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Research Article

An Investigation of the Knowledge Levels of Pre-service Science Teachers on Laboratory Safety

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Abstract

The present study aimed to determine the level of knowledge hold by pre-service science teachers about laboratory safety. 50 pre-service teachers participated in the study. The study employed a basic qualitative research design and data were collected through a questionnaire comprising 12 items. The items were written as scenarios and two answer choices were presented for each item. The participants were asked to mark one of these choices and explain the rationale for their answers. The data were analyzed using the descriptive analysis technique and the participant responses for each scenario were divided into four categories: (a) correct answer with correct justification, (b) correct answer with partially correct justification, (c) correct answer with incorrect justification, and (d) incorrect answer. The results revealed that the participants generally provided correct responses to the items, but they did not justify their answers accurately.

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Introduction

Science, as an activity-based exploration of the natural world, regards laboratory learning as an essential part of instruction (Ding & Harskamp, 2011). Laboratory practices support students' cognitive process skills such as analysis, synthesis, and observation, develop their psychomotor skills, and help them gain a sense of responsibility (Soslu et al., 2011). Students who have the opportunity to work individually or in groups in science laboratories can gain a deeper understanding of and explore nature more tangibly through experimentation and observation, utilizing original, concrete materials (Hofstein & Mamlok-Naaman, 2007). It is therefore evident that the use of laboratory methods in the teaching of science courses is of great importance. Although academic research in laboratories is generally considered to be lower risk compared to other process industries, it is clear that laboratories are prone to accidents that can lead to economic losses, injuries, and even deaths

(Chen et al., 2020). To minimize the occurrence of accidents in laboratory environments, it is essential that all individuals working therein are educated about laboratory safety (Walters et al., 2017).

Laboratory safety is the process of taking measures against possible dangers to the tools, equipment, teacher, students, and school in experiments carried out in laboratories, identifying defects, and approaching problems related to the laboratory by scientific methods to ensure laboratory arrangement (Akpullukçu & Çavaş, 2012). In the absence of laboratory safety protocols, unwanted incidents such as fires, leaks, explosions of glassware, contact with harmful chemicals, and equipment malfunctions due to improper use of devices are inevitable. Although there are no researchers, institutions or organizations that keep a systematic record of accidents in the laboratories (Benderly, 2010), researchers working in the laboratories have noted that such accidents occur frequently and are sometimes narrowly avoided (Miller & Tonks, 2018; Young, 2011). For example, Sheharbano Sangji, a researcher in the laboratory of Dr Patrick Harran at the University of California (UCLA), experienced an extremely tragic incident on 29 December 2008 while working with a large amount of tert-butyl lithium in the laboratory. The pyrophoric chemicals that spilled on him bleached his clothes and caused third and fourth-degree burns on more than 2% of his body. The 23-year-old researcher died in hospital after 18 days (Ménard & Trant, 2020). Following the incident, the California Division of Occupational Safety and Health reported in their audit that Sangji was not wearing a lab coat at the time of the accident, did not follow the manufacturer's safety protocols when working with large quantities of pyrophoric (e.g., clamping the reactive bottle and using a plastic syringe instead of glass), supervisor Harran did not train him on the proper use of pyrophoric. However he knew that Sangji had limited experience working independently in chemistry laboratories, and the necessary technical instructions were not available in the laboratory. As a result of the investigations, the California Occupational Health and Safety Unit categorized these accident-causing factors into three dimensions; namely, the individual, the laboratory/department/institution, and the discipline itself (Baudendistel, 2009). Another fatal accident occurred at Yale University. Michele Dufault, a 22-year-old undergraduate student working in the laboratory, got her hair caught in a lathe in the machine shop, died on the spot, and the body was found by other students (Van Noorden, 2011). There have also been laboratory accidents involving mass fatalities. There was an explosion in a laboratory at Beijing Jiaotong University while students were conducting a sewage treatment experiment and three students involved in the experiment were killed in the explosion. On the other hand, some accidents resulted in injuries. Preston Brown, a graduate student in chemistry at Texas Tech University in Lubbock, in an experiment he carried out, ground particles of nickel hydrazine perchlorate using a hundred times the recommended amount. Preston Brown lost three fingers of his left hand (Ménard & Trant, 2020) in the explosion caused by this. Such tragic accidents in the laboratory reveal the importance of laboratory safety.

Ensuring Laboratory Safety

The establishment of a safe laboratory environment that will minimize the potential risk of accidents can be achieved first and foremost only if all employees in laboratories, from inexperienced students to senior researchers, are cognizant of the necessity that they are in an environment that requires special precautions. Researchers should know what measures can be taken against potential hazards in the laboratory environment and have an action plan on how to act in case of unexpected events that occur despite all precautions. The National Academies of Sciences, Engineering, and Medicine (2014) listed the main conditions for ensuring safety in laboratories as follows:

- Awareness of the physical and chemical properties of the laboratory reagents used and the safety and health hazards they pose.
- Availability and utilization of appropriate instrumentation and control infrastructure for the safe conduct of procedures.
- Additional special operations necessary to reduce the risks in the application.
- Familiarity with and skill in emergency procedures, including the use of safety showers, fire extinguishers and eye/observation stations.
- A well-designed and organised working area that facilitates safe work, protects workers from hazardous environments, and allows unlimited movement within the laboratory.
- Use of appropriate personal protective equipment.

Purpose of the Study

The large number of accidents that have resulted in serious injuries and deaths in laboratories worldwide has raised the issue of laboratory safety. Nevertheless, the place of laboratory safety on the agenda has generally been limited to third-page news. The absence of a systematic record of the types and frequency of laboratory accidents is an indication of this (Ménard & Trant, 2020). In this regard, it is considered important to address the issue of laboratory safety on an academic basis. Studies on laboratory safety help improve scientific knowledge because they provide scientific data to investigate the effectiveness of existing safety practices, and this information helps develop safety protocols. Studies will enable potential risks to be systematically examined, thus making it possible to identify risks and take preventive measures. Research on laboratory safety helps to adopt a safe work culture and increases the awareness of laboratory workers about safety. Again, studies conducted examine the causes of accidents and incidents and contribute to the development of effective strategies to prevent such situations. As a result, academic studies on laboratory safety help to provide a safe working environment and to help students pay better attention to their lessons and focus on their experiments without fear of accidents.

Undoubtedly, one of the most important steps of these studies is the identification of the knowledge about laboratory safety by those who are in a position of instructor in the laboratory environment or who will be instructors in the future. Therefore, it is important to determine whether pre-service teachers have sufficient knowledge about the sources of danger while working in the laboratory, the correct and complete implementation of the procedures to be performed in the event of a hazardous situation during the experiment, and the level of knowledge about taking the necessary safety precautions during the experiment. From this point on, the purpose of this study is to determine the level of knowledge of pre-service science teachers about laboratory safety.

Method

Research Design

This study has a basic qualitative research design. In qualitative studies, data such as words and sentences, audio recordings, images, stories, pictures, etc. are collected to answer the research question (İlhan & Gezer, 2021). Since the data collected in this study to determine the knowledge and awareness levels of pre-service teachers about laboratory safety are generally included in this scope, the research can be said to be qualitative in nature.

Participants

The study was conducted with 50 pre-service teachers (36 females and 14 males) studying at Dicle University Ziya Gökalp Faculty of Education, Department of Science in the spring term of 2022-2023 academic year. Thirty-two of the prospective teachers were in the third year and 18 of them were in the fourth year of their education. Participants were selected using convenience and criterion sampling techniques. The study included prospective teachers who were studying at the university where the researcher worked. In this respect, sample selection process involves convenience sampling technique. Further, the sample determination also contains criterion sampling in the sense that the participants were selected among the prospective teachers who had taken the laboratory course. It was observed that the facilities in the science laboratory of the faculty where the research was conducted were in appropriate conditions, which was also confirmed by the lecturers who are teaching or have taught the laboratory course at the faculty. Appropriate conditions refer to the availability of the tools and materials needed, adequacy of the ventilation system, existing of safety equipment such as fire extinguishers and first aid kits, and enough lighting.

Data Collection Tool

'Laboratory safety semi-structured interview form' was used as a data collection tool in the study. While preparing the form, the aim was to measure the level of knowledge of pre-service teachers regarding laboratory safety and to determine their appropriate and inappropriate behaviors for ensuring laboratory safety; a variety of scenarios were identified and evaluated to such ends. The form included 12 scenarios and two-choice fill-in-the-blank type questions belonging to the scenarios (see appendix for a sample question from the instrument). While determining the scenarios and the questions following the scenarios, the related literature on laboratory safety was examined (e.g., Aydın et al., 2011; Coştu et al., 2005); documents on laboratory rules and accidents and first aid in case of accidents in the laboratory were reviewed as well. The scenarios in the data collection tool were formed according to the topics that emerged as a result of this review. All the scenarios in the Laboratory safety semi-structured interview form developed within the scope of the study were prepared by the researcher. In writing the scenarios, it was noted that the statements were clear, they did not contain any clues to the correct answer, the options were not contingent on one another, and they focused on only one mental skill.

Based upon the review of the related literature, the frequently confused issues of the students were identified and written as distractors and special attention was paid to ensure that the distractor did not give a clue about the correct answer. The scenarios were not aimed at providing accurate information and teaching. Six instructors including three science education experts and three chemistry experts evaluated the draft scenarios. The required arrangements in the scenarios were formulated following the recommendations of the experts. The content of the scenarios includes the behaviors of the instructor and pre-service teachers conducting experiments in the science laboratory. Furthermore, the experiments in the scenarios were described in detail, identifying undesirable events and critical situations that may occur in the laboratory. The pre-service teachers were asked to code the options as true and false depending on the given scenarios and to describe the actions they would take in detail by expressing their reasons. The themes contained in the scenarios consisted of the rules that should be followed to ensure laboratory safety and the accidents frequently encountered in the laboratory environment and were coded as follows: *i)* working with flammable materials, *ii)* fire, *iii)* electricity leakage, *iv)* storage of chemicals, *v)* working with caustic materials/combustibles, *vi)* working with toxic materials, *vii)* formation of toxic gases, *viii)* working with explosive materials, *ix)* breakage of glass materials and *x)* occurrence of acid-base burns. As there was more than one scenario in some themes, there were 10 themes in the measurement tool but the number of scenarios was 12.

Data Collection and Analysis

Before the data collection process, ethics committee permission was obtained from the Dicle University Social and Human Sciences Ethics Committee (approval letter dated 04/01/2023 and numbered 423862). Data were collected between 15/01/2023 and 15/03/2023 after the study was approved to meet current ethical standards. Prior to the data collection process, the participating pre-service teachers were informed of the purpose of the study and were assured that the data would be utilized exclusively for scientific purposes. It was explicitly stated that the data would not be employed for grading purposes or shared with third parties or institutions. The data were collected in a classroom setting and in the form of a paper-and-pencil questionnaire, and the applications in each class were completed in about one lesson hour. The answers given by the pre-service teachers to the questions about the scenarios were analyzed in four categories: (1) correct answer with correct justification, (2) correct answer with partially correct justification, (3) correct answer with wrong justification, and (4) wrong answer. Direct quotations from the justifications provided by the pre-service teachers for their answers were included in order to increase the validity of the study. In this process, a coding in the style of P1, P2, ..., P50 was adopted instead of writing the names of the participants explicitly.

Findings

In the first scenario in the data collection tool used in the study, whether the pre-service teachers knew what to use as a heater while preparing the oil bath setup for the experiment in the laboratory was questioned. In the scenario, the expression 'Magnetic stirrer heater because' was given as the correct option, and the expression 'Bunzen heater because' was used as a distracter. Findings in Table 1 were obtained as a result of the analysis of the participants' responses.

Table 1. Findings related to the scenario on the theme of heater selection for the oil bath setup

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	15	- Since the oil burns, it should be kept away from the flame and a flameless heater should be used. (P37)
Correct answer partially correct justification	11	- Advantageous for use in high-temperature and long-term processes (P30)
Correct answer wrong justification	9	- I think it is used in liquid substances. (P24)
Wrong answer	12	- The preparation of the setup is simple. (P14)

As shown in Table 1, the number of participants who could choose the correct answer and justify it correctly in this scenario remained at 15 (30%). The second scenario of the study questioned what to do first in case the oil bath, which is preferred to provide heating in long-lasting experiments such as polymerization reactions, catches fire. The two options presented in the scenario are "I pour salt on it quickly and abundantly because" and "I try to extinguish the flame with water because". While the first one was the correct answer, the second one was given as a distractor. The findings obtained by analyzing the student responses are presented in Table 2.

Table 2. Findings related to the second scenario on what to do when the oil bath catches fire

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	29	- If we pour salt or baking soda, the combustion rate slows down and we can control the flame in a short time. We should also not pour water on the flaming oil. The water will stay on the oil and cause the oil to splash around, increasing the flame even more. Therefore, the best method would be to pour salt. (P11)
Correct answer partially correct justification	16	- Since oil flares up even more in water, I think dry powdered substances should be used. (P1)
Correct answer wrong justification	2	- It is necessary to cut off the connection with oxygen as quickly as possible. It should not be extinguished with water because it will flare up more because there are oxygen molecules in the water. (P17)
Wrong answer	1	- It is easy to intervene (P13)

Table 2 shows that there was only one respondent who gave an incorrect answer, and that 29 of the 47 participants who gave a correct answer were able to justify their answer correctly. The third scenario in the research is to ask what to do first if a flash is observed when plugging in an electronic balance to measure the mass of a chemical substance. In this context, the correct answer "I turn off the fuse switch because" and the statement "I unplug the plug from the socket because" were presented as distracters. Table 3 summarizes the distribution of pre-service teachers' responses.

Table 3. Findings for the scenario with the theme of the first thing to do when a flash is observed in the socket when plugging in the plug

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	37	- For our safety due to the flash in the socket, we need to get the switch down first. Otherwise, a wrong movement may cause a shock because the switch is not turned off. (P22)
Correct answer partially correct justification	2	- In the event of a problem in the electrical installation, I turn off the switch and cut off all the electricity so that the plugs plugged into other sockets in the environment are not damaged or the fire does not start from somewhere else. (P48)
Correct answer wrong justification	6	- A rapid combustion occurs with the glow formed in the socket. (P24)
Wrong answer	5	- The first thing I would do is pull the plug out. If I turn off the fuse switch first, it may spread to other sockets. I would turn off the fuse switch after unplugging the plug. (P21)

When Table 3 is examined, it is seen that the number of participants who gave the correct answer and justified it correctly was 37. Fourthly, prospective teachers' knowledge about the things to be considered during the safe storage of chemical substances was questioned. In this scenario, in addition to the correct answer the statements "I store flammable substances in a separate place from oxidizers because" and "I store acids and bases in one place because" were given as the second option. Table 4 shows the findings obtained when the options chosen by the pre-service teachers and their justifications are analyzed.

Table 4. Findings related to the scenario on the storage of chemical substances

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	41	- Oxygen contained in oxidizing agents may ignite with flammable substances and increase the intensity of combustion. (P50)
Correct answer partially correct justification	5	- In case of any mishap, I store them in a separate place to prevent any major explosions or leaks in the laboratory as a result of the interaction of these substances with each other. (P20)
Correct answer wrong justification	1	- At least it does not affect other chemicals when it catches fire. (P45)
Wrong answer	3	- Acid and base reactions can pose serious hazards. Harmful reactions can also occur in contact with other chemicals. (P9)

As illustrated in Table 4, the majority of the participants were able to answer the question about the storage of chemical substances by selecting the correct option and providing the correct reasoning. In the fifth scenario in the study, information about the material to be used when preparing Hydrogen Fluoride (HF) solution, a type of acid, was questioned. In this context, the correct answer was “Plastic flask because” and the distractor was “Glass flask because”. A detailed analysis of the options marked by the students and their justifications led to the generation of findings summarized in Table 5.

Table 5. Findings related to the scenario on the material to be used while preparing hydrogen fluoride solution

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	28	- HF reacts with glass and metals and corrodes them. Therefore, the best preparation method would be a plastic balloon flask. (P18)
Correct answer partially correct justification	2	- I use plastic balloon flask because I want to be precise in titration processes and to store the solution. (P36)
Correct answer wrong justification	-	-
Wrong answer	18	- Plastic materials can melt and mix into the solution (P23)

Looking at Table 5, it can be seen that the respondents who chose the correct option about the material to be used in the preparation of hydrogen fluoride solution were generally able to support this with the correct justification, but a significant number of pre-service teachers made the wrong choice regarding the material to be used. Sixthly in the research, while experimenting with a mercury thermometer, information about what to do in case a toxic substance such as mercury spills on the ground when the thermometer breaks was questioned. In this scenario where the correct answer was “I would throw powdered sulfur on it because”, while the option “I would dilute it with water because” was used as a distracter. When the answers given by the participants were analyzed, the findings in Table 6 were obtained.

Table 6. Findings related to the scenario on the theme of what to do if mercury is spilled around

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	19	- Sulfur binds mercury and forms an insoluble substance. Thus, as the mercury is bound, it is less mixed into the air and its toxic effect is reduced. Also, the room should be ventilated. (P10)
Correct answer partially correct justification	9	- Since mercury is a very volatile element, powdered sulfur is poured on it to solidify it. (P28)
Correct answer wrong justification	4	- If intervened with water, the water will sink in mercury. (P1)
Wrong answer	10	- Mercury is a heavy metal and its high concentration in an area can have bad consequences, so it should be diluted. (P2)

Looking at Table 6, it is understood that 10 participants chose the wrong option, 32 participants in total chose the correct option, but only 19 of them were able to support their answer with a completely correct justification. The seventh scenario of the research is aimed at questioning the knowledge of what to do when a gas leak is detected in the laboratory. In this scenario, the correct answer was formed as "I go out walking close to the ground because" and the statement "I open the windows to provide a draft because" was used as a distracter. The findings obtained as a result of reviewing the participants' justifications for why they chose the option related to the option they selected are presented in Table 7.

Table 7. Findings for the scenario themed on what to do in case of a gas leak

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	10	- Carbon monoxide is a lighter-than-air gas. For this reason, they are not found close to the ground. Therefore, when we walk close to the ground, we are minimally affected by the gas. (P10)
Correct answer partially correct justification	13	- Carbon monoxide is a very toxic gas because it retains red blood cells in the blood and prevents blood circulation. It should first be removed from the environment and the environment should be ventilated after the necessary precautions are taken. (P28)
Correct answer wrong justification	1	- There is a need for fresh air and oxygen to get rid of the effects of carbon monoxide (P29)
Wrong answer	26	- CO gas is a poisonous gas heavier than air; I open the window to let oxygen in. (P13)

When the findings in Table 7 are examined, it is noticeable that the number of participants who can mark the correct answer and support it with the correct justification is quite limited. Seventhly, the participants were asked what to do if sodium catches fire while experimenting with a highly reactive metal such as sodium (Na) in the laboratory. In the scenario prepared for this purpose, the option "I try to cover the flame because" represented the correct answer, while the expression "I intervene with water because" was a distracter. The distribution of the answers given by the participants according to the options and the findings regarding the accuracy of the justifications presented are summarized in Table 8.

Table 8. Findings related to the scenario on the theme of what to do if sodium catches fire

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	25	- It is necessary to disconnect it from oxygen; most importantly, if it is intervened with water, the reaction occurs and explosions that can cause damage can occur. (P17)
Correct answer partially correct justification	16	- Sodium burns with oxygen. (P14)
Correct answer wrong justification	-	-
Wrong answer	3	- In the water-sodium interaction, we see that the reaction slows down. (P43)

As can be seen in Table 8, the participants who chose the correct option in this scenario were generally able to justify their answers correctly. Looking at Table 8, it is noteworthy that there were no participants whose justification was incorrect despite giving the correct answer and only 3 participants gave the wrong answer. In the ninth scenario of the study, the actions to be taken in case of contact with acid while working with acid in the laboratory were questioned. For this scenario, the option "I wash my hands in the sink with plenty of water because" corresponded to the correct answer, while the option "I keep it in 10% $NaHCO_3$ (sodium bicarbonate) solution because" served as a distracter. Upon analysis of the participant responses, the findings presented in Table 9 were obtained.

Table 9. Findings related to the scenario on what to do in case of contact with acid

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	9	- In case of contact of acids with the skin, the part contaminated with acid should be washed with plenty of water first. Then a mild alkali solution with low concentration should be applied. (P30)
Correct answer partially correct justification	25	- Water decreases the concentration of strong acid and brings it closer to neutral. (P4)
Correct answer wrong justification	1	- HCl is a strong acid and should be washed with plenty of water to bring it closer to neutral and if option b is applied, its reaction with detergent can damage our tissue. (P2)
Wrong answer	12	- If HCl reacts with water, it irritates more. Therefore, I wash it with sodium bicarbonate because if acid and base react, a neutralization reaction takes place. (P22)

The findings in Table 9 show that the number of participants who were able to integrate the correct answer with the correct justification was limited, reflecting that half of the participants selected the correct option but were able to provide partially correct justifications for it. While the number of participants who provided incorrect justifications despite choosing the correct option was 1, 12 participants chose the wrong option. The tenth scenario in the study focused on the question of what to do in case of a cut on the hands while working with glassware in the laboratory. For this question, "I cover it with a clean cloth and go to the nearest health institution because" was the correct answer, while "I remove the broken glass and apply tincture of iodine because" was written as a distracter. When the answers given by the participants were analyzed, the findings in Table 10 were obtained.

Table 10. Findings related to the scenario on the theme of what to do in case of a cut while working with glass material

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	26	- The glass shard may have hit an artery and in fact the glass may have acted as a buffer. When we remove the piece of glass, we may experience intense bleeding. Also, when we try to remove the glass, we give the second blow by removing the glass. The glass should not be removed, since we may damage tissues and nerves while removing it; we should definitely cover it with a clean cloth and go to the nearest health institution. (P14)
Correct answer partially correct justification	6	- Since the experimental material contains chemicals, I prevent making a wrong application. (P8)
Correct answer wrong justification	4	- My pain may increase when I take it out. (P32)
Wrong answer	14	- Once the piece is removed, there is not much of a problem anyway, and if I apply tincture of iodine, it will pick up the germs. (P23)

According to Table 10, approximately half of the participants were able to select the correct option and provide a completely correct justification for it. Although 10 of the remaining 24 participants chose the correct option, they gave partially correct or incorrect explanations in their justifications. 14 participants chose the wrong option. In the next scenario of the research, what should be done in the experiment of separating the solid-solid mixture with benzene, a toxic and volatile solvent, while performing extraction in the laboratory was questioned. In this direction, following the scenario, two options were given: "Distillation because" as the correct answer and "Evaporation because" as a distracter. When the options marked by the participants and the justifications they wrote were analyzed, the findings given in Table 11 were obtained.

Table 11. Findings related to the scenario on the theme of what should be done in the benzene removal process

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	5	- Since I cannot control the decomposing substances, it may harm the environment. This is actually different from distillation. (P39)
Correct answer partially correct justification	2	- Distillation is used to separate homogeneous mixtures (P37)
Correct answer wrong justification	19	- Distillation method should be preferred because the density difference between the two liquids is very high. The distillation method should be preferred for separating liquid-liquid mixtures. The evaporation method is a more suitable method for separating solid-liquid mixtures. (P41)
Wrong answer	16	- Because their boiling points are different. (P2)

Finally, the information about the things to be considered while preparing acid solution in the laboratory was questioned. In the scenario created for this purpose, the correct answer was "I take the required amount of H_2SO_4 into a balloon flask with some water and fill it to the line because", while the distractor was "I put H_2SO_4 into a clean and dry balloon flask and fill it with water to the line because". The findings obtained by examining the options marked and the justifications given by the participants are presented in Table 12.

Table 12. Findings related to the scenario on the preparation of H_2SO_4 solution

Accuracy of the answer	n	Examples of participant statements
Correct answer correct justification	25	- When acid dissolves in water, an exothermic reaction takes place. If water was added to the acid, the large amount of acid would evaporate the water and the water vapor would react by splashing around. (P40)
Correct answer partially correct justification	3	- If we put it in the water, there may be an interaction. Therefore, acid should be added slowly where there was water before. (P6)
Correct answer wrong justification	9	- When diluting acids, it is better to add the acid to water to prevent the irritating properties of the acid. (P47)
Wrong answer	10	- If done the other way around, there could be explosive results. First, place it in a dry balloon flask and slowly add water and stir. (P9)

As seen in Table 12, half of the participants were able to mark the correct option and justify their answers correctly. On the other hand, 3 of the 12 participants who chose the correct option provided partially correct justifications, while 9 provided completely incorrect justifications. It was determined that 10 participants turned to the distractor and answered the question incorrectly.

Discussion and Conclusion

This study investigated the level of pre-service science teachers' knowledge about laboratory safety. In this context, the participants were presented with various scenarios and asked to respond to them. In the first scenario, the participants were expected to choose the heater they would use while preparing an oil bath setup in an experiment that would take place at high temperatures in the laboratory. 6% of the students left this scenario unanswered and 24% chose the wrong heater. On the other hand, 70% of the students chose the appropriate heater, but only 30% of the students who chose the correct heater justified their choice correctly. The combustion of oil is a chemical reaction, specifically an oxidation reaction. At high temperatures the oil undergoes an exothermic reaction with oxygen, there is a continuous build-up of heat as it oxidizes, and then it burns and finally explodes in flames when the temperature reaches the flash point of the oil. The scenario in the study is one of the oil bath heating techniques commonly used in the laboratory and should be used with extreme caution. The fact that only 30% of the students answered the question with the correct reason indicates that they have insufficient knowledge about heater selection.

In the second scenario, the participants were asked what they should do first when extinguishing the fire in the oil bath apparatus that caught fire during the experiment. When the answers given were analyzed, it was seen that 4% of the participants left the question unanswered and 2% answered incorrectly. Although this scenario was answered correctly at a high rate of 94%, the rate of participants who justified their answers appropriately remained at 58%. It is absolutely undesirable for students to intervene with water in accidents that result in small-scale fire, such as flames, which are frequently encountered in the laboratory. One of the drawbacks of intervening with water is that it increases the flame when it comes into contact with oil, and the other is that since it is a conductive substance it can cause irreversible fatal mistakes in cases where the electric current is not cut off. It would be more correct to intervene with dry chemical powders instead of water. In this respect, although the percentage of correct answers and correct justifications was higher in this scenario compared to the first scenario, it still symbolizes that pre-service teachers have significant knowledge gaps about intervention in possible fires that may occur in laboratories. Indeed, Xu et al. (2023) reported in their studies classifying the accidents in university laboratories according to their types that 44% of the accidents were caused by fires.

In the third scenario, the focus was on what to do when a flash is observed while plugging in the electronic balance for weighing. There were no participants who left this scenario unanswered and the question was answered correctly by 90%. The number of participants who both answered correctly and provided correct justification was 74%. In the event of a short circuit or flashover, the electric current increases rapidly and the devices are exposed to overcurrent. Turning off the switch prevents sudden overload and prevents malfunctions. It also reduces the possibility of fire. Students generally learn that they should turn off the switch in cases of electrical leakage, short circuit, or fire in primary and secondary school level science courses, and the knowledge that the switch should be turned off in case of fire, which is taught in fire drills held in schools, is a part of these training. In addition, due to the high number of electrical appliances and devices we use at home, this information has also been given within the family since childhood. In light of these data, the fact that the participants answered the third question correctly at a high rate of 90% and justified it correctly at a rate of 74% is an expected result due to the education they have received from an early age.

The fourth scenario focused on what needs to be considered for the safe storage of chemicals. Again, it was observed that there were no participants who left the scenario unanswered; the proportions of participants who answered correctly and justified the correct answer correctly were 94% and 84%, respectively. In the question, the participants were expected to write the reason for not keeping flammable and oxidizing substances together. Flammable substances are liquid substances with a flash temperature of 21^0C to 55^0C that can heat up even in contact with air at ambient temperature and can spontaneously combust even in short-term contact with a fire source. Oxidizers are substances that cause a significant exothermic reaction in contact with other substances, especially flammable substances. Exothermic reactions can result in an explosion. Such information is provided to pre-service teachers from the first week of both the science laboratory and laboratory safety courses under the title of hazard symbols and harmful effects of chemicals. In light of this basic information, it is an expected result that 94% of the participants answered the question correctly, with 84% stating the correct reasoning.

In the fifth scenario, the participants were asked about material knowledge for the preparation of hydrogen fluoride solution. When the responses of the participants were analyzed, it was seen that 4% of the participants left the question blank and 36% answered incorrectly. While 60% of the participants answered the questions correctly, the proportion of participants who justified their choice correctly remained at 54%. This finding is partially in line with the results of Coştu et al.'s (2005) study in which pre-service teachers' skills in preparing solutions and using laboratory materials correctly were examined. Coştu et al. (2005) concluded that 23% of pre-service science teachers made mistakes in preparing solutions by using appropriate tools and equipment despite having taken laboratory courses.

The sixth scenario presented to the participants is concerned with what to do when mercury is spilled around. 16% of the students left the question of this scenario blank, and 20% answered it incorrectly. While the rate of students giving correct answers was 64%, only 38% of the participants justified their answers correctly. Aydoğdu and Yardımcı (2013), in their study on accidents in primary school science laboratories and their causes, revealed the explosion of test tubes, the spread of chemical substances, the release of gas, and the explosion of mercury tubes as the main causes of accidents. Metallic mercury evaporates at room temperature and rapidly penetrates the lungs, causing toxic effects. In this regard, the finding that 38 percent of respondents were correctly justified as to how they could get rid of the toxic effects of mercury released around indicates a lack of information about laboratory safety that could result in death.

The seventh scenario of the study relates to what to do when a gas leak is detected in the laboratory. 52% of respondents answered the question in this scenario incorrectly, 48% answered correctly, but 20% supported their answer with the right reasons. Gas leakage is one of the most common accidents in the laboratory, often difficult to detect and with serious consequences (Zhang et al., 2020). Calculating the density of the gas at the moment of the accident and taking action accordingly is achieved with a high level of laboratory safety information. The findings indicate that the vast majority of participants lacked this information.

In the eighth scenario, participants were asked about the burning of sodium (Na), an explosive substance. 12% of respondents left the question empty, and 6% responded to the question incorrectly. A relatively high percentage of respondents, e.g. 82% responded correctly, but 50% responded correctly and explained the answer correctly. Sodium, an active metal found in the first group of the periodic table, reacts strongly when it comes into contact with water. The heat is then released and hydrogen gas, a flammable substance, is formed. The heat released causes the hydrogen to burn and explode. In this sense, the lack of this information by half of the participants is a threat that could pose a life-threatening risk in the laboratory environment.

The ninth scenario in the study asked what to do in case of concentrated hydrochloric acid (HCl) spill. 8% of respondents left this question empty and 24% answered it incorrectly. 70% of respondents answered the question correctly, but 18% were able to explain it correctly. The findings in the study are consistent with the findings of Demir (2016). Demir (2016) examined the physical conditions of science laboratories and the levels of knowledge of science teachers on laboratory safety: "When skin is in contact with acid, which of the following should be washed first? 70.3 percent of teachers answered correctly and 29.7 percent incorrectly. However, Demir (2016) did not provide a finding as to whether participants correctly justified the correct answer. Thus, the correlation between the findings of this study and the results of Demir's (2016) study can be interpreted as a partial similarity.

In the tenth scenario, participants were asked what to do if a hand was cut off while trying to open a glass bottle in the lab and some glass shards got stuck in the hand. 28% of respondents answered the question incorrectly, 72% answered correctly, but 52% of those answering correctly justified it correctly. Surprisingly, half of the participants could not provide the correct answer and justification, although it is an accident that can be frequently encountered in various areas of everyday life. This result hints that students should be made aware of which of the possible injuries that may occur in the laboratory course should be intervened directly and which should be referred to professional institutions/persons.

The eleventh scenario in the study includes a question about the method to be followed in removing carcinogenic, flammable, toxic, and toxic benzene, used as a solvent in laboratory extraction experiments. 16% of respondents did not answer the question, while 32% answered incorrectly. 50 percent of respondents answered the question correctly, while only 10 percent based the correct answer on the correct reason. One of the most common accidents in chemical laboratories is fire. When working with flammable substances such as diethyl ether, acetone, benzene, and ethyl alcohol, special attention should be paid to the absence of flame near them, and distillation instead of evaporation should be used to remove these solvents. However, the findings in this scenario suggest that participants are far from this awareness.

The final scenario in the study examines how H_2SO_4 solution can be prepared in the laboratory at the required volume and concentration from a 98% H_2SO_4 stock solution. The question in this scenario was left empty by 6% of respondents, while 20% answered incorrectly. 74 percent of respondents answered the question correctly, while 50 percent were able to justify the answer correctly. Findings Demir (2016) obtained from his study support the findings of this very research. Demir in his study asked the participants, "Which of the following is made when preparing a solution of diluted acid? and 55.4% of participants answered it correctly and 44.6% wrongly. Demir's study (2016) does not provide a conclusion on the reasoning behind the correct answer, but it overlaps with the results of this research in terms of the percentage of correct answers.

In summary, the study found that prospective teachers lacked significant information on laboratory safety. In fact, in many studies, participants stated that they found the traditional training given at the undergraduate level on laboratory safety poor and that their previous knowledge was insufficient (Ateş & Özarslan, 2014; Aydın et al., 2011; Gökmen &

Atmaca, 2019; Kırbaşlar et al., 2010), or that they did not have sufficient knowledge about the recognition of laboratory security symbols and signs (Yılmaz, 2005) or the procedures to be applied in the event of accident and injury (Aydoğdu & Assistant, 2013; Alı et al., 2018; Artdej, 2012; Coşkun, 2017; Olajumoke & Benjamin, 2017). In previous studies, it has been reported that teacher candidates lack knowledge and skills in either designing or selecting materials for experiments (Coştu et al., 2005).

Suggestions

The study concluded that the pre-service science teachers' knowledge of science was missing and mistaken in some fundamental points on laboratory safety. When the training programs in Türkiye were examined, it was seen that the laboratory safety training provided in the first few weeks of laboratory courses is not sufficient in terms of both duration and content. In this regard, it may be suggested that laboratory safety should be addressed more comprehensively, starting from secondary school, that students should be provided with detailed safety measures against possible laboratory accidents, that an exam should be given at the end of this training, and that practices should be put in place to prevent students who fail to pass the examination from continuing their laboratory lessons at the end of this training. In order for science teacher candidates to have sufficient knowledge about laboratory safety, the use of teaching methods such as analogy (first aid intervention in x-case of accidents such as acid spillage, glass sting, etc.), sample events (watching videos or news about previous incidents, bringing newspapers about accidents, etc.), and simulations (images of the interaction of volatile, flammable, explosive, etc.) may be effective. Given the limited scope of this study to science teacher candidates, a similar one may be proposed for teacher candidates in physics, chemistry, and biology as well as for students from pharmacy, engineering, veterinary, and pharmacy.

Ethical Committee Permission Information

Name of the board that carries out ethical assessment: Dicle University Social and Humanities Scientific Research and Publication Ethics Board

The date and number of the ethical assessment decision: 04.01.2023 -423862

Author Contribution Statement

Duygu BİLEN: *Conceptualization, literature review, data curation, methodology, implementation, data analysis, original draft, organization and writing*

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Appendix

You took a mercury thermometer from the cabinet to be used in an experiment to determine the melting temperature of a solid. The thermometer fell out of your hand and broke while you were carrying it to the bench. For the mercury spilled on the floor

a) I throw powdered sulfur on it because……………………………………………………...
....
....

b) I dilute it with water because ....
....
....