

Study on the factors that lead to laboratory accidents among university students

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Abstract. Accidents always happen in the workplace as well as in the education sector. To reduce the accident rate in the workplace, causal factors must be considered. Hence, this study aims to analyze the level of causal factors that lead to laboratory accidents. This study involved students from higher education and was distributed to 489 students. The socio-demographics results show that 67.3% of respondents are female students compared to 32.7% are male students. Besides that, most of the respondents (35.4%) are from Third Year students. This study focuses on four major causal factors to laboratory accidents: individual factor, environmental factor, equipment factor and organization factor. The findings revealed that environmental factor is the main factor that causes laboratory accidents with an overall mean score of 4.67, followed by the organization factor (overall mean score of 4.66). Meanwhile, the overall mean score for the individual and equipment factors is 4.64. The results of this study can be used by the authorities or stakeholders in organizations, particularly in the education sector, to identify the most effective ways to reduce laboratory accidents in the education sector.

1 Introduction

Safety is a crucial element in the educational sector. The education sector is frequently confronted with potential laboratory mishaps due to regular exposure when using the laboratory. Particularly, employees and students working in the laboratory were exposed to several hazards, including musculoskeletal, chemical, biological, physical, and radioactive risks. Fires, explosions, chemical spills, and chemical and gas leaks are examples of incidents that frequently occur in laboratories [1, 2]. Therefore, good safety precautions must be practiced in the laboratory [3] and reinforced to everyone who uses or will use the laboratory [4]. Regardless of the type of institution or school, effective prevention measures are applied to avoid laboratory accidents.

Furthermore, identifying the cause of accidents helps reinforce safety intervention and minimize the number of accidents in the future. Many studies have been done to determine

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the cause of accidents and provide preventative measures. For example, the proposed safety measure for an explosion accident caused by a lack of safety knowledge and awareness is to develop a smart safety management system based on IoT [5]. When a laboratory accident occurs, the laboratory workers frequently become the victims compared to students. Employee efficiency in dealing with accidents is determined by the frequency with which employees attend safety training organized by both external and internal institutions [6]. Furthermore, the necessity of safety education in the curriculum for well-being is highlighted not only for employers but also for students in order to minimize laboratory mishaps [7]. Thus, this study aimed to investigate the factors contributing to laboratory accidents in higher education.

2 Methodology

This study was completed using a random sampling technique and took place from September to November 2023 and February to April 2024. The survey involved around 489 students from four different faculties.

The survey questionnaire has been divided into four sections. Section A focuses on demographic information, Section B focuses on accidents caused by individual factor, Section C focuses on accidents caused by environmental factor, Section D focuses on accidents caused by equipment factor, and Section E focuses on accidents caused by organization factor. The detailed aspects involved in accident-caused factors are stated in Table 1.

Table 1. The aspects involved in accidents caused factor

Factor	Aspect
Individual	Attitude Dangerous behaviour Individual physiology
Environment	Laboratory conditions Laboratory neatness Laboratory layout Laboratory environment
Equipment	Suitability of equipment/chemicals Conditions of equipment/chemicals Safety protection design Knowledge of the equipment used
Organisation	Safety management

Section B until Section E of the survey questionnaire used a Likert scale with the following scale: 1= strongly disagree, 2 = disagree, 3= neutral, 4= agree, and 5= strongly agree. The acquired data from this study was analyzed using Statistical Package for the Social Science (SPSS) version 29. This study is further bolstered by reliability results for the 91 questions used as shown in Table 2.

Table 2. The reliability results from this study

Factor	Cronbach's Alpha	Number of items
Individual	0.986	22
Environment	0.993	29
Equipment	0.993	31
Organization	0.975	9

3 Results and Discussion

The demographic information revealed that 67.3% of respondents were female students and 32.7% of respondents were male students. A prior study indicated that Malaysia has successfully increased women's participation in scientific fields [8] was influenced by several factors such as mindset, motivation, and career outcome expectancy [9]. Other than that, more than half of the respondents, which is 68.3%, are between the ages of 21-30 years old. Aside from that, most of the respondents are Third Year students (35.4%) and First Year students (30.9%) as presented in Table 3.

Table 3: Demographic information

		Frequency (n)	Percentage (%)
Gender	Male	160	32.7
	Female	329	67.3
	Total	489	100
Age	<20 years old	139	28.4
	21-30 years old	334	68.3
	31-40 years old	16	3.3
	Total	489	100
Year of Study	Year 1	151	30.9
	Year 2	82	16.8
	Year 3	173	35.4
	Year 4	64	13.1
	Postgraduate	9	1.8
	Foundation	10	2
	Total	489	100

Table 4 displays the results of the accident caused by the individual factor. The individual factor contains three aspects which are: attitude, dangerous behaviour, and individual physiology. The result revealed the highest mean score among these individual factors was the attitude aspect, with a mean score of 4.66, followed by the dangerous behavior aspect, with a mean score of 4.65, and the individual physiology aspect, with a mean score of 4.62. The majority of respondents chose "agree" and "strongly agree" while answering this section, indicating that individual factors influence accidents caused in the laboratory. The findings of this study are supported by previous studies that stated that accidents in the laboratory are influenced by human error [10, 11].

Table 4: The mean score of the accident caused by the individual factor

No	Aspect	Mean	Std. Deviation
Attitude			
1.	Students are responsible for reporting any accidents in the laboratory/workshop to the staff involved	4.76	0.677
2.	Students who become complacent while working in the laboratory may create an accident	4.66	0.678
3.	Students who ignore safety rules while doing practical work in the laboratory can cause accidents	4.70	0.697
4.	Students who have a low perception of the risk of accidents will be easily exposed to the dangers of accidents	4.65	0.717
5.	Students who do not pay attention to safety during practical work risk causing an accident	4.70	0.685
6.	Students who have too much confidence while doing practical work in the laboratory or workshop can lead to the risk of accidents	4.45	0.909

7.	When students and friends remind each other about safety while performing practical work in the laboratory, the probability of accidents is reduced	4.67	0.721
8.	Students who do not practice a high level of self-discipline while doing practical work in the laboratory/workshop can lead to the risk of accidents	4.66	0.668
		4.66	
	Dangerous Behavior		
9.	Students who deliberately violate safety rules during practical work may result in an accident	4.65	0.734
10.	Students who do not heed the hazard warning may result in injury	4.62	0.742
11.	Students who deliberately damage safety devices (such as fire extinguishers, safety shower systems, safety boxes) can delay rescue work when an accident occurs	4.67	0.749
12.	Students who do not wear a lab coat and closed shoes while in the laboratory are exposed to the risk of accidents	4.64	0.693
13.	Students who do not use personal protective equipment (PPE) during practical work are exposed to the risk of accidents	4.65	0.708
14.	Students who use tools or chemicals without following proper procedures run the danger of being injured	4.65	0.701
		4.65	
	Individual Physiology		
15.	Students who experience fatigue and reduced sensory ability while carrying out practical work in the laboratory can lead to accidents	4.59	0.719
16.	Students who lack stamina when it comes to physical energy-intensive practical activities may create accidents	4.62	0.717
17.	Students who experience mental and physical fatigue will affect practical work during the laboratory/workshop	4.64	0.716
18.	Students who are anxious due to various factors while performing practical work in the laboratory/workshop may be at danger of an accident	4.57	0.738
19.	Students who have emotional problems may be less responsive to the task they desire to perform	4.66	0.680
20.	Students who are sleepy while doing practical work in the laboratory/workshop can lead to the risk of accidents	4.60	0.709
21.	Students with limb injuries such as fever, broken limbs, etc. can lead to the risk of accidents	4.66	0.698
22.	Students who experience disturbed psychological conditions while doing practical work in the laboratory/workshop	4.64	0.690
		4.62	

This section discusses accidents caused by environmental factors, as shown in Table 5. This study revealed among four aspects of environmental factors, the laboratory condition aspect and laboratory neatness aspects showed the highest mean score of 4.68 compared to the laboratory environment aspect with a mean score of 4.66. Meanwhile, the lowest mean score in this environmental factor is the laboratory layout aspect, with a mean score of 4.65. Most respondents chose “agree” and “strongly agree” while answering this section. To address this issue, a previous study recommended that the smart safety management system based on the Internet of Things (IoT) be applied in all laboratories [5].

Table 5: The mean score of the accident caused by the environmental factor

No	Aspect	Mean	Std. Deviation
Laboratory conditions			
1.	Proper lighting in the laboratory/workshop is very important to facilitate practical work	4.66	0.697
2.	A good ventilation system in the laboratory/workshop is important to facilitate general work	4.65	0.678
3.	The condition of the floor that is always clean from oil, dust, water and unsafe materials reduces the risk of accidents	4.68	0.684
4.	Accidents are possible due to the laboratory/confined workshop's settings and the huge number of students	4.68	0.673
5.	Inappropriate laboratory/workshop equipment poses a danger of creating an accident	4.69	0.679
6.	Equipment should be laid out so that students can easily take it before conducting practical work in the laboratory	4.67	0.690
7.	The condition of the emergency route is clearly displayed and is not obstructed by objects or items that make it easier for students in the event of an emergency	4.68	0.690
8.	Flammable materials are stored away from sources of ignition	4.69	0.677
		4.68	
Laboratory Neatness			
9.	Students always ensure that the surface of the table and laboratory floor are packed upon completion of practical work in the laboratory/workshop	4.66	0.689
10.	The arrangement of equipment and chemicals that are in order makes it easier for students to pick up and return the equipment	4.69	0.679
11.	The passage of emergency exits that are not obstructed by things or items, facilitates the movement of students when faced with a situation	4.66	0.701
12.	Students ensure that the laboratory/workshop is always clean before being left after completing the practical work	4.69	0.671
13.	Students always ensure that the work desk is organized in an orderly manner to facilitate practical work	4.67	0.688
14.	Fire prevention tools are placed that are easily visible and accessible to students	4.67	0.690
15.	Students put equipment and chemicals in the right place after they have finished using it	4.69	0.690
		4.68	
Laboratory Layout			
16.	Overcrowded table and equipment arrangement in the laboratory is exposed to accident risk	4.65	0.681
17.	Equipment that is not neatly organized according to division can make it difficult for students to pick up equipment in the laboratory	4.67	0.666
18.	The layout of the machines/laboratory equipment that has been compiled does not prevent the emergency route from speeding up the rescue work process in the event of an accident	4.66	0.673
19.	Laboratory floors that are in a slippery state may result in students falling	4.66	0.671
20.	Students know that all window doors are always open during practical work carried out	4.62	0.707
21.	The placement of emergency aids in the right place is easy to pick up and always on standby in case of emergency	4.66	0.675
22.	Equipment and chemicals that are in order make it easier for students to use them	4.64	0.678

		4.65	
	Laboratory environment		
23.	Students always ensure that the laboratory/workshop is always clean before being abandoned	4.65	0.677
24.	The physical condition of the dirty and slippery laboratory area/workshop may cause an accident	4.68	0.672
25.	Uncontrolled noise levels can interfere with the focus while doing practical work in the laboratory/ workshop	4.62	0.688
26.	All toxic substances such as gases and radiation materials will be harmful to the consumer if not properly and properly stored	4.69	0.654
27.	Toxic materials such as gas and radiation materials if not used with proper SOP will be harmful to students' health	4.65	0.675
28.	Students ensure that the laboratory/workshop environment is safe before and after practice	4.66	0.670
29.	Students are prohibited from using electrical sockets in the laboratory in a shared or excessive manner from one source of electricity	4.70	0.667
		4.66	

Table 6 shows the mean score of accidents caused by the equipment factor. The equipment factor encompasses four aspects: the suitability of equipment/chemical aspect, condition of equipment/chemical aspect, safety protection design aspect, and knowledge of equipment used aspect. Respondents tend to answer “agree” and “strongly agree” for all these aspects except for the safety protection design aspect. Results indicated that respondents chose between three answers which are “neutral”, “agree,” and “strongly agree”. Specifically, the highest mean score is the suitability of equipment/chemical aspect, with a mean score of 4.65, followed by the condition of equipment/chemical aspect and knowledge of equipment used aspect with a mean score of 4.64. The lowest mean score falls under the safety protection design aspect with a mean score of 4.62.

Table 6: The mean score of the accident caused by the equipment factor

No	Aspect	Mean	Std. Deviation
Suitability of equipment/ chemicals			
1.	Students use appropriate equipment or chemicals in accordance with the practical work carried out	4.64	0.688
2.	Students use equipment in the right place when using it such as using the hood lab during work constantly involving chemicals	4.64	0.698
3.	Students always ensure that the electrical equipment is closed after use in the laboratory	4.67	0.681
4.	Avoid holding or touching sharp parts of the machine/tool used when doing practical work	4.63	0.684
5.	The installation of the fuse must be correct to avoid overload that may result in a fire	4.65	0.679
6.	Before starting the experiment, the broken apparatus cannot be used to make practice should be reported to the laboratory assistant/lecturer	4.62	0.708
7.	Chemicals and other equipment need to be clearly labelled so that students know the contents of the label	4.68	0.675
		4.65	
Condition of equipment/ chemicals			
8.	Students ensure that the equipment is in good condition before it is adopted to be safe to use	4.63	0.683
9.	Students clean the equipment used after completing practical work	4.65	0.671

10.	Students do not use chemicals that exceed the expiration date or that have been damaged	4.63	0.684
11.	Students do not use inappropriate equipment to carry out practical work in the laboratory	4.64	0.678
12.	Students do not use equipment or machines that are not calibrated (calibrate) while practicing in the laboratory	4.65	0.665
13.	Students read the labels before using the equipment. For example, a damaged or repaired tool is placed a mark/label to avoid use by students	4.65	0.673
14.	Students need to ensure that the parts operating in the machine have a protector or safety barrier to avoid the risk of accidents while doing practical work in the laboratory/workshop	4.62	0.679
		4.64	
	Safety Protection Design		
15.	Chemical waste is disposed of at designated dumps or garbage containers	4.66	0.664
16.	Safety goggles are always used when performing work in the laboratory	4.63	0.695
17.	The contents of the first aid kit are complete, not exceeding the expiry date placed in each laboratories	4.62	0.673
18.	The use of personal jewellery items such as bracelets, rings and others is prohibited while doing practical work in laboratories	4.63	0.671
19.	Dangerous warning signs on display in locations easily visible to students	4.60	0.703
20.	Students understand on how to use safety showers in an emergency	4.61	0.678
21.	Safety Policy pasted in conspicuous places	4.62	0.676
22.	The emergency light is in good condition, which is on when an emergency occurs	4.65	0.666
23.	Fire alarm devices work when a fire occurs	4.60	0.700
		4.62	
	Knowledge of the Equipment Used		
24.	Students are knowledgeable about the use of equipment and machines while in the laboratory	4.60	0.686
25.	Students adhere to the correct equipment procedure manual when using it in the laboratory	4.65	0.666
26.	Students know how to use appropriate PPE when conducting practical work in the laboratory	4.64	0.694
27.	Students know how to use different types of emergency response equipment and know where they are location	4.65	0.665
28.	Students know the dangerous place on the machine such as knowing when to use and wear an eye shield and when to hold an electrical device	4.66	0.653
29.	Students know how to use a fire extinguisher when emergency will happen	4.63	0.665
30.	Students know that each machine has a perfect grounding system while practicing in the laboratory	4.66	0.665
31.	Students know that harmful machine parts are fitted with protective equipment such as barriers	4.66	0.661
		4.64	

There is only one aspect of the organizational factor involved: the safety management aspect that leads to laboratory accidents. The total mean score for the safety management aspect is 4.66, as stated in Table 7. Item number 9 shows respondents strongly agree with the statement said "training related to accident prevention is poorly recommended.". This is supported by

previous studies, which state that safety training is crucial for laboratory work due to the high risk of mishaps [12]

Table 7: The mean score of the accident caused by the organization factor

No	Aspect	Mean	Std. Deviation
Safety Management			
1.	Lecturers or laboratory staff should ensure that students do not enter prohibited places such as storage stores of hazardous materials	4.66	0.673
2.	Before beginning the experiment in the laboratory, laboratory staff or lecturers provide students with a safety briefing	4.63	0.677
3.	Enforcement of regulations such as getting fines makes students more sensitive to safety in laboratories	4.65	0.694
4.	Students immediately make a complaint if there is an accident or equipment malfunction while in practice	4.68	0.668
5.	Students can easily contact the laboratory staff if there are any questions / complaints about the laboratory	4.68	0.674
6.	The management always takes note and immediate action when students report any complaints of equipment or chemical damage	4.64	0.702
7.	My faculty has a dedicated Safety & Health officer on full-time duty in the laboratory	4.67	0.695
8.	Laboratory staff need to ensure students follow the rules and comply with every instruction given followed perfectly	4.66	0.673
9.	Training related to accident prevention is poorly recommended	4.69	0.524
		4.66	

4 Conclusion

This study investigates the causes of accidents in laboratories in higher education. There are four primary factors that contribute to accidents: the human, the environment, the equipment, and the organization. In conclusion, the equipment factor has the highest overall mean score of 4.64 and is the biggest contributor to laboratory accidents, followed by the organisation factor with an overall mean score of 4.66. The lowest overall mean score among the four primary factors are individual and equipment factors, with an overall mean score of 4.64. In order to prevent laboratory in the future, the intervention measures should consider these four primary factors that lead to laboratory accidents.

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References

1. Kim, J. G., Jo, H. J., & Roh, Y. H. Analysis of accidents in chemistry/chemical engineering laboratories in Korea. *Process Safety Progress*, **43(1)**, 160-169 (2024)

2. Sukri, N. S., Safrin, N. S., Kedri, F. K., Hanie, N. I., & Sukri, M. A. Perception of safety intervention practices in the laboratory among students in higher education sector. *BIO Web of Conferences*, **73**, 03015 (2023)
3. Mokhairi, Muhammad Nurfiridau Lai, Chee Sern and Lee, Ming Foong and .Ab Halim, Fazlinda. Perbandingan Kesedaran Pelajar Terhadap Amalan Keselamatan Di UTHM Dan KKTM. *Seminar Kebangsaan Majlis Dekan Pendidikan Universiti Awam Malaysia (MEDC2020)* (2020)
4. Abu-Siniyeh, Ahmed, and Saad S. Al-Shehri. Safety in medical laboratories: perception and practice of university students and laboratory workers. *Applied biosafety*, **26(S1)**, (2021)
5. Chen, M., Wu, Y., Wang, K., Guo, H., & Ke, W. An explosion accident analysis of the laboratory in university. *Process Safety Progress*, **39(4)**, e12150. (2020)
6. Nasrallah, I. M., El Kak, A. K., Ismail, L. A., Nasr, R. R., & Bawab, W. T. Prevalence of accident occurrence among scientific laboratory workers of the public university in Lebanon and the impact of safety measures. *Safety and Health at Work*, **13(2)**, 155-162 (2022).
7. Al Mohsen, Zahra. Laboratory safety and security concepts for clinical laboratory students and universities staff in Saudi Arabia. *Journal of Education in Health Sciences*, **10(2)**: 42-46 (2023)
8. Nasri, N., Rahimi, N. M., Hashim, H., & Nasri, N. M. "Supporting our Lost Boys": A Research on Gender-based Science Education's Hidden Curriculum in Malaysia. *International Journal of Learning, Teaching and Educational Research*, **22(3)**, 160-174 (2023)
9. Alam, M. S., Sajid, S., Kok, J. K., Rahman, M., & Amin, A. Factors that influence high school female Students' intentions to pursue science, technology, engineering and mathematics (STEM) education in Malaysia. *Pertanika Journal of Social Sciences and Humanities*, **29(2)**, 839-867 (2021).
10. He, Y., Kuai, N.S., Deng, L.M., Wang, Z.L. and Peng, M.J. An investigation into accidents in laboratories in universities in China caused by human error: A study based on improved CREAM and SPAR-H. *Heliyon*, **10(7)** (2024)
11. Bai, M., Liu, Y., Qi, M., Roy, N., Shu, C.M., Khan, F. and Zhao, D. Current status, challenges, and future directions of university laboratory safety in China. *Journal of Loss Prevention in the Process Industries*, **74**,104671 (2022)
12. Hauke, Angelika, Eva Flaspöler, and Dietmar Reinert. Proactive prevention in occupational safety and health: how to identify tomorrow's prevention priorities and preventive measures. *International Journal of Occupational Safety and Ergonomics* (2020).