

These results suggest that, although there is a slight progression in performance during the first years of training, the variation between years is not statistically significant, which may indicate that visual knowledge of chemical hazards symbols is not systematically reinforced throughout the academic course.

This trend is illustrated in Figure 7, which shows the knowledge score across academic years.

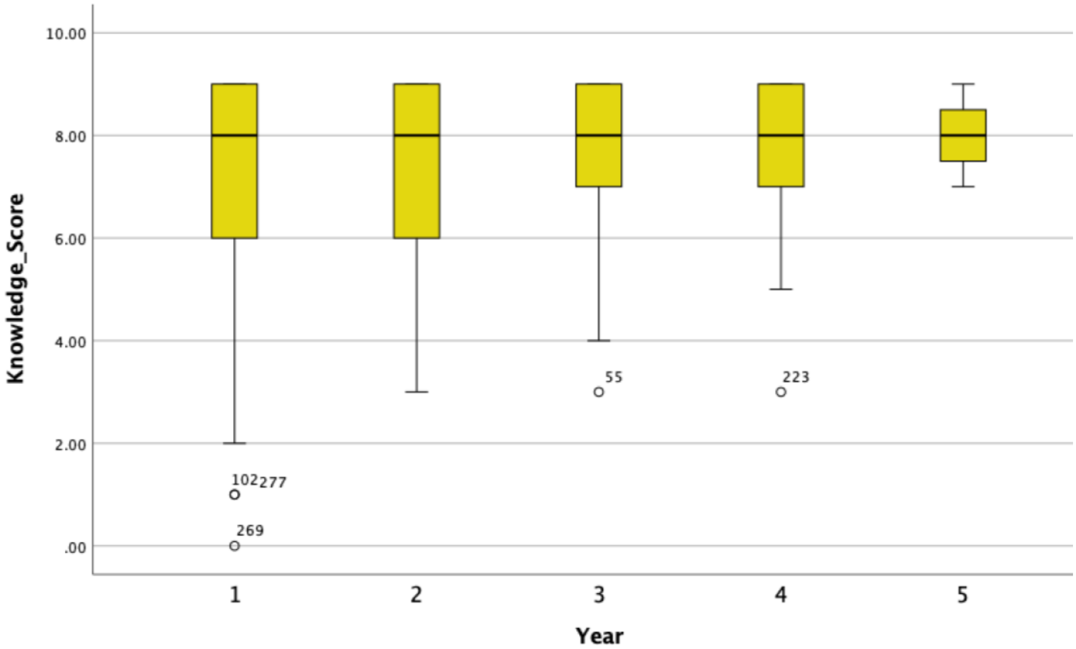

Figure 7 Boxplot of Knowledge Score across academic years

It can be seen that the median Knowledge Score remains high between years, with greater variability in the early years and less dispersion in the 5th year, reflecting the small number of participants. The represented outliers indicate knowledge score below the group trend.

3.3. Attitudes Toward Laboratory Chemical Safety – Factorial Structure and Internal Consistency

This section of the questionnaire aimed to assess students' attitudes toward chemical safety in the laboratory environment. This section consists of four items, rated on a five-point Likert scale ranging from "Strongly disagree" to "Strongly agree".

To explore the latent structure of this section, an EFA was conducted using principal component extraction. The purpose of this approach was to verify unidimensionality of the scale and the internal consistency of its items.

Table 6 KMO and Barlett's Test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,644
Bartlett's Test of Sphericity	Approx. Chi-Square	51,038
	df	6
	Sig.	<,001

The suitability of the data for EFA was verified using the KMO measure and Bartlett's sphericity test, as showed in Table 6. The KMO value was 0.644, considered acceptable, indicating that the correlation matrix presents sufficiently small partial correlations to justify the application of EFA. Bartlett's test proved to be statistically significant ($x^2(6)$ = 51.038; $p<0.001$), confirming that the correlation matrix differs significantly from an identity matrix and is therefore appropriate for factor analysis.

Table 7 Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,562	39,054	39,054	1,562	39,054	39,054
2	,876	21,903	60,957			
3	,803	20,083	81,040			
4	,758	18,960	100,000			

Extraction Method: Principal Component Analysis.

Factor extraction was performed based on the principal component method, adopting the criterion of eigenvalues greater than 1 for factor retention (Table 7). The results indicated the presence of a single factor with and eigenvalue of 1.526, explaining 39.05% of the total variance of data. The remining factors had eigenvalues below 1 and were therefore not considered in the final solution. Analysis of the scree plot corroborated this unifactorial solution.

Table 8 Cronbach's Alpha

Reliability Statistics

Cronbach's Alpha	N of Items
,434	4

The internal consistency of the scale was assessed using Cronbach's alpha coefficient (Table 8), obtaining a value of a α=0,434, which indicates low reliability. This value is below the minimum threshold of 0.70 generally accepted as an indicator of satisfactory internal consistency (Adeniran, 2025; Tavakol & Dennick, 2011).

Table 9 Factor weights (λ) to all components

Component	λ	λ^2
1	1,562	2,440
2	,876	0,767
3	,803	0,645
4	,758	0,575

Although all items had factor weights (λ) greater than 0.5 and the factor analysis revealed a unifactorial structure and as factorial validity. Also, $\lambda^2 \geq 0{,}25$, revealed individual reliability of each of the 4 items (Table 9). The low alpha value could suggest that the items may not be sufficiently correlated with each other or that they do not consistently capture the same latent dimension, reflecting limitations in the formulation of the items, conceptual heterogeneity, or even differences in interpretation by the participants. However, the results, as the scale showed factorial validity, the low number of items, could be the reason for the low Cronbach alpha.

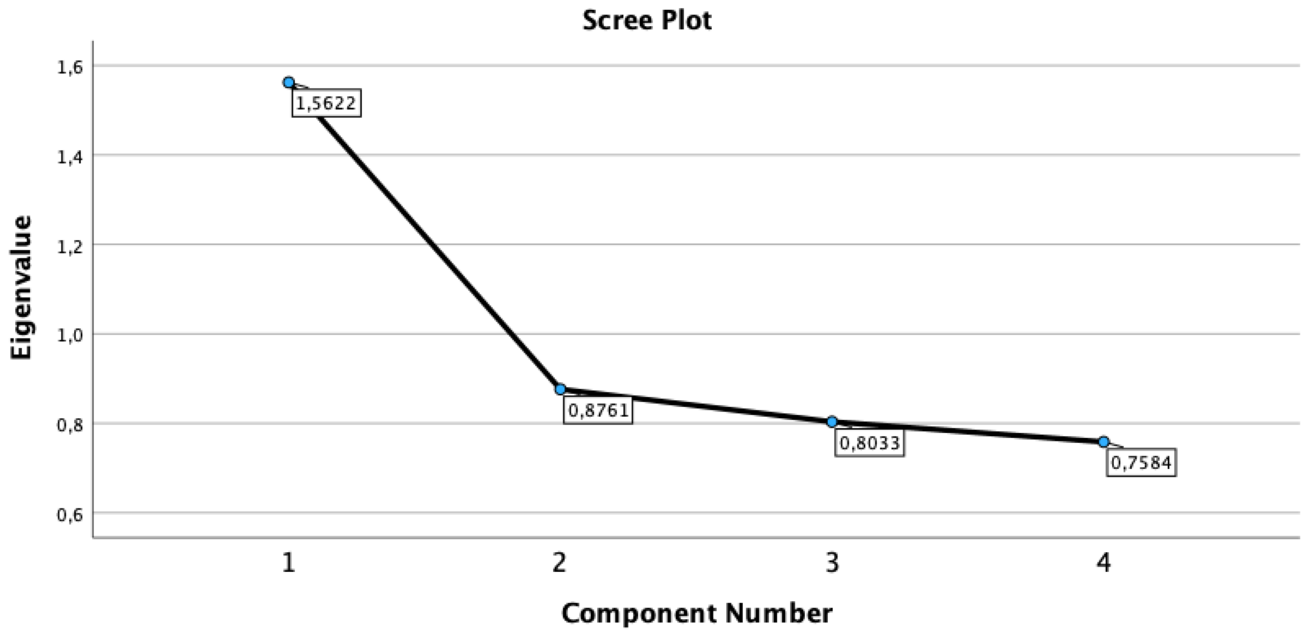

Figure 8 Scree plot representing the eigenvalues of the extracted components.

The scree plot analysis (Figure 8) shows a clear inflection between the first and second components, indicating that only the first factor makes a significant contribution to the local explained variance. The remaining components have eigenvalues below 1 and a smooth, progressive decline, characteristic of a unifactorial structure. This visual pattern reinforces the decision to retain only one factor, in line with Kaiser's criterion (eigenvalues >1).

3.4. Self-Reported Practices Related to Chemical Laboratory Safety

Section 4 of the questionnaire includes three independent items that assess safety behaviors adopted by students in a laboratory environment: reading SDS (Q19), use of PPE (Q20) and adequate ventilation of spaces (Q21). Although these items do not constitute a formal psychometric scale, they can be analyzed as specific behavioral indicators, allowing for the exploration of patterns of safe practices in the context of higher education.

The normality of the variables associated with safety behaviors was tested using Kolmogorov-Smirnov test, based on our sample of 284 participants, according to Table 10.

Table 10 Tests of Normality (Kolmogorov-Smirnov and Shapiro-Wilk)

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Q19	.226	284	<.001
Q20	.413	284	<.001
Q21	.340	284	<.001

The significance values (p<.001) indicate that the distribution of the three variables differs significantly from a normal distribution, which justifies the choice of nonparametric methods in comparative and association analysis, such as Spearman's correlation coefficient and Mann-Whitney U test.

These results confirm that, although the variables represent simple response scales, their asymmetric distribution requires caution in the choice of statistical tests, ensuring greater rigor in the analysis of students' self-reported behaviors.

Despite the violation of normality in the items, EFA was maintained, given the sample size greater than 200 and the exploratory objective of the analysis.

In order to assess the convergent validity between the behaviors themselves, Spearman's correlation coefficients were calculated between the three questions of the instrument, with the data presented in Table 11.

Table 11 Spearman Correlation Matrix for Items Q19-Q21

Correlations

			Q19	Q20	Q21
Spearman's rho	Q19	Correlation Coefficient	1.000	.189**	.244**
		Sig. (2-tailed)	.	.001	<.001
		N	284	284	284
	Q20	Correlation Coefficient	.189**	1.000	.366**
		Sig. (2-tailed)	.001	.	<.001
		N	284	284	284
	Q21	Correlation Coefficient	.244**	.366**	1.000
		Sig. (2-tailed)	<.001	<.001	.
		N	284	284	284

**. Correlation is significant at the 0.01 level (2-tailed).

The results revealed positive and statistically significant correlations between all pairs of variables: between item Q19 and item Q20 there was a weak correlation (ρ=.198, p=.001); between item Q19 and Q21 a weak to moderate correlation was observed (ρ=.211, p=<.001); the strongest correlation was between Q20 and Q21, with a moderate association (ρ=.266, p=<.001).

These results suggest that the three items are related to each other but measure distinct dimension, given that the correlation coefficients do not exceed the values indicative of redundancy (>.80). the existence of positive correlations indicates that, as a response to one item increase, they also tend to increase the others, albeit with variations in the intensity of this association.

To assess the influence of self-reported knowledge levels on perceptions of chemical risk in the laboratory, the Kruskal-Wallis test was applied to items Q19 to Q21 of the questionnaire. This nonparametric analysis was considered appropriate, given that the data in question did not have a normal distribution, as previously demonstrated by the Shapiro-Wilk and Kolmogorov-Smirnov tests.

The continuous variable Knowledge_Score was categorized into three groups - low, medium, and high knowledge – based on the division into thirds, allowing for comparison of responses to items across different levels of knowledge.

The results, shown in Table 12, indicate that, in item Q19 there were no statistically significant differences between the groups ($\chi^2(2)$ = 0.236, p=.889). The mean scores were relatively close, suggesting a homogenous perception among participants, regardless of their level of knowledge. Similarly, item Q20 showed no significant differences between the groups ($\chi^2(2)$ =n2.258, p=.323), although there was a slight tendency toward an increase in the mean rank in the groups with greater knowledge. However, this tendency did not reach statistical significance. In item Q21, a statistically significant difference was identified between the knowledge groups ($\chi^2(2)$ = 8.765, p=.012). The average rank was substantially higher in the group with greater knowledge, indicating that participants with higher levels of knowledge assign higher ratings to this item.

In interpretative terms, these results suggest that, although the overall perception of the risks addressed in items Q19 and Q20 appears to be relatively consistent among students, item Q21 proves to be more sensitive to the level of knowledge, possibly reflecting a more technical or cognitive dimension of chemical risk. This difference may indicate that some aspects of risk perception (particularly those related to more specific knowledge) are influenced by prior literacy in laboratory and chemical safety.

Table 12 Kruskal-Wallis Test by Knowledge Group

Item	Mean Rank Low	Mean Rank Medium	Mean Rank High	H (Kruskal-Wallis)	p-valor
Q19	132.50	140.22	143.46	0.236	.889
Q20	139.44	130.21	145.63	2.258	.323
Q21	119.67	118.47	149.30	8.765	.012*

*p<0.05

With the purpose of analyzing whether prior training in laboratory safety influences the adoption of safety practices, the nonparametric Mann-Whitney U test was applied to all three items of section 4, since the independent variable (training: yes/no) is binary and the dependent variable (safety practices) is ordinal with three categories (never, rarely, always).

The results, shown in Table 13, revealed that in item Q19, no statistically significant differences were observed between the groups (U = 5818.500, Z = -0.938, p = .348), suggesting that prior training does not significantly influence behaviors related to the specific practice of reading SDS's. In item Q20, there was a statistically significant difference between groups (U = 5080.000, Z = -2.694, p = .007), indicating that students with prior training tend to adopt the practice of using PPE more frequently. Item Q21 also showed a significant difference, although less pronounced (U = 5334.500, Z = -1.994, p = .046), also pointing to an association between prior training and greater adherence to the practice in question.

Table 13 Mann-Whitney U Test Results Comparing Safety Practices by Prior Laboratory Safety Training

Test Statistics[a]	Q19	Q20	Q21
Mann-Whitney U	5818.500	5080.000	5334.500
Wilcoxon W	7358.500	6620.000	6874.500
Z	-.938	-2.694	-1.994
Asymp. Sig. (2-tailed)	.348	.007	.046

a. Grouping Variable: Previous_Training

These results suggest that the prior training in laboratory safety can have a positive impact on certain safety practices, reinforcing the importance of systematically integrating this content into academic curricula. However, not all practices appear to be equally influenced, which may indicate differences in the internalization or practical applicability of the content acquired.

3.5. Students' Knowledge and Use of Emergency Equipment

In this section, students were asked about their practical knowledge regarding the use of emergency equipment in laboratories.

Questions such as, how often they adopt certain safety practices in the laboratory, namely adequate ventilation of the space, correct use of PPE, and consultation of SDS before handling new chemicals, were made. The results, shown in Figure 9, show that most students report adopting these practices regularly although there are variations between the behavior analyzed.

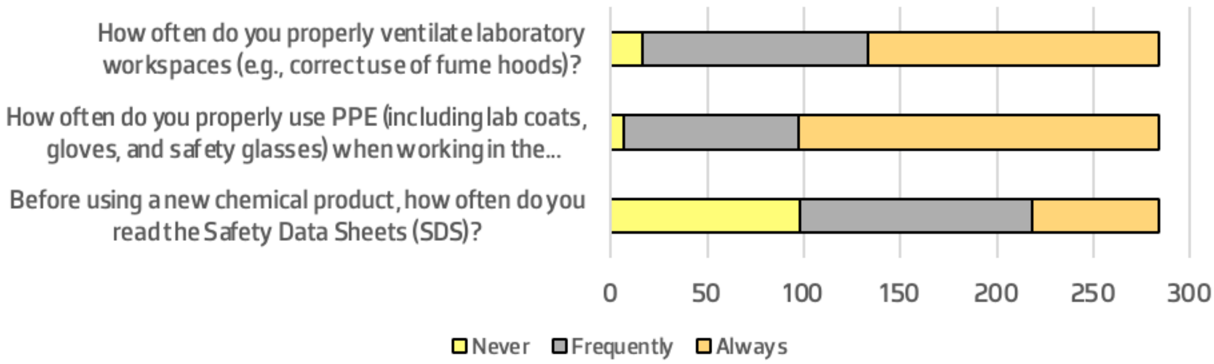

Figure 9 Self-reported frequency of chemical safety practices among higher education students in laboratory settings.

For the first question, "adequate ventilation in laboratory spaces" (e.g., correct use of fume hoods), most participants indicated that they "always" (n=151) perform this practice, with a smaller proportion responding "frequently" (n=117) and a very small fraction indicating that they "never" (n=16) do so.

Regarding the use of PPE (gowns, gloves, and protective eyewear), more than a half of the students indicated that they “always” (n=187) use PPE, with a significant portion selecting “frequently” (n=90) and a minority selecting “never” (n=7).

Consultation of SDS before using a new chemical product, this practice showed greater variability, with a significant number of students reporting that they only do so “frequently” (n=120) or “never” (n=98), highlighting a potential gap in access to or appreciation of this critical source of information.

These results suggest that, although safety behaviors are well established in some areas, systematic consultation of SDSs remains a less established practice, which may justify more specific awareness-raising interventions in this area.

In order to understand students’ behavior regarding the disposal of chemical waste after completing laboratory procedures, a question was included about the practice usually adopted in this context.

The results, shown in Figure 10, clearly show that the overwhelming majority of participants say they place waste in appropriate containers (n=279), in accordance with hazardous laboratory waste management standards.

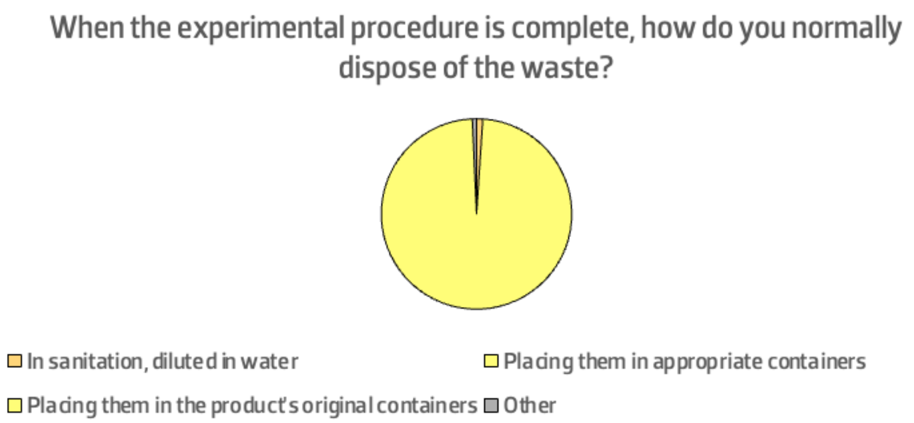

Figure 10 Self-reported waste disposal practices among students following experimental procedures.

The remaining options – namely disposal in the sewage system after dilution in water (n=3), placing the waste in the original product containers (n=0), or other practices (n=2) – were mentioned only rarely, with no more than a symbolic number of responses.

This trend is encouraging, as it demonstrated environmental awareness and a basic understanding of the rules for separating and storing chemical waste. Nevertheless, it is important to ensure that this practice is properly consolidated through ongoing practical training and institutional reinforcement, to prevent possible errors or inconsistent behavior in real laboratory contexts.

The students' level of knowledge regarding the location of emergency equipment in the laboratory was also assessed, including eye wash stations, emergency showers, fire extinguishers, fire blankets and first aid kits.

As shown in Figure 11, most participants stated that they know where only some of the emergency equipment is located (n=161), revealing partial knowledge about the organization and signage of the available resources.

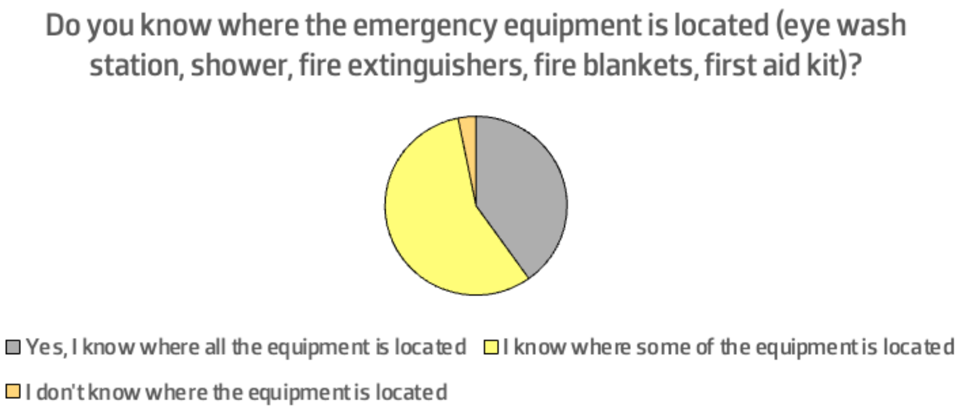

Figure 11 Students' awareness of the location of emergency equipment in laboratory settings

A smaller proportion of students indicated that they knew the location of all equipment (n=114), demonstrating a higher level of familiarity with the laboratory spaces and its safety resources.

On the other hand, a small number of respondents revealed that they did not know where any of the equipment was located (n=9), which may indicate a lack of practical training, insufficient signage, or a lack of clear instructions at the beginning of laboratory activities.

This pattern of responses highlights the importance of strengthening visual communication, adequate signage, and initial training on the location and handling of emergency equipment, promoting a rapid and effective response in the event of an incident.

In addition to location, students were also asked about their level of practical knowledge regarding the use of laboratory emergency equipment. As shown in Figure 12, most participants indicated that they know how to use only some of this equipment (n=124), revealing partial knowledge that is possibly limited to those items with which they have more frequent contact.

Do you know how to use emergency equipment (eye wash, shower, fire extinguishers, fire blankets, first aid kit)?

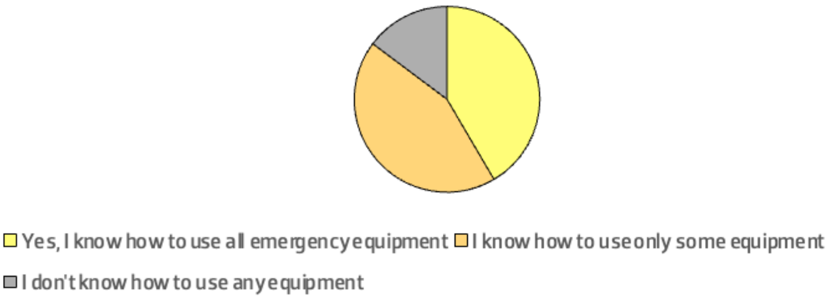

Figure 12 Self-reported ability to use emergency laboratory equipment among higher education students

A smaller proportion said they were proficient in the use of all emergency equipment (n=118), which may reflect more intensive laboratory experience or additional training in academic or professional context. On the other hand, a significant group revealed that they did not know how to use any equipment (n=42), raising relevant concerns in terms of practical preparedness to deal with emergency situations.

These data reinforce the need to focus not only theoretical awareness, but also on regular practical training on the correct handling of emergency equipment, ensuring that all students have the ability to act effectively in the event of an accident.

How to proceed in the event of an acid or base spill on a workbench or on the laboratory floor during an experimental procedure was also one of the questions posed to participants.

According to the data presented in Figure 13, most students indicated that they would use a specific neutralizer (Spill Control Kit) (n=191), which is the most appropriate and safest response according to good laboratory practices.

When an acid/base spill occurs on the workbench or floor while conducting an experimental procedure, how do you react?

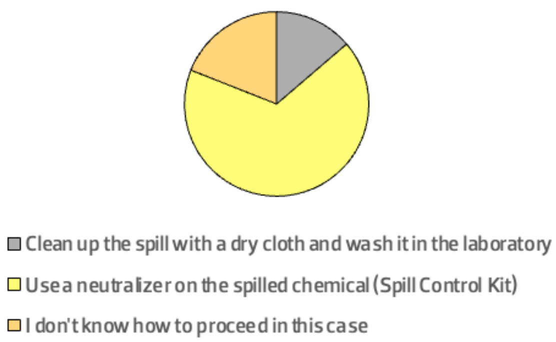

Figure 13 Students' self-reported responses to acid/base spills during laboratory procedures

A smaller percentage said they would clean it up with a dry cloth, followed by washing in the laboratory itself (n=39), which can be considered an inappropriate procedure, especially when it involves corrosive or toxic substances. Finally, a significant proportion of students (n=54) admitted that they did not know how to respond to this type of occurrence, highlighting an important gap in practical training in chemical safety.

This result reveals that, although there is a knowledge base on the use of neutralization kits, the lack of comprehensive and systematic training on chemical emergency response still affects a portion of students. The inclusion of practical simulations, training on spill kits, and accident response protocols may be essential to consolidate a more robust safety culture.

The students' perception of the immediate procedure to be adopted in case of contact of acid or base with the skin was also evaluated.

According to the data presented in Figure 14, the response most selected by the participants was to immediately place the contact area under running water (n=234), which is in accordance with the recommender first aid protocols for this type of accident. A small number of students indicated incorrect alternatives, such as cleaning with a dry towel (n=16) or attempting to neutralize with another chemical (n=33), which may represent an increased risk of aggravating the injury or causing an unwanted chemical reaction. The "other" option was selected by a small fraction (n=1), which may include non-standard, unclear, or possibly correct answers that do not fit into the categories provided.

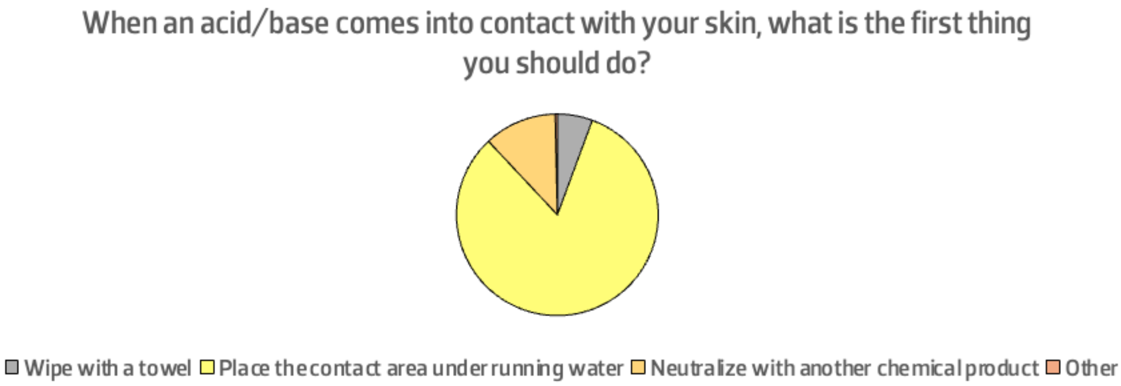

Figure 14 Students' responses to chemical contact with skin involving acids or bases

These results are generally positive, as they show that most students have adequate knowledge about the first aid measures to take in case of skin contact with corrosive products. Nevertheless, it is important to ensure that this knowledge is universal among students and that is associated with practice and training in simulated contexts, in order to promote quick and effective responses in real situations.

In a more serious situation, participants were asked about the immediate action to take in case of accidental contact of an acid or base with the eyes, one of the most critical scenarios in a laboratory environment.

As illustrated in Figure 15, the overwhelming majority of students correctly identified immediate washing of the eyes with running water as the most appropriate procedure (n=227). This response is in line with international first aid protocols for cases of eye exposure to corrosive chemicals.

Despite this encouraging result, a fraction of students selected incorrect or potentially dangerous responses, such as using towel to clean the eye area (n=3) or attempting to neutralize the chemical with another product (n=2) – practices that should be avoided at all costs. Some responses indicate seeking immediate medical help (n=52), which, although recommended at a later stage, does not replace the priority and urgent action of continuous irrigation with water.

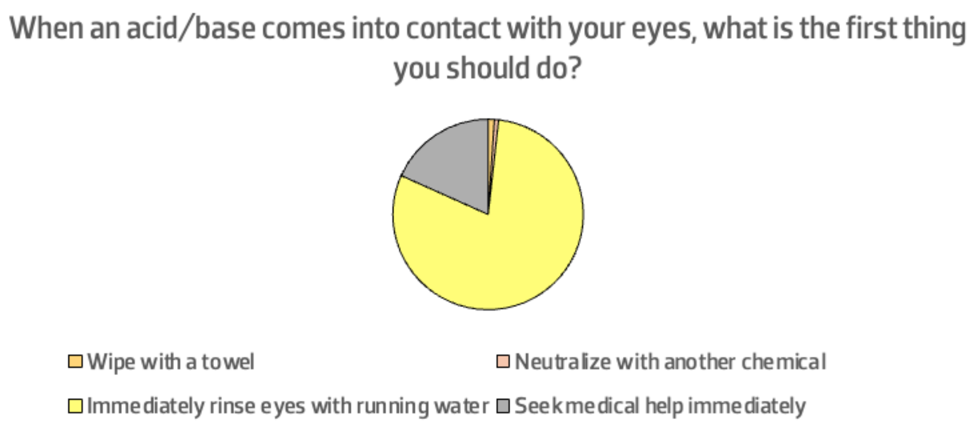

Figure 15 Students' responses to accidental acid/base contact with the eyes during laboratory activity

The data therefore reveal a high level of knowledge about the first aid measures to be taken in situations of eye risk, which is essential to minimize permanent injury. However, the existence of incorrect answers still present in the group, indicates that chemical safety training should continue to reinforce the role of eye wash stations and the appropriate conduct in the event of this type of accident.

Overall, the results show that higher education students demonstrate satisfactory levels of knowledge and practices related to laboratory safety, particularly regarding the use of emergency equipment, response to critical situations, and compliance with preventive measures. Most participants were able to correctly identify the immediate procedures in case of contact with acids/bases on the skin or in the eyes and indicated that they knew the location (albeit partial) and use of some of the most common emergency equipment, such as eye wash stations, safety showers, and first aid kits.

However, some important gaps remain, particularly in responding to chemical spills, the proper management of laboratory waste, and the uniformity of practical knowledge among all students. The discrepancies observed in some incorrect or incomplete answers reinforce the need to strengthen practical training, signage, and simulation exercises, ensuring that the knowledge acquired is not only theoretical but can also be effectively applied in a real-life context. These results underscore the importance of ongoing educational strategies and the effective integration of a culture of safety throughout the academic journey.

4. Conclusion

Safety in educational laboratories is one of the most critical areas of academic practice. All risks must be systematically identified, assessed, and controlled, following the principles of the risk management process. In disciplines such as life sciences, engineering, or health sciences, laboratories are essential pedagogical tools for training future professionals. It is therefore crucial to ensure that these environments are also safe places.

The literature review and empirical data collected in this study confirm that students' knowledge of chemical safety plays a decisive role in shaping their attitudes and behaviors. Consequently, training in this area should be extensive, comprehensive, and transversal across all study programs and academic years.

The results further indicate that students' perceptions, attitudes, and knowledge about chemical safety can be significantly influenced by safety interventions promoted by teachers or peers. This finding reinforces the usefulness of person-centered and behavior-centered approaches as effective strategies for promoting safety in laboratory environments. Notably, the active participation of professors and laboratory supervisors in safety supervision has a positive impact, as it is associated with increased use of PPE and a reduction in laboratory accidents. Based on this evidence, it is recommended that professors, researchers, and supervisors be actively involved in implementing safe practices, namely through direct communication with EH&S (Environmental Health & Safety) technicians, continuous training, and reinforcement during inspections. It should be considered curricula adjustment to insert health and safety modules across different study programs. In parallel, a top-down approach by departmental managers is also suggested, promoting the systematic integration of a safety culture in faculty meetings and management structures (Schröder et al., 2016).

Despite the recognized importance of chemical safety in academic laboratories, this study highlights a significant gap in Portugal regarding systematic research on chemical management practices in educational contexts. The lack of such data hampers the development of effective safety policies and programs that protect students, professors, staff, and the environment. To address this, several measures are recommended: continuous training and awareness-raising activities for teachers, supervisors, researchers, and students on chemical safety; easy and practical access to SDSs, for example through digital platforms or an online open inventory accessible via QR code; chemical spill simulation exercises to prepare for accident scenarios and minimize potential negative consequences. The implementation of these measures will not only strengthen the culture of safety and accident prevention but also contribute to training more aware and better-prepared future professionals. This, in turn, expands the potential for generalizing the results presented here and provides a more comprehensive understanding of the national reality.

Nonetheless, some limitations should be acknowledged. Data collection was based on a voluntary self-response questionnaire administered to higher education students, which may restrict the generalization of results across all study programs. The sample size could have been larger, as the timeframe for distributing the questionnaire was relatively short.

Even so, this study enabled the identification of relevant conclusions to improve the integration of safety and learning in teaching laboratories, thereby meeting one of its main objectives. For future research, a conceptual review of questionnaire items is recommended, with the possible introduction of new items to strengthen internal consistency and enrich the assessment tool. In this sense, the present work can be considered preliminary research on the psychometric properties of the Portuguese version of the questionnaire. Longitudinal studies are needed to examine test–retest reliability, as well as further investigations into its validity.

The availability of a questionnaire that assesses higher education students' perceptions, attitudes, and practices regarding chemical safety in laboratories represents an important and innovative contribution to the Portuguese academic and technical community, opening doors for future research in this area.

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Appendix

Appendix 1 – Information in Safety Data Sheets

Section 1: Identification

This section identifies the chemical on the SDS as well as the recommended uses. It also provides the essential contact information of the supplier. The required information consists of:

- Product identifier used on the label and any other common names or synonyms by which the substance is known.
- Name, address, phone number of the manufacturer, importer, or other responsible party, and emergency phone number.
- Recommended use of the chemical (e.g., a brief description of what it does, such as flame retardant) and any restrictions on use (including recommendations given by the supplier).

Section 2: Hazard(s) Identification

This section identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards. The required information consists of:

- The hazard classification of the chemical (e.g., flammable liquid, category).
- Signal word.
- Hazard statement(s).
- Pictograms (the pictogram or hazard symbols may be presented as graphical reproductions of the symbols in black and white or be a description of the name of the symbol (e.g., skull and crossbones, flame)).
- Precautionary statement(s).
- Description of any hazards not otherwise classified.
- For a mixture that contains an ingredient(s) with unknown toxicity, a statement describing how much (percentage) of the mixture consists of ingredient(s) with unknown acute toxicity. Please note that this is a total percentage of the mixture and not tied to the individual ingredient(s).

Section 3: Composition/Information on Ingredients

This section identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives. This section includes information on substances, mixtures, and all chemicals where a trade secret is claimed. The required information consists of:

Substances

- Chemical name.
- Common name and synonyms.
- Chemical Abstracts Service (CAS) number and other unique identifiers.
- Impurities and stabilizing additives, which are themselves classified and which contribute to the classification of the chemical.

Mixtures

- Same information required for substances.
- The chemical name and concentration (i.e., exact percentage) of all ingredients which are classified as health hazards.
- The concentration (exact percentage) of each ingredient must be specified expect concentration ranges may be used in the following situations: a trade secret claim is made; there is a batch-to-batch variation or; the SDS is used for a group of substantially similar mixtures.

Chemicals where a trade secret is claimed

- A statement that the specific chemical identity and/or exact percentage (concentration) of composition has been withheld as a trade secret is required.

Section 4: First-Aid Measures

This section describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical. The required information consists of:

- Necessary first-aid instructions by relevant routes of exposure (inhalation, skin and eye contact, and ingestion).
- Description of the most important symptoms or effects, and any symptoms that are acute or delayed.
- Recommendations for immediate medical care and special treatment needed, when necessary.

Section 5: Fire-Fighting Measures

This section provides recommendations for fighting a fire caused by the chemical. The required information consists of:

- Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not appropriate for a particular situation.
- Advice on specific hazards that developed from the chemical during the fire, such as any hazardous combustion products created when the chemical burns.
- Recommendations on special protective equipment or precautions for firefighters.

Section 6: Accidental Release Measures

This section provides recommendations on the appropriate response to spills, leaks, or releases including containment and cleanup practices to prevent or minimize exposure to people, properties, or the environment. It may also include recommendations distinguishing between responses for large and small spills where the spill volume has a significant impact on the hazard. The required information may consist of recommendations for:

- Use of personal precautions (such as removal of ignition sources or providing sufficient ventilation) and protective equipment to prevent the contamination of skin, eyes, and clothing.
- Emergency procedures, including instructions for evacuations, consulting experts when needed, and appropriate protective clothing.
- Methods and materials used for containment (e.g., covering the drains and capping procedures).
- Cleanup procedures (e.g., appropriate techniques for neutralization, decontamination, cleaning or vacuuming; adsorbent materials; and/or equipment required for containment/clean up).

Section 7: Handling and Storage

This section provides guidance on the safe handling practices and conditions for safe storage of chemicals. The required information consists of:

- Precautions for safe handling, including recommendations for handling incompatible chemicals, minimizing the release of the chemical into the environment, and providing advice on general hygiene practices (e.g., eating, drinking, and smoking in work areas is prohibited).
- Recommendations on the conditions for safe storage, including any incompatibilities. Provide advice on specific storage requirements (e.g., ventilation requirements).

Section 8: Exposure Controls/Personal Protection

This section indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure. The required information consists of:

- OSHA Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the safety data sheet, where available.
- Appropriate engineering controls (e.g., use local exhaust ventilation, or use only in an enclosed system).
- Recommendations for personal protective measures to prevent illness or injury from exposure to chemicals, such as personal protective equipment (PPE) (e.g., appropriate types of eyes, face, skin, or respiratory protection needed based on hazards and potential exposure).
- Any special requirements for PPE, protective clothing, or respirators (e.g., type of glove material, such as PVC or nitrile rubber gloves; and breakthrough time of the glove material).

Section 9: Physical and Chemical Properties

This section identifies physical and chemical properties associated with the substance or mixture. The minimum required information consists of:

- Appearance (physical state, color...);
- Odor;
- Odor threshold;
- pH;
- Melting point/freezing point;
- Initial boiling point and boiling range;
- Flash point;
- Evaporative rate;
- Flammability (solid, gas);
- Upper/lower flammability or explosive limits;
- Vapor pressure;
- Vapor density;
- Relative density;
- Solubility(ies);
- Partition coefficient: n-octanol/water;
- Auto-ignition temperature;
- Decomposition temperature;
- Viscosity.

The SDS may not contain every item on the above list because information may not be relevant or is not available. When this occurs, a notation to that effect must be made for that chemical property. Manufacturers may also add other relevant properties, such as the dust deflagration index (Kst) for combustible dust, used to evaluate a dust's explosive potential.

Section 10: Stability and Reactivity

This section describes the reactivity hazards of the chemical and the chemical stability information. This section is broken into three parts: reactivity, chemical stability, and other. The required information consists of:

Reactivity

- Description of the specific test data for the chemical(s). This data can be for a class or family of the chemical if such data adequately represent the anticipated hazard of the chemical(s), where available.

Chemical stability

- Indication of whether the chemical is stable or unstable under normal ambient temperature and conditions while in storage and being handled.
- Description of any stabilizers that may be needed to maintain chemical stability.
- Indication of any safety issues that may arise should the product change in physical appearance.

Other

- Indication of the possibility of hazardous reactions, including a statement whether the chemical will react or polymerize, which could release excess pressure or heat, or create other hazardous conditions. Also, a description of the conditions under which hazardous reactions may occur.
- List of all conditions that should be avoided (e.g., static discharge, shock, vibrations, or environmental conditions that may lead to hazardous conditions).
- List of all classes of incompatible materials (e.g., classes of chemicals or specific substances) with which the chemical could react to produce a hazardous situation.
- List of any known or anticipated hazardous decomposition products that could be produced because of use, storage, or heating. (Hazardous combustion products should also be included in Section 5 (Fire-Fighting Measures) of the SDS.)

Section 11: Toxicological Information

This section identifies toxicological and health effects information or indicates that such data are not available. The required information consists of:

- Information on the likely routes of exposure (inhalation, ingestion, skin, and eye contact). The SDS should indicate if the information is unknown.
- Description of the delayed, immediate, or chronic effects from short- and long-term exposure.
- The numerical measures of toxicity (e.g., acute toxicity estimates such as the LD50 (median lethal dose)) - the estimated amount [of a substance] expected to kill 50% of test animals in a single dose.
- Description of the symptoms. This description includes the symptoms associated with exposure to the chemical including symptoms from the lowest to the most severe exposure.
- Indication of whether the chemical is listed in the National Toxicology Program (NTP) Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions) or found to be a potential carcinogen by OSHA.

Section 12: Ecological Information (non-mandatory)

This section provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment. The information may include:

- Data from toxicity tests performed on aquatic and/or terrestrial organisms, where available (e.g., acute, or chronic aquatic toxicity data for fish, algae, crustaceans, and other plants; toxicity data on birds, bees, plants).
- Whether there is a potential for the chemical to persist and degrade in the environment either through biodegradation or other processes, such as oxidation or hydrolysis.
- Results of tests of bioaccumulation potential, referring to the octanol-water partition coefficient (K_{ow}) and the bioconcentration factor (BCF), where available.
- The potential for a substance to move from the soil to the groundwater (indicate results from adsorption studies or leaching studies).
- Other adverse effects (e.g., environmental fate, ozone layer depletion potential, photochemical ozone creation potential, endocrine disrupting potential, and/or global warming potential).

Section 13: Disposal Considerations (non-mandatory)

This section provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices. To minimize exposure, this section should also refer the reader to Section 8 (Exposure Controls/Personal Protection) of the SDS. The information may include:

- Description of appropriate disposal containers to use.
- Recommendations of appropriate disposal methods to employ.
- Description of the physical and chemical properties that may affect disposal activities.
- Language discouraging sewage disposal.
- Any special precautions for landfills or incineration activities

Section 14: Transport Information (non-mandatory)

This section provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea. The information may include:

- UN number (i.e., four-figure identification number of the substance).
- UN proper shipping name.
- Transport hazard class(es).
- Packing group number, if applicable, based on the degree of hazard.
- Environmental hazards (e.g., identify if it is a marine pollutant according to the International Maritime Dangerous Goods Code (IMDG Code)).
- Guidance on transport in bulk (according to Annex II of MARPOL 73/783 and the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (International Bulk Chemical Code (IBC Code)).

- Any special precautions which an employee should be aware of or needs to comply with, in connection with transport or conveyance either within or outside their premises (indicate when information is not available).

Section 15: Regulatory Information (non-mandatory)

This section identifies the safety, health, and environmental regulations specific for the product that is not indicated anywhere else on the SDS. The information may include:

- Any national and/or regional regulatory information of the chemical or mixtures (including any OSHA, Department of Transportation, Environmental Protection Agency, or Consumer Product Safety Commission regulations).

Section 16: Other Information

This section indicates when the SDS was prepared or when the last known revision was made. The SDS may also state where the changes have been made to the previous version. You may wish to contact the supplier for an explanation of the changes. Other useful information also may be included here.

Appendix 2 – Original questionnaire by Al-Zyoud et al., 2019

Section 1: Demographic Data

Put "X" next to your appropriate response:

1. Gender
   ◻ Male ◻ Female
2. Age group
   ◻ 20 and below ◻ 21–25 ◻ 26–29 ◻ 30 and above
3. What is your major?
   - ◻ Biomedical engineering
   - ◻ Pharmaceutical and chemical engineering
   - ◻ Energy engineering
   - ◻ Water and Environmental Engineering
   - ◻ Civil Engineering
   - ◻ Mechatronics Engineering
   - ◻ Industrial Engineering
   - ◻ Mechanical Engineering
4. Academic year
   ◻ Year 1 ◻ Year 2 ◻ Year 3 ◻ Year 4 ◻ Year 5 ◻ Other: __________
5. Prior to your undergraduate studies, did you have any experience in a laboratory environment?
   ◻ Yes ◻ No
6. Have you ever received training about chemical laboratory safety rules and procedures?
   ◻ Yes ◻ No
   If you answer "yes" to question 6, please go to question 7; if you answer "no", please go to question 8.
7. Where did you receive the training?
   - ◻ School
   - ◻ Attended chemical laboratory safety workshop
   - ◻ Course in the BSc curriculum
   - ◻ Internet (e-learning)
   - ◻ Others
8. What is the highest level of chemistry lab course you have taken?
   ____
9. Did you complete part of your curriculum in Germany yet (The German Year)?
   ◻ Yes ◻ No
   If you answer "yes" to question 9, please go to question 10; if you answer "no", please go to Section 2
10. Did you have an experience in a chemical laboratory in Germany?
    ◻ Yes ◻ No

Section 2: Assessment of Familiarity and Understanding of Chemical Hazard Warning Signs

Match hazard warning symbol (column A) with the corresponding description of the chemical property it represents (column B). If you do not know what the symbol represents, then put "X" in the box beside "I don't know what this symbol represents".

Question #	Column A (Pictogram)	Chemical Property	Column B (Chemical Properties)
11.		☐ I don't know what this symbol represents	
12.		☐ I don't know what this symbol represents	
13.		☐ I don't know what this symbol represents	
14.		☐ I don't know what this symbol represents	A. Health Hazard B. Irritant C. Toxic D. Explosive E. Corrosive F. Flammable G. Oxidizing H. Compressed gas I. Environmental Hazard
15.		☐ I don't know what this symbol represents	
16.		☐ I don't know what this symbol represents	
17.		☐ I don't know what this symbol represents	
18.		☐ I don't know what this symbol represents	
19.		☐ I don't know what this symbol represents	

Section 3: Attitude towards Chemical Laboratory Safety

Please answer the following statements using the scale below:
Strongly Agree Agree Neutral Disagree Strongly Disagree

20. Personal Protective Equipment (PPE) is required only when you are using chemicals in the laboratory.
    Strongly Disagree Disagree Neutral Agree
21. It is always safe to dispose of chemical waste by throwing it down the sink and diluting it with large amounts of water.
    Strongly Disagree Disagree Neutral Agree Strongly Agree
22. Before every chemistry lab, it is not necessary to repeat safety rules.
    Strongly Disagree Disagree Neutral Agree Strongly Agree
23. Minor chemical spills are not dangerous, regardless of the spilled chemical.
    Strongly Disagree Disagree Neutral Agree Strongly Agree

Section 4: Chemical Laboratory Safety Practices

Please answer the following statements using the scale below:

Never Sometimes Always

24. Before using a new chemical, how often do you read the MSDS (Material safety data sheet)?
    Never Sometimes Always
25. How often do you wear appropriate PPE, (including a laboratory coat, gloves, eye goggles, closed shoes) when you are working in the laboratory?
    Never Sometimes Always
26. How often do you use appropriate ventilation such as laboratory chemical hoods when working with hazardous chemicals?
    Never Sometimes Always

For the following question, choose the most appropriate answer:

27. When the experiment is finished, how do you often get rid of the chemicals you have used?

    a. I pour the chemicals into the sink drain.
    b. I place them in the waste container.
    c. I pour them back in the original container.
    d. Other. Please specify ______________________________

Section 5: Emergency Equipment and Procedures

28. Do you know the location of the emergency safety equipment (eyewash unit, safety showers, fire extinguisher, fire blanket, first aid kit)?

    a. Yes, I know the location of all safety equipment
    b. I know the location of some of the safety equipment
    c. No, I don't know the location of any of the safety equipment

29. Do you know how to use emergency safety equipment (eyewash unit, safety showers, fire extinguisher, fire blanket, first aid kit)?

    a. Yes, I know how to use **all** safety equipment.
    b. I know how to use **some** of the safety equipment. (Put a (√) beside the equipment you know how to use).
       Eyewash unit Safety showers Fire Extinguisher Fire Blanket First Aid Kit
    c. No, I don't know how to use any of the safety equipment.

30. When an acid/base is spilled on the bench or on the floor while you are performing an experiment, what would you do?

    a. Wipe the spilled chemical with a towel and rinse the towel in the sink.
    b. Use certain chemicals to neutralize the spilled acid/base (spill kit).
    c. I don't know how to react in this case.
    d. Other. Please specify ______________________________

31. When an acid/base comes into contact with your skin, what is the first thing you would do?

    a. Wipe it with a towel
    b. Place it under running water
    c. Neutralize it with another chemical

d. Other. Please specify ____

32. When an acid/base comes into contact with your eyes, what is the first thing you would do?

a. Wipe it with a towel
b. Neutralize it with another chemical
c. Flush the eye immediately with water
d. I would seek medical attention immediately
e. Other. Please specify ____

Appendix 3 – Questionnaire translated to portuguese

Segurança Química em Laboratórios de Ensino Superior

A manipulação de produtos químicos (substâncias e misturas) em laboratórios de ensino, poderá acarretar implicações para a segurança e saúde de estudantes, docentes e funcionários, naturalmente expostos a uma série de potenciais riscos químicos.

A perceção dos estudantes relativamente aos perigos e riscos existentes em laboratório, bem como as suas atitudes face a situações de risco, são influenciadas por uma variedade de fatores, incluindo a educação, experiência e cultura.

No âmbito da Unidade Curricular de Dissertação, inserida no 2º ano do Mestrado em Higiene e Segurança nas Organizações da Escola Superior de Saúde do Politécnico do Porto (E2S|P.PORTO), e **caso se encontre inscrito num ciclo de estudos com prática laboratorial**, solicito a sua colaboração no seguinte questionário com uma duranção prevista de 5 minutos.
A sua resposta será importante para o processo de adaptação cultural e análise psicométrica do questionário, que permitirá avaliar a perceção de risco, atitudes e práticas face ao risco químico por parte dos estudantes inseridos em contexto de ensino superior.

O questionário é anónimo, respeitando a confidencialidade e o cumprimento a proteção de dados dos inquiridos.

Em caso de dúvida ou para mais informações, poderá entrar em contacto com o responsável pelo estudo - Inês Marques Ribeiro, através do email 10190354@ess.ipp.pt

RGPD

O responsável pelo tratamento de dados será Inês Ribeiro 10190354@ess.ipp.pt

Os estudantes podem a qualquer momento exercer os seus direitos consignados no RGPD de Acesso, Retificação, Cancelamento e Oposição (direitos ARCO), bem como o direito de portabilidade previsto no mesmo Regulamento, enviando uma mensagem de correio eletrónico para 10190354@ess.ipp.pt .
O tratamento dos dados será efetuado pelo prazo de vigência de um ano ou o previsto na Legislação, aplicando-se o maior destes prazos.
Este inquérito é pseudonimizado não tendo acesso ao cruzamento de dados que permita a identificação de quem responde.
Se o titular dos dados considerar que houve ilicitude de tratamento, pode apresentar reclamação à Autoridade Nacional de Controlo.

1

Declaro que: *

○ Todas as informações prestadas no presente formulário são verdadeiras

2

Declaro que: *

○ Tomei conhecimento da finalidade, prazo de tratamento e direitos ao abrigo do RGPD que assitem aos dados pessoais solicitados e por mim facultados

Secção 1: Informação Demográfica

3

Género *

◯ Feminino

◯ Masculino

◯ Outro

◯ Prefiro não responder

4

Faixa Etária *

◯ 18-20

◯ 21-25

◯ 26-29

◯ +30

5

Qual o ciclo de estudos que se encontra inscrito? *

◯ CTeSP

◯ Licenciatura (Ensino Superior Universitário)

◯ Licenciatura (Ensino Superior Politécnico)

◯ Mestrado (Ensino Superior Universitário)

◯ Mestrado (Ensino Superior Politécnico)

◯ Mestrado Integrado (Ensino Superior Universitário)

◯ Doutoramento (Ensino Superior Universitário)

◯ Doutoramento (Ensino Superior Politécnico)

6

Em que ano se encontra inscrito? *

- 1º ano
- 2º ano
- 3º ano
- 4º ano
- 5º ano
- 6º ano

7

Alguma vez teve formação relativa a procedimentos de segurança em laboratório? (Incluindo módulos/aula sobre temática no âmbito de uma Unidade Curricular do seu curso) *

- Sim
- Não

Familiarização e conhecimento de Pictogramas de Perigo

Escolha a opção que se adequa ao pictograma apresentado

8

*

- Perigoso para a saúde
- Irritante
- Tóxico
- Explosivo
- Corrosivo
- Inflamável
- Comburente
- Gás sob pressão
- Perigoso para o ambiente
- Não sei o que este símbolo representa

9

*

- Perigoso para a saúde
- Irritante
- Tóxico
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10

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11

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12

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13

*

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14

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15

*

- ◯ Perigoso para a saúde
- ◯ Irritante
- ◯ Tóxico
- ◯ Explosivo
- ◯ Corrosivo
- ◯ Inflamável
- ◯ Comburente
- ◯ Gás sob pressão
- ◯ Perigoso para o ambiente
- ◯ Não sei o que este símbolo representa

16

*

- ◯ Perigoso para a saúde
- ◯ Irritante
- ◯ Tóxico
- ◯ Explosivo
- ◯ Corrosivo
- ◯ Inflamável
- ◯ Comburente
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- ◯ Não sei o que este símbolo representa

Atitudes perante Segurança Química em Laboratório

17

Por favor, responda às seguintes questãos utilizando a seguinte escala: *

	Discordo Totalmente	Discordo	Neutro	Concordo	Concordo Totalmente
Equipamentos de Proteção Individual (EPI) são obrigatórios apenas quando se manuseiam químicos em laboratório.	○	○	○	○	○
É sempre seguro descartar resíduos químicos na rede de saneamento pública quando os diluimos em grandes quantidades de água.	○	○	○	○	○
Antes de um procedimento químico, não é necessário repetir as regras de segurança.	○	○	○	○	○
Derrames de produtos químicos em pequenas quantidades não é perigoso, independentemente do tipo de produto.	○	○	○	○	○

Práticas de Segurança Química em Laboratório

18

Por favor, responda às seguintes questão utilizando a seguinte escala *

	Nunca	Frequentemente	Sempre
Antes de utilizar um novo produto químico, com que frequência lê as Fichas Dados de Segurança (FDS)?	○	○	○
Com que frequência utiliza apropriadamente os EPI (incluindo bata, luvas, óculos de proteção), quando trabalha em laboratório?	○	○	○
Com que frequência ventila apropriadamente os espaços de trabalho em laboratório (EX: utilização correta das hottes)?	○	○	○

19

Quando o procedimento experimental estiver terminado, como é que normalmente descarta os resíduos? *

- ○ No saneamento, diluídos em água
- ○ Colocando-os nos recipientes adequados
- ○ Colocando-os nos recipientes originais do produto
- ○ Outro

Equipamentos de Emergência e Procedimentos

20

Sabe onde se encontram localizados os equipamentos de emergência (lava olhos, chuveiro, extintores, mantas ignífugas, kit de primeiros socorros)? *

- ◯ Sim, sei onde estão localizados todos os equipamentos
- ◯ Sei onde estão localizados alguns equipamentos
- ◯ Não sei onde estão localizados os equipamentos

21

Sabe como utilizar os equipamentos de emergência (lava olhos, chuveiro, extintores, mantas ignífugas, kit de primeiros socorros)? *

- ◯ Sim, sei utilizar todos os equipamentos de emergência
- ◯ Sei como utilizar apenas alguns equipamentos
- ◯ Não sei utilizar nenhum equipamento

22

Se escolheu a opção "Sei como utilizar alguns equipamentos", identifique quais os equipamentos que sabe utilizar.

23

Quando ocorre um derrame de um ácido/base na bancada de trabalho ou no chão, enquanto elabora um procedimento experimental, como reage? *

- ◯ Limpar o derrame com um pano seco e lavá-lo no laboratório
- ◯ Utilizar um neutralizante no químico derramado (Kit Controlo de Derrames)
- ◯ Não sei como proceder neste caso

24

Quando um ácido/base entra em contacto com a pele, qual é a primeira coisa que deve fazer? *

- ◯ Limpar com uma toalha
- ◯ Colocar o local de contacto debaixo de água corrente
- ◯ Neutralizar com outro produto químico

25

Quando um ácido/base entra em contacto com os olhos, qual a primeira coisa que deve fazer? *

- ◯ Limpar com uma toalha
- ◯ Neutralizar com outro produto químico
- ◯ Limpar imediatamente os olhos com água corrente
- ◯ Procurar ajuda médica imediatamente

P.PORTO

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