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Perceptions of Chemical Safety in Laboratories

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Abstract: This study investigates the state of the perceptions of chemical safety in laboratories among undergraduate students of the Biomedical Engineering and Pharmaceutical and Chemical Engineering departments at the German Jordanian University in Jordan. A cross-sectional survey was conducted anonymously with a random sample size of 174 students. A questionnaire of 32 questions was designed with five sections: demographic data, familiarity of chemical hazard signs, attitude towards chemical laboratory safety, safety practices, and familiarity with emergency equipment and procedure. The descriptive statistics showed that students demonstrated fair to good familiarity and understanding of chemical hazard warning signs. Most students had poor to fair attitudes towards chemical laboratory safety; but the assessment of students' chemical laboratory safety practices revealed fair to good practices. While students safety awareness and practices, but not attitude, at this university were acceptable, safety procedures need to be implemented within a more professional safety education and coherent risk and safety climate management.

Keywords: chemical safety; safety perceptions; laboratory safety; undergraduate students; German Jordanian

1. Introduction

Different organizations have recently recognized the role of safety perceptions and safety climate in maintaining a safe working environment [1]. Undergraduate student safety and its related measures should gain more attention, since many of them may live and study on campus where there is a risk of being exposed to fire or electrical shock [2]. They may also work in chemical and biological laboratories as part of their curriculum, or conduct research in collaboration with faculty members. Faller et al. have defined the occupational accidents experienced by university students in Germany as "the accidents that happen during their presence at the university, or on their way to and from the university" [3].

Chemistry and biology laboratories have gained special attention and considerations because students are dealing with material that can be an irritant, explosive, flammable, radioactive, or a health hazard [4]. Accidents in chemical laboratories have been reported worldwide for several reasons, such as an absence of personal protective equipment (PPE), limited experience, mishandling of chemicals, and lack of knowledge about the proper actions to be taken in emergency cases [5]. Examples of the manifestation of these issues include an incidence of fire in three different universities in Malaysia in 2001 at the Department of Chemistry, University of Malaya; in 2002 at an engineering laboratory, University of Putra Malaysia; and in 2005 at the School of Applied Physics, University Kebangsaan [6]. In addition, dimethyl mercury poisoning has led to the death of a chemistry professor in Dartmouth

College in New Hampshire [7]. The likelihood of these events can be minimized if chemicals are used and stored properly and under strict safety regulations and rules. As a result, regulations and laws have been developed by different organizations for using chemicals with potential hazards, through Safety Data Sheets (SDS) or labels [8]. Labels are assigned to each chemical according to the potential hazard it may cause, and anyone who enters the lab should be familiar with the meaning of each label in order to know how it should be handled [5]. Crucially, the United Nations Conference on the Environment and Development (UNCED) has recognized that a Globally Harmonized System (GHS) of classification and labeling of chemicals was needed [9].

Proper comprehension and interpretation of the chemical labels is a very important factor for preventing accidents in the laboratory [10]. Walters et al investigated awareness, attitudes, and practices towards chemical laboratory safety among college students in Trinidad and Tobago at different institutions through a self-administered questionnaire; their results indicated that emergency response and hazard identification were deficient [11]. Withanage and Priyadarshani used a 60-item structured self-administered questionnaire to assess the knowledge of laboratory safety precautions among Allied Health Sciences students; they concluded that this was inadequate [12]. In another study conducted by Adane and Abeje at the Departments of Chemistry and Biology at Jimma University, a structured questionnaire was used to assess students' familiarity and understanding of chemical hazard warning signs. Their results have shown that the comprehensibility of hazard warning signs is low [5]. Karapantsios et al used a questionnaire where the students and laboratory staff were asked to match different chemicals with their correct warning signs at the Department of Food Technology at the Technological Educational Institution of Thessaloniki in Greece. The analysis of their findings has shown that only one out of four students recognized the correct hazard label that is associated with every chemical in the questionnaire [10]. Lunar et al revealed that students enrolled in Chemistry and Biology laboratory classes at De La Salle Lipa, in the Philippines, have low levels of familiarity and comprehension of hazard warning signs [4]. Collectively, these studies outline a critical role for safety training and education in chemical laboratories and the need to implement strict safety policies among undergraduate students.

The aim of this study is two-fold. The first is to assess the knowledge and familiarity of the School of Applied Medical Sciences students (SAMS) at German Jordanian University towards the potential hazards of chemicals in the laboratory. In addition to assessing the ability of students to comprehend GHS pictograms, we also investigate their attitude towards undertaking safety measures in the laboratory, safety practices, and knowledge about the appropriate responses to be taken in emergency cases and the use of related equipment. The data collected will be shared with policy makers, such as the Ministry of Higher Education, in order to adopt the appropriate measures for safety in chemical laboratories.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at the German Jordanian University (GJU), in Amman, Jordan in 2018. GJU is one of the public universities in both Jordan and Germany. The university is the only university in Jordan that adopts an international dual university educational system. It is a compulsory requirement for students to spend at least one academic year in one of the 110 partner universities in Germany. Students in Germany undertake 12 credit hours as an internship in addition to 12 credit hours of technical elective courses. Furthermore, there is a possibility for the students to undertake their graduation project in Germany as an extension. This year is known in the university as the German year. At the time of this study, the total number of enrolled students at the GJU was approximately 4000 students.

2.2. The Study Population and Sample Size

The population of this survey was 327 students and six supervisors from the School of Applied Medical Sciences, which has two departments: the Department of Pharmaceutical and Chemical Engineering and the Department of Biomedical Engineering. The survey population was limited to the students of the School of Applied Medical Sciences due to the fact that the highest exposure frequency to chemical laboratories is found in two majors within that school; either in Jordan or in Germany, during their German year. Eligibility criteria required students to have been registered in one of the chemistry laboratory courses and the total number of enrolled students at the time of the study in both departments was 327 students. Approximately 53% of the population of students, which is equal to 174 students, were randomly sampled, in addition to each enrolled supervisor. It should be noted that the supervisors were only from the Pharmaceutical and Chemical Engineering Department because that department only offers the chemistry courses included in the curriculum of the students of both departments. The students and staff have signed a consent form according to the declaration of Helsinki.

2.3. Study Method and Survey Instrument

The study was a survey-based study where the questionnaire was designed by reviewing prudent practices in the Laboratory and the Globally Harmonized System (GHS) to assess the chemical laboratory safety awareness among the undergraduate university students. The questionnaire consisted of 32 questions organized into five sections, and the questions were both open and closed ended (Appendix A). The questionnaire was validated as a paid service by an English linguistic specialist at the German Jordanian University and scientifically validated and approved by Dr. Nigel Jalsa from the Department of Chemistry, The University of the West Indies, St. Augustine Campus, Trinidad and Tobago. The first section consisted of 10 demographic questions including different variables: gender, age group, major, academic year, previous laboratory experience, previous training on laboratory safety, the highest level of chemistry laboratory completed, and whether the student has completed the international internship in Germany. The second section included nine different GHS pictograms, and the students were asked to match every pictogram with the corresponding hazard it represents. The third section consisted of four Likert scale questions to assess the attitude of students towards safety in chemical laboratories. The fourth section was designed to assess students' practices in the laboratory, it consisted of four questions, three of them were on the Likert scale, and one multiple choice. The fifth section consisted of five multiple choice questions that assessed students' knowledge and familiarity with emergency equipment and procedure. In some of the multiple choice questions the students were given the option to write their own answers under "other" choice. A modified version of the questionnaire was used for the supervisors, with changes being made to questions in Sections 1 and 4.

2.4. Data Collection and Analysis

Data were collected randomly and analyzed using descriptive statistics, which included the calculation of measures of central tendency (means and medians), standard deviations and frequency counts; these were displayed using frequency tables and bar charts. To analyze the responses to Section 2–4 of the questionnaire, the data was transformed to a score that was calculated for each of the following variables: familiarity and understanding (knowledge), attitude and practice.

In Section 2, which has tested knowledge, participants were asked to identify nine symbols, i.e., answer nine questions. A correct response was assigned a score of '1' and an incorrect response; a score of 'zero', therefore, the maximum achievable score was '9'. In Section 3, the responses to statements used a five-point Likert scale and the attitude score was calculated by assigning a score of '2' for strongly disagree, '1' for disagree, 'zero' for neutral, '−1' for agree and '−2' for strongly agree. The maximum achievable score was 8. However, because none of the participants gained scores of '8' and '−8' these maximum and minimum scores were omitted and the actual maximum and minimum scores used were '7' and '−7' respectively. A three-point Likert scale was used to assess questions 24–26 in Section 4 and the responses were scored as follows: always assigned '2', sometimes assigned '1' and never assigned 'zero'; hence the maximum achievable practice score was '6'.

After calculating the scores, they were each categorized into good, fair, or poor, based on a modified version of the original Bloom's cut off points [13]. Categories were as follows: Knowledge (0 to 4 = poor, 5 to 6 = fair, 7 to 9 = good), Attitude (−7 to 2 = poor; 3 to 5 = fair; 6 to 7 = good) and Practice (0 to 3 = poor; 4 = fair; 5 to 6 = good).

For the survey of supervisors, Sections 2, 3 and 5 were analyzed similarly to the description given above for the students. For Section 4, however question 25 was divided into three parts, resulted in the maximum achievable practice score being '8'. After calculating the practice scores they were each categorized into good, fair and poor based on the following criteria: 0 to 4 = poor; 5 = fair; 6 to 8 = good.

3. Results and Discussion

3.1. Demographic Data (Questionnaire Section 1)

The demographic data showed that 54% of the 174 student respondents were female (Table 1). Most students were in the age group "20 and below" (54.6%), and in their first three years of study (63.8%). It also showed that the majority of students (75.3%) reported having received chemical laboratory safety training, 32.2% received it while at secondary school. In terms of students' major, 58.6% were biomedical engineering students, and 40.2% were pharmaceutical and chemical engineering students, which represents one of the limitations of this study. This is due to that biomedical engineering is possibly more attractive to the students than that of pharmaceutical engineering at the university because pharmaceutical and chemical engineering is relatively a new major in Jordan and in the entire region. The students were also asked about the highest level of chemistry lab course that they have taken. Level 1 here means a course code within the first year of the study plan, Level 2 within the second year and so on. Usually Level 4 is taken during the German year, where only 21.3% of the students were back from Germany in this study. Another limitation of this study was that some respondents did not reply to all of the questions in the survey. The Table 1 also shows the detailed frequencies and percentages for each category within each variable.

3.2. Assessment of Students' Familiarity and Understanding of Chemical Hazard Warning Signs (Questionnaire Section 2)

The chemical warning signs in the study included the symbols of health hazard, irritant, toxic, explosive, corrosive, flammable, oxidizing, compressed gas, and environmental hazard. The majority of students (70.7%) demonstrated having good to fair levels of knowledge of the chemical warning symbols as shown in Figure 1; (a) full histograms for each sore and (b) a summary. The 95% confidence interval error bars did not overlap indicating that there are statistically significant differences between the means of students who were classified into the three groups: poor, fair and good. This suggests that these students referred to what is known as a "digital generation" or "millennial generation", who are typically visual learners due to the effect of today's technology where the graphical communication media are rich and based on screen devices such as smartphones, tablets, and projectors [14].

Students in their fourth academic year obtained the highest mean score 6.95 while those who received their chemical laboratory safety training through e-learning on the internet obtained the lowest score 2.00. The fourth academic year is the year students spend in Germany where students have a higher chance to be exposed to proper lab safety training either during the internship phase, or during the technical elective courses phase. The e-learning training is a form of self-dependent study, which is contingent on the learners themselves. Based on score classification (0 to 4 = poor, 5 to 6 = fair, 7 to 9 = good), Table 2 shows that the mean knowledge score was fair (5.63) and the median and standard deviation values calculated confirmed that scores were similar across the selected demographic groups. Some respondents have chosen the option "other" without specifying what kind of other learning resources they received their chemical laboratory safety training through from which add a limitation to the study.

Table 1. Frequency distribution of students by demographics.

Variable	Frequency	Percent
Gender		
Male	80	46.0
Female	94	54.0
Age Group		
20 and below	95	54.6
21–25	76	43.7
26–29	2	1.1
Major		
Biomedical Engineering	102	58.6
Pharmaceutical and Chemical Engineering	70	40.2
Academic Year		
Year 1	41	23.6
Year 2	38	21.8
Year 3	32	18.4
Year 4	19	10.9
Year 5	29	16.7
Other	15	8.6
What is the highest level of chemistry lab course you have taken?		
General Chemistry Laboratory (Level 1)	43	24.7
Bioorganic, Analytical or Pharmaceutical Physical Chemistry Laboratory (Level 2)	42	24.1
Biochemistry, Pharmaceutical Technology Liquid Forms, Heat and Reaction or Instrumental Analysis Laboratory (Level 3)	25	14.4
Separation Processes Laboratory (Level 5)	7	4.0
Have you ever received training about chemical laboratory safety rules and procedures?		
No	42	24.1
Yes	131	75.3
Where did you receive the training?		
School	56	32.2
Attended Chemical Laboratory safety workshop	44	25.3
Course in the BSc. Curriculum	20	11.5
Internet (e-learning)	2	1.1
Other	11	6.3
Did you complete the part of your curriculum in Germany yet?		
No	136	78.2
Yes	37	21.3

NB. Percentages do not all add up to 100 because some respondents did not reply to all of the questions in the survey.

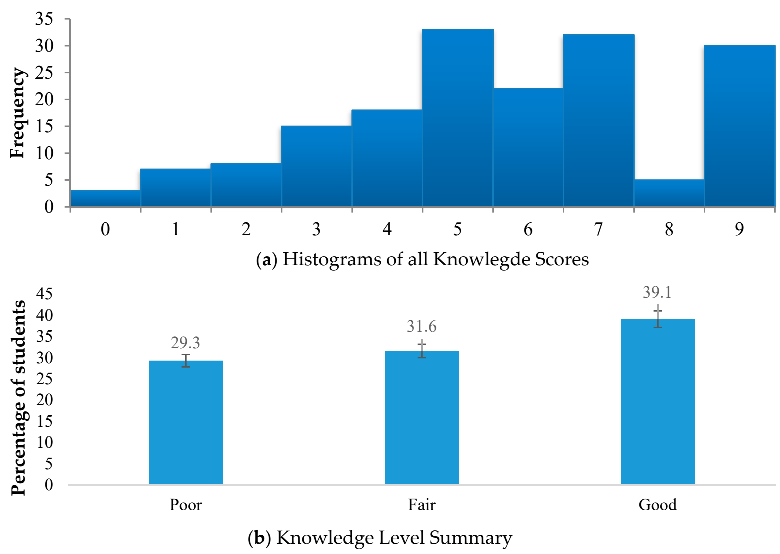


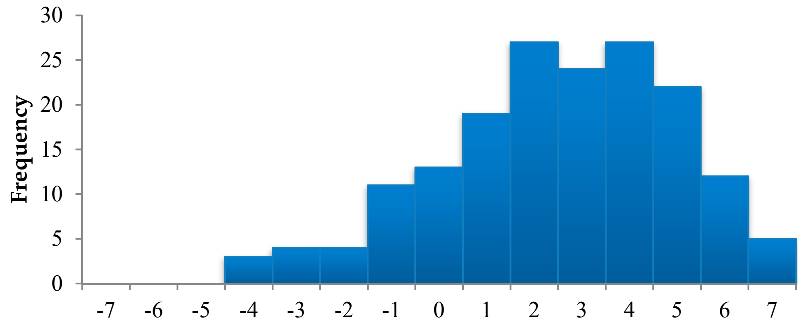
Figure 1. Student Knowledge of Chemical Hazard Warning Signs.

Table 2. Descriptive statistics for the knowledge scores by selected demographics.

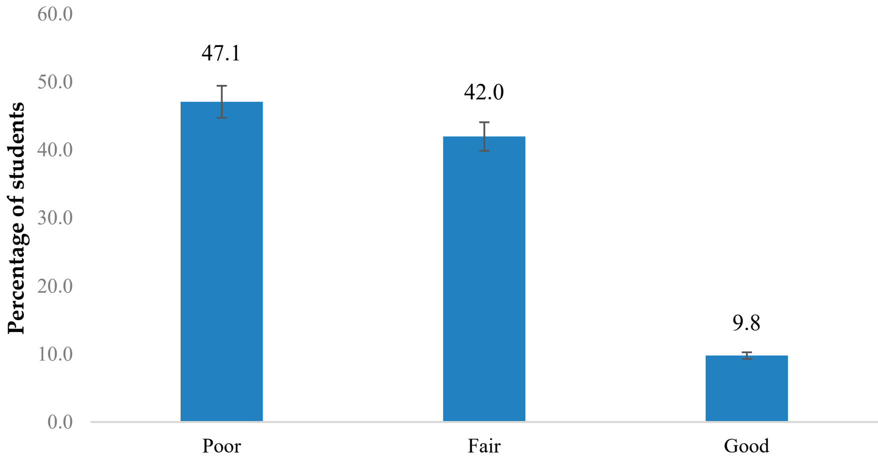
Variable	Frequency	Mean	Median	Std. Deviation
Overall	**174**	**5.63**	**6.00**	**2.35**
Gender				
Male	80	5.25	5.00	2.44
Female	94	5.96	6.00	2.24
Age Group				
20 and below	95	5.23	5.00	2.21
21–25	76	6.22	7.00	2.39
26–29	2	3.50	3.50	3.54
Major				
Biomedical Engineering	102	5.43	5.00	2.44
Pharmaceutical and Chemical Engineering	70	5.93	6.00	2.24
Academic Year				
Year 1	41	4.98	5.00	2.33
Year 2	38	5.39	5.50	2.34
Year 3	32	5.09	5.00	2.21
Year 4	19	6.95	8.00	2.59
Year 5	29	6.41	7.00	2.23
Other	15	6.00	6.00	2.17
What is the highest level of chemistry lab course you have taken?				
General Chemistry Laboratory (Level 1)	43	5.14	5.00	2.37
Bioorganic, Analytical or Pharmaceutical Physical Chemistry Laboratory (Level 2)	42	5.48	5.00	2.31
Biochemistry, Pharmaceutical Technology Liquid Forms, Heat and Reaction or Instrumental Analysis Laboratory (Level 3)	25	6.72	7.00	2.03
Separation Processes Laboratory (Level 5)	7	7.86	8.00	0.90
Have you ever received training about chemical laboratory safety rules and procedures?				
No	42	5.62	5.50	1.95
Yes	131	5.64	6.00	2.48
Where did you receive the training?				
School	56	6.07	6.50	2.33
Attended Chemical Laboratory safety workshop	44	4.80	5.00	2.59
Course in the BSc. Curriculum	20	6.10	6.00	1.92
Internet (e-learning)	2	2.00	2.00	1.41
Other	11	6.73	7.00	2.72
Did you complete the part of your curriculum in Germany yet?				
No	136	5.33	5.00	2.40
Yes	37	6.78	7.00	1.78

3.3. *Assessment of Students' Attitude Towards Chemical Laboratory Safety (Questionnaire Section 3)*

As there is poor documentation and declaration of safety related accidents at the Jordanian universities, the students were unaware of the actual importance of following safety rules. Figure 2; (a) full histograms for each sore and (b) a summary, illustrates that almost half of the students had negative attitudes towards chemical laboratory safety (47.1%). A possible explanation for this result is that students tend to underestimate the importance of complying with safety rules during work in chemical laboratories. This result is consistent with those of other studies that suggest that the correct attitude towards safety, while working in chemistry laboratories, arise from being aware of the nature of different potential chemical hazards [6]. This implies that there is a need for further training of students for risk assessment and potential hazard identification [11]. None of the 95% confidence interval error bars overlapped which suggests that there are statistically significant differences between the means of students who obtained scores at each level.



(**a**) Histograms of all Attitude Scores



(**b**) Student Attitude towards Chemical Laboratory Safety.

Figure 2. Student Attitude towards Chemical Laboratory Safety.

The available safety trainings on the internet are usually not standardized or certified courses which is a general limitation. Conversely, the similar scores across all demographic groups that received training via school curricula, attended chemical laboratory safety workshops, or who attended a bachelor degree, suggests that these sources are effective in improving the students' attitude towards chemical laboratory safety. Based on the score classification of this section (−7 to 2 = poor; 3 to 5 = fair; 6 to 7 = good), in Table 3, the overall attitude score is 2.49 and median is 3.00, which are both classified as poor. However, the relatively large standard deviation of 2.47 indicates that attitude scores vary widely from, poor to fair. Scores were similar across all demographic groups and students who obtained chemical laboratory safety training via "other" sources obtained the highest mean score 3.82 while those who received their safety training through the internet obtained the lowest mean score −1.00.

3.4. Assessment Of Students' Chemical Laboratory Safety Practices (Questionnaire Section 4)

In the assessment of students' chemical laboratory safety practices, most students revealed a total fair to good practices (84.4%) when in the chemistry laboratory (Figure 3; (a) full histograms for each sore and (b) a summary), this indicates that students follow the proper safety rules inside laboratories. This result might be explained by the fact that strict rules are applied to students enrolled in chemistry laboratories. Students are not allowed to enter chemistry laboratories without wearing personal protective equipment, and that chemicals are kept in the fume hoods, so students are not allowed to carry them to their benches. There are statistically significant differences among the score means of students who displayed poor, fair or good practices. There was no overlap in the interval error bars at 95% confidence.

Table 3. Descriptive statistics for the attitude scores by selected demographics.

Variable	Frequency	Mean	Median	Std. Deviation
Overall	**172**	**2.49**	**3.00**	**2.47**
Gender				
Male	80	2.75	3.00	2.74
Female	94	2.27	2.00	2.21
Age Group				
20 and below	95	2.88	3.00	2.37
21–25	76	2.05	2.00	2.54
26–29	2	1.00	1.00	2.83
Major				
Biomedical Engineering	102	2.58	3.00	2.59
Pharmaceutical and Chemical Engineering	70	2.41	2.00	2.28
Academic Year				
Year 1	41	2.71	3.00	2.72
Year 2	38	3.18	3.50	2.24
Year 3	32	2.10	2.00	2.16
Year 4	19	1.63	2.00	2.34
Year 5	29	2.07	2.00	2.42
Other	15	2.87	4.00	2.95
What is the highest level of chemistry lab course you have taken?				
General Chemistry Laboratory (Level 1)	43	2.63	3.00	2.78
Bioorganic, Analytical or Pharmaceutical Physical Chemistry Laboratory (Level 2)	42	2.24	2.00	2.35
Biochemistry, Pharmaceutical Technology Liquid Forms, Heat and Reaction or Instrumental Analysis Laboratory (Level 3)	25	2.92	3.00	2.06
Separation Processes Laboratory (Level 5)	7	2.29	2.00	1.80
Have you ever received training about chemical laboratory safety rules and procedures?				
No	42	2.88	3.00	2.48
Yes	131	2.38	2.00	2.48
Where did you receive the training?				
School	56	2.38	2.00	2.14
Attended Chemical Laboratory safety workshop	44	1.76	2.50	2.83
Course in the BSc. Curriculum	20	3.10	3.50	2.27
Internet (e-learning)	2	−1.00	−1.00	2.83
Other	11	3.82	4.00	2.04
Did you complete the part of your curriculum in Germany yet?				
No	136	2.40	2.50	2.50
Yes	37	2.73	3.00	2.31

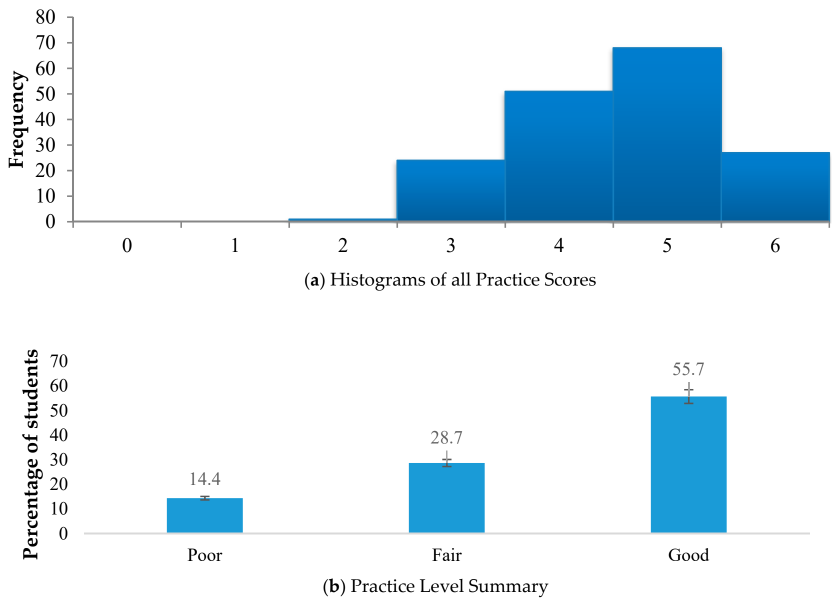


Figure 3. Chemical Laboratory Safety Practices adopted by students.

Students who completed the Separation Processes Laboratory course recorded the highest mean score 5.29. This result might be due to students taking this course in their senior year, when they have the greatest accumulative experience with working in chemistry laboratories, and some of them are already exposed to laboratory work during their German year. Walters et al and Karapantsios et al made similar observations related to age and year of study. Students in their third year obtained the lowest mean score 4.10; this is probably due to that chemistry courses were concentrated in the first and second year of the degree structure, with only pharmaceutical technology laboratories during the third year where the use of hazardous chemicals is very limited. Based on the score classification to measure the students response on practice (0 to 3 = poor; 4 = fair; 5 to 6 = good), the overall mean practice score is 4.56 ± 0.94 and is classified as "good" which is confirmed by the overall median of 5.00 (Table 4).

Table 4. Descriptive statistics for the practice scores by selected demographics.

Variable	Frequency	Mean	Median	Std. Deviation
Overall	**172**	**4.56**	**5**	**0.94**
Gender				
Male	80	4.64	5	1.00
Female	94	4.50	5	0.88
Age Group				
20 and below	95	4.53	5	0.88
21–25	76	4.59	5	1.01
26–29	2	5.00	5	1.41
30 and above	0	0.00	0	0.00
Major				
Biomedical Engineering	102	4.59	5	0.92
Pharmaceutical and Chemical Engineering	70	4.56	5	0.97
Academic Year				
Year 1	41	4.73	5	0.87
Year 2	38	4.66	5	0.85
Year 3	32	4.10	4	0.99
Year 4	19	4.58	5	0.90
Year 5	29	4.72	5	0.92
Other	15	4.47	5	1.13
What is the highest level of chemistry lab course you have taken?				
General Chemistry Laboratory (Level 1)	43	4.72	5	0.93
Bioorganic, Analytical or Pharmaceutical Physical Chemistry Laboratory (Level 2)	42	4.36	4.5	1.03
Biochemistry, Pharmaceutical Technology Liquid Forms, Heat and Reaction or Instrumental Analysis Laboratory (Level 3)	25	4.28	4	0.94
Separation Processes Laboratory (Level 5)	7	5.29	5	0.76
Have you ever received training about chemical laboratory safety rules and procedures?				
No	42	4.71	5	0.90
Yes	131	4.52	5	0.95
Where did you receive the training?				
School	56	4.50	5	0.95
Attended Chemical Laboratory safety workshop	44	4.45	4	0.99
Course in the BSc. Curriculum	20	4.50	4.5	0.69
Internet (e-learning)	2	4.50	5	2.12
Other	11	4.82	5	1.08
Did you complete the part of your curriculum in Germany yet?				
No	136	4.50	5	0.91
Yes	37	4.76	5	1.01

Chemical Laboratory Safety Practices (Questionnaire Section 5)

Students indicated that they adopt different methods for waste disposal, the most popular response reported (46.0%) being that they utilize a waste container, as seen in Figure 4. A minor percentage of students indicated that the waste chemicals are placed into the original container, while a similarly small number would consult with their instructor. This inconsistency in students' responses emphasizes the urgent need for an Environmental Health and Safety Office at the university, which will be responsible for the custody of chemical waste containers and undertaking regular inspections of the waste disposal procedure followed inside the labs. Furthermore, the lack of knowledge of the potential environmental hazards associated with the improper disposal of chemical waste should be addressed in the curriculum.

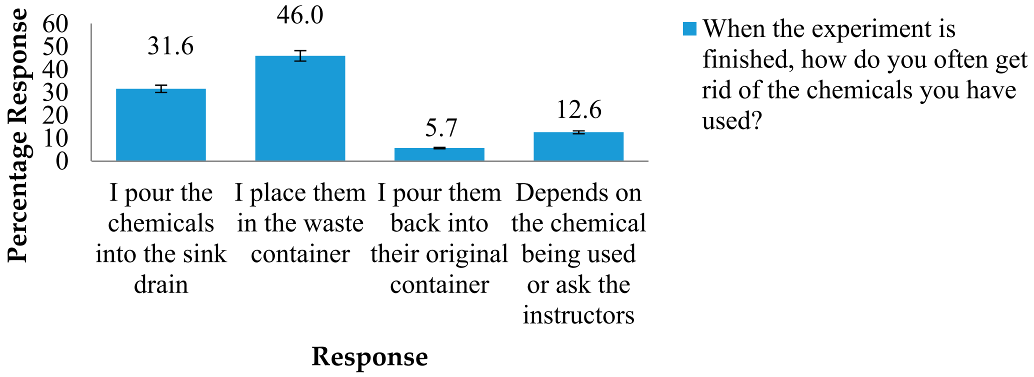


Figure 4. Percentage distribution of students' response for the question on chemical safety practice (Question 27).

3.5. Emergency Equipment and Procedure

Usually, students receive an orientation session on the location of all emergency equipment during the first week of the course. As in any university, the first week might be the "drop and add week" for students to confirm their registration status in the chemistry laboratory courses. Hence, many students may miss the safety and emergency equipment orientation. This highlights how important it is for the university to guarantee a compulsory safety orientation session, even for those students who miss the first week due to registration arrangements, in order for them to know the location and the proper usage of the emergency equipment based on the university policy for risk management. Approximately half of the students indicated that they know the location of all the emergency equipment in the Chemistry laboratory while the remaining 47.1% did not (Figure 5).

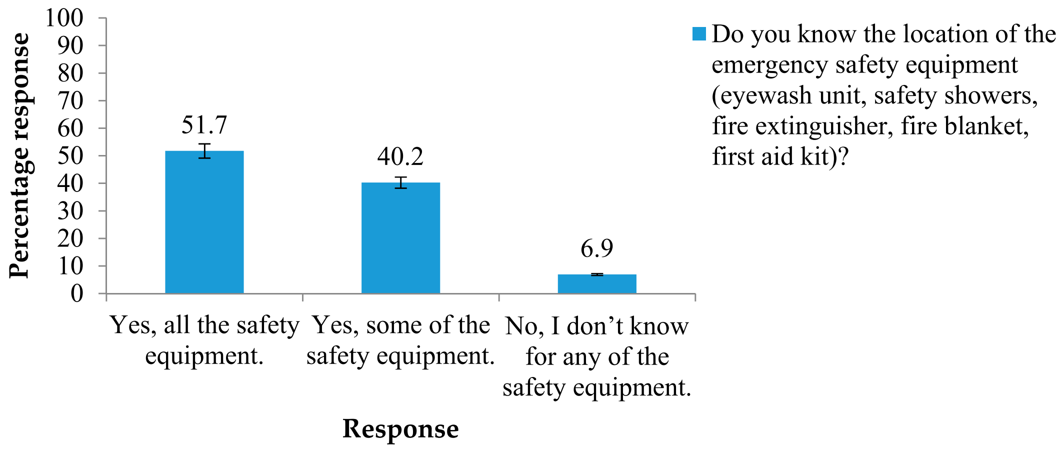


Figure 5. Percentage distribution of students' response for the question on Emergency Equipment and Procedures (Question 28).

Based on information given by lab supervisors, students were informed about the different available emergency equipment in the orientation session and how to use them, but hands on training and demonstration is not usually offered because the supervisors themselves were not trained in the practical aspects. Close to half of the students confirmed that they know how to use all the emergency equipment in the Chemistry laboratory while the remaining 53.4% indicated that they do not (Figure 6). Therefore, there is a need for training both students and lab supervisors on the proper practical use of these equipment, which should be carried out by specialized personnel from a dedicated Safety Office. In addition, this can be considered as an important policy directive, applicable to all universities across Jordan.

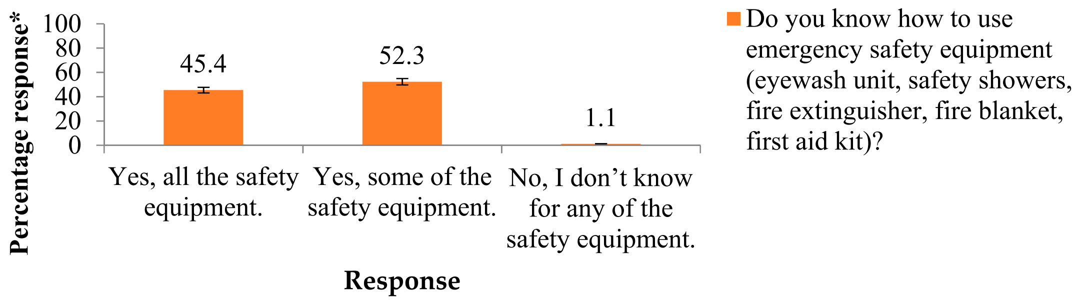


Figure 6. Percentage distribution of students' response for the questions on Emergency Equipment and Procedures (Question 29). * Note: the percentages do not all add up to 100 in Figure 6 and Figures 8–10 because some respondents did not reply to all of the questions in the survey.

The safety showers and the eyewash units are usually the least technical equipment to use. More than half of the surveyed students do not know how to use fire extinguishers properly, which is one of the most crucial pieces of safety equipment in chemical labs. Figure 7 shows that out of the five types of emergency safety equipment, it is more common for students to know how to use safety showers with 86% and eyewash units with 58%.

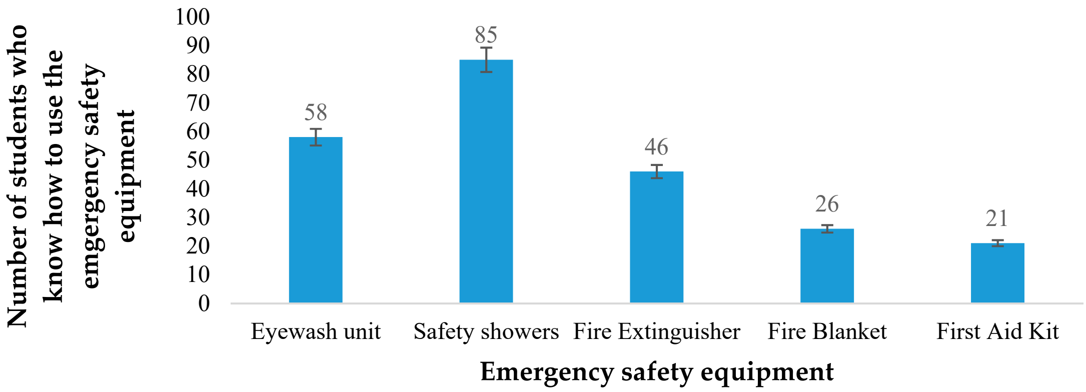


Figure 7. Student awareness of how to use the existing emergency safety equipment in laboratories.

Reviewing the responses of students to dealing with chemical spills, only 55.2% of the students are aware of the correct procedure to be used to clean up a spilled acid or base on the laboratory bench or floor, while approximately half of the other students did not know how to react in the case of chemical spills (Figure 8). This indicates a weakness of how students can deal with such emergency incidents, which can be explained by the fact that spill kits are unavailable in these chemistry labs as well as the lack of knowledge and awareness of the potential health and environmental hazard of the improper handling of such situations, which should be addressed in the curriculum.

In emergencies where chemicals come in contact with skin or eyes, the majority of students (82.2%) were aware of the correct procedure to be followed when an acid or base comes into contact with their skin (Figure 9). This high awareness percentage can be attributed to the fact that students are informed during the orientation session and reminded regularly on how to react in such a situation in a proper way.

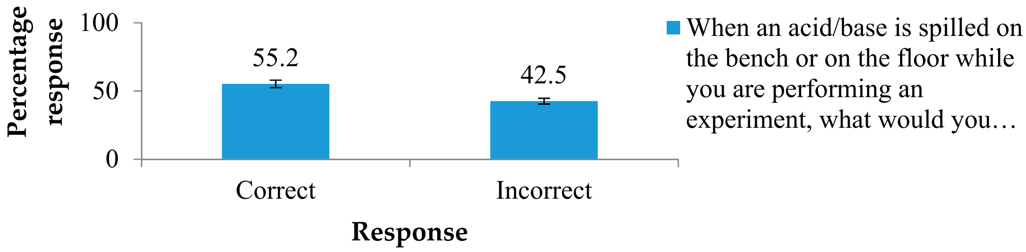


Figure 8. Percentage distribution of students' response for the questions on Emergency Equipment and Procedures (Question 30).

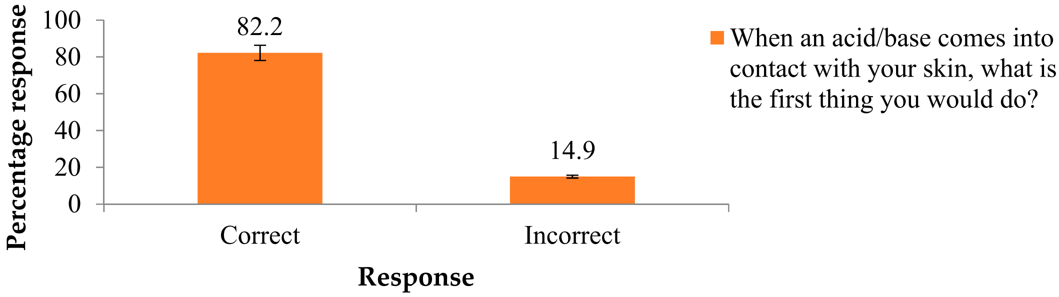


Figure 9. Percentage distribution of students' response for the questions on Emergency Equipment and Procedures (Question 31).

The majority of students were aware of the correct emergency procedure to be followed when acid or base encounters their eyes as illustrated in Figure 10.

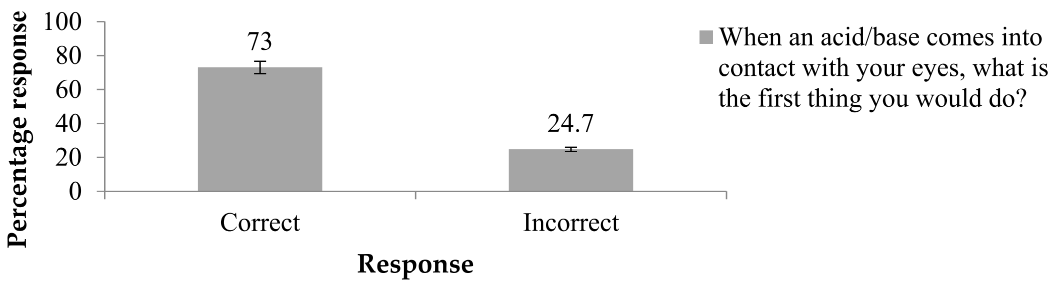


Figure 10. Percentage distribution of students' response for the questions on Emergency Equipment and Procedures (Question 32).

It is interesting to note that students were more aware of how to react in emergencies that are related to their own health and wellbeing, than how to react when chemicals are spilled on the bench or floor. These differences can be explained in part by the fact that university faculty and staff are more concerned with students' health status; this is why the greater emphasis during orientation session is placed on how to react when a chemical gets in contact with the student themselves. Furthermore, students tend to pay more attention to information that is related to their wellbeing. However, students should be warned about the importance of dealing with chemical spills on benches and floors, as if such emergencies were not handled properly, these might eventually get in contact with their skin and eyes, and present an environmental hazard.

3.6. Supervisors

The supervisors were predominately female with 83.33% and in the age group "30 and above" with 50%, as shown in Table 5. Supervisors all completed at least a Bachelor of Science degree and among them, only 33.3% had previous safety training.

Table 5. Frequency distribution of supervisors by selected demographics.

Variable	Frequency	Percent
Gender		
Male	1	16.7
Female	5	83.3
Age Group		
21–25	2	33.3
26–29	1	16.7
30 and above	3	50.0
Major		
Biomedical Engineering	0	0.00
Pharmaceutical and Chemical Engineering	6	100.0
Highest Degree earned		
BSc.	5	83.3
MSc.	1	16.7
Have you ever received training about chemical laboratory safety rules and procedures?		
No	4	66.7
Yes	2	33.3
Where did you receive the training?		
School	1	16.7
Internet (e-learning)	1	16.7

The scores calculated for the supervisors in response to the questions from Sections 2–4 were all deemed "good" (Table 6).

Table 6. Descriptive statistics for the overall knowledge, attitude and practice scores of the supervisors.

Variable	Frequency	Mean	Median	Std. Deviation
Knowledge	6	8.67	9.00	3.83
Attitude	6	4.33	4.50	2.04
Practice	6	6.17	6.50	3.01

It is noted, from Table 7, that all lab supervisors have good knowledge of GHS pictograms, because they hold a BSc in chemistry related majors and are experienced in lab work. They also have shown fair to good attitude towards chemical lab safety and practices. Supervisors were found to be aware of what to do during emergencies. However, it was noted that four supervisors did not know how to use a fire extinguisher. The training on how to use a fire extinguisher usually happens in coordination with the Civil Defense Directorate (CDD) in Jordan. The data from the supervisors indicate a lack of proper knowledge and skills on how to use fire extinguishers, which should be considered by the school administration to offer them the appropriate training and workshops.

The findings of this study are in line with previous studies reported by Walters et al where their results indicated that emergency response and hazard identification were deficient [11], and by Adane and Abeje where their results have shown that the comprehensibility of hazard warning signs is low [5]. The findings of this study are also in line with a previous study by Karapantsios et al, where the students and laboratory staff were asked to match different chemicals with their correct warning signs. The analysis of their findings has shown that only one out of four students recognized the correct hazard label that is associated with every chemical in the questionnaire [10]. In addition, Lunar et al revealed that students enrolled in Chemistry and Biology laboratory classes have low levels of familiarity and comprehension of hazard warning signs [4].

Table 7. Supervisor knowledge of chemical hazard warning signs, attitudes towards chemical laboratory safety, and chemical laboratory safety practices.

Variable	Frequency	Percent
Knowledge		
Poor	0	0
Fair	0	0
Good	6	100
Attitude		
Poor	0	0
Fair	2	33.3
Good	4	66.7
Practice		
Poor	0	0
Fair	1	16.67
Good	5	83.3

4. Conclusions

To the best of our knowledge, there are no dedicated safety offices concerned with undergraduate safety at Jordanian universities, and there is no systematic way to report undergraduate accidents—especially those related to laboratory work. We believe that this is the first study conducted concerning laboratory safety issues at this university and other universities in the country. The findings of the study revealed the strengths and weaknesses of student awareness of chemical safety. We assessed different aspects of safety for students: assessment of students' familiarity and understanding of chemical hazard warning signs; and assessment of students' attitude towards chemical laboratory safety. The levels of awareness ranged between fair to good for the majority of assessment criteria, but students have shown poor attitude towards safety in chemical laboratories. It was also shown that there were weaknesses regarding how staff deal with specific emergency incidents, such as the proper use of fire extinguishers, which also explains the poor knowledge of students in these situations.

The limitations of this study included that some respondents have chosen the option 'other', in Tables 1 and 2 without specifying what kind of other learning resources they received their chemical laboratory safety training through from. Another limitation was that some respondents did not reply to all of the questions in the survey. Based on the findings, it is recommended to improve the culture of safety ethics and risk management among the university staff and students who have multiple chemistry laboratories in their study plan; in particular the pharmaceutical and chemical engineering and biomedical engineering students. This can be achieved by establishing an Environmental Health and Safety Office at the university that is responsible for applying and following up on compliance with safety rules and procedures, and developing a course on hazardous waste and risk management, to be made compulsory for all university students who are undertaking a program of study that involves chemical laboratory exercises.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "conceptualization, W.A.-Z. and A.M.Q.; methodology, A.U.C.W.; software, A.U.C.W.; validation, W.A.-Z. and N.K.J.; formal analysis, A.U.C.W.; investigation, W.A.-Z. and A.M.Q.; resources, W.A.-Z.; data curation, A.U.C.W.; writing—original draft preparation, W.A.-Z., A.M.Q., A.U.C.W. and N.K.J.; writing—review and editing, W.A.-Z. and N.K.J.; visualization, A.U.C.W.; supervision, W.A.-Z. and N.K.J.; project administration, W.A.-Z. and N.K.J.

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Appendix A (The Questionnaire)

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
15.		□ I don't know what this symbol represents	D. Explosive E. Corrosive F. Flammable
16.		□ I don't know what this symbol represents	G. Oxidizing H. Compressed gas I. Environmental Hazard
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 ____

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