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Thinking about the Chemical Substances through Real-life Incidents: A Case Study on Pre-service Teachers' Knowledge on Various Dimensions of Laboratory Safety

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Abstract

Pre-service teachers who conduct experiments are faced with various risks in terms of physical, health and environment due to the chemicals they are exposed to in the laboratory classes. Working in a laboratory without knowing these risks causes accidents such as chemical spills, explosions and fires, and even individual injuries. For this reason, pre-service teachers should be trained about the importance of safety and the properties of the chemicals with using various learning strategies. In this context, we aimed to determine the knowledge about lab safety among the pre-service teachers through real-life laboratory accidents. This study, which focuses especially on the role of chemical substances in laboratory safety, was discussed with its various dimensions. 21 pre-service teachers taking the Laboratory Safety course and attending the Chemistry Teaching Program in a state university's the Faculty of Education in Aegean region (Turkey), participated in this research, based on the case study method. Worksheets containing cases related to laboratory accidents and semi-structured interview form were used as data collection tools. Considering the results of the research, we found that the pre-service teachers generally had a lack of knowledge on the chemicals' hazard classifications, physical, health and environmental hazards, pictograms, chemical properties, and safety precautions of chemicals within the frame of laboratory safety.

Keywords: Laboratory Safety, Chemical Substance, Hazard Classification, Accident, Pre-service Teacher

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Introduction

Regarding natural phenomena, experimental studies are undoubtedly critical in obtaining scientific information in situations where observations cannot be made directly. Chemistry, a branch of natural science, is one of the fundamental fields in which experimental studies are conducted together with applied working methods, principles and inventions. The environment in which chemistry finds a field of application is laboratories (Lunetta et al., 2007). Laboratory environments in which various activities carried out have been a valuable part of a chemistry curriculum since they provide students with authentic and concrete experiences, which, when structured properly, improve their learning (Hofstein et al., 2013). The students acquire a variety of skills and establish a link between practice and theory with laboratory activities in which they interact with materials to observe and understand the natural world (Akkuzu & Uyulgan, 2017; Hofstein & Lunetta, 2003; Kang & Wallace, 2004). The fact that students perform the experimental activities carried out in the laboratory environment step-by-step helps them to understand and learn the chemistry lesson. In this whole process, laboratory applications make learning more meaningful and permanent by improving students’ hand skills, research and problem solving, and scientific process skills. In this process, in which knowledge and skills are acquired by students through experiments, students need the knowledge of many laboratory equipment such as glassware, lab machines and chemicals and the ability to use them in the laboratory (Uyulgan & Akkuzu, 2019). Because all kinds of studies on education and research performed in the laboratory bring along various risks. For example, chemicals used during experiments may carry flammable, explosive, toxic, oxidizing, corrosive and irritating hazardous properties. All these properties carry various risks in terms of physical, health and environment (Adane & Abeje, 2012; Ryder, 2014). Trump and Moore (2001) stated that the potential threat posed by hazardous chemicals is just as serious as school violence. In addition to this, tools, equipment, and instruments used during experiments in the laboratory pose risks, including glassware, burners, gas bottles, and instruments with high pressure and temperature (Wu et al., 2021). Due to these reasons, taking necessary precautions is one of the prerequisites to provide safe working environments for the students exposed to hazardous substances and used laboratory equipment. If laboratory safety is not given priority, unplanned and unexpected laboratory incidents, namely real-life accidents, are unavoidable which result in life threats that cannot be recycled such as hurts, physical injuries, poisonings or deaths (Hill & Finster, 2016). Real-life accidents include accidents experienced by individuals in the laboratory environment and are the accidents that are the subject of newspapers and news.

When real-life accidents in the laboratory environment are examined, it is observed that among the most common accidents are fire, explosion, spills of chemicals, chemical and thermal burns, cuts from broken pipes and thermometers, absorption of toxic (but non-corrosive) chemicals through the skin, electric shock and inhalation of toxic fumes (Aydogdu, 2015; Aydogdu &Yardımcı, 2013; Feszterová et al., 2007, as cited in Feszterová, 2015, p.893; Grabowski, 2017; Rohr Daniel, 2011). Similarly, Hill and Finster (2016) emphasized that chemical spills, electrical hazards, runaway reactions are the most common incidents in laboratories. Li (2014) analyzed 100 accidents in the period from 2001 to 2013 and he found that the fire, explosion and poisoning were the main laboratory accidents. The toxic effects of vapors formed because of spilling chemical substances such as mercury, nitric acid, sulfuric acid and phenol (American Industrial Hygiene Association [AIHA], 2015, as cited in Hill & Finster, 2016), fire, and explosion events that occur by exposing the tubes containing organic solvents and liquids such as flammable alcohol to fire (Shariff & Norazahar, 2012), toxicity or fire and explosions because of gas leaks from a cylinder (Zhang et al., 2020), fires and explosions caused by contact of active metals with water or flammable organic solvents are examples from the literature regarding the accidents (Hill & Finster, 2016). The most common of these accidents are those that can occur simultaneously during the experiment. For example, before starting the distillation experiment, it should be ensured that the system is vented. Otherwise, an explosion may occur at the beginning of the experiment due to heating. As a result of such an explosion, hot glass shards and corrosive chemicals may be splattered. Besides, other real-life accidents such as ingestion of toxic chemicals also occur as a result of accidentally ingesting harmful chemicals by pipette, from dirty hands, from contaminated food or drink, by using chemicals taken from the laboratory.

Real-life accidents in the laboratory are often the result of carelessness and/or ignorance (Wu et al., 2021). In a laboratory environment, students are sometimes in a hurry and they can trip over something while carrying chemicals, or spill while transferring chemicals, besides that they can make the wrong choice in selecting safe practices or do not use safe handling practices. Considering these situations, we can say that incidents are often intrinsically linked to individuals' at-risk behavior while working in the laboratory and this is due to either a lack of knowledge about the danger of the behavior or knowing about the danger but ignoring it. Many studies have shown that the root cause of the incidents in a laboratory environment is due to a lack of safety management, poor judgment on the teachers' part, lack of safety knowledge and training, lack of proper facilities and safety equipment, inadequate laboratory space and intentional, irresponsible, reckless, or dangerous individual acts (Fuller et al., 2001; Hill & Finster, 2016; Hoff, 2003; Richards-Babb et al., 2010; Schenk et al., 2018; West et al., 2003). When all these reasons are examined, it can be said that the kinds of incidents are generally caused by human errors. The main reasons are that teachers and students do not have enough information about the properties of chemical substances and the use of tools and equipment, or they have incorrect knowledge, they are careless during the experiments, and they do not know how to behave in the face of possible dangers (Abu-Siniyeh & Al-Shehri, 2021; Hill, 2016). Therefore, to minimize the occurrence of incidents in lab environments, it is an indispensable requirement that all individuals working in the chemistry lab should be trained about the importance of safety and the properties of the chemicals with proper instructions and it is extremely important providing safe working environments (National Research Council [NRC], 2011; Walters et al., 2017). In this context, it is essential to train pre-service teachers who constitute the sample group of the present study, who will frequently encounter the laboratory environment in their professional life and who will be responsible for informing their students about laboratory safety.

Pre-service teachers need to create a positive safety environment in order to reduce or eliminate the accidents that may occur in the laboratory environment in the schools where they will work and to provide their students with laboratory safety awareness so that they can acquire an effective safety culture (Wu et al., 2007; Yılmaz, 2005). This primarily depends on the pre-service teachers' experiences in this subject. Studies indicate that while planning the training courses to be given in the laboratories, it is necessary to recognize the chemical symbols, evaluate the damage possibilities, perform risk planning to minimize the harms, and adopt holistic approaches to be prepared for emergencies (Banda & Sichilongo, 2006; Stuart & McEwen, 2016). For example, Scheck et al. (2018) investigated the call records of the Swedish Poisons Information Centre (PIC) about severe injuries and accidents in the laboratory environments. In the results of their research, they determined that 70% of the reports were composed of students exposed to laboratory chemicals (especially in accidents caused by acids and alkali). To avoid similar situations, they reported that teachers and their students who work in the laboratory need to have knowledge of chemicals risks and safety measures. Also, in another study by Ziara et al. (2021), a case study was conducted with undergraduate analytical chemistry students about their chemical safety awareness. Their results were similar in this respect that the students should get some sort of chemical safety training or asked to complete a chemical safety course prior to their graduation. Feszterová (2015) stated that laboratory safety was critical in chemistry laboratories, especially in the academic preparation courses of the pre-service chemistry teachers and also emphasized that such preparation would be a precaution against occupational injuries and risks that could threaten health and cause injury. In their studies with university students, Wu et al. (2021) found that they had deficiencies in laboratory safety issues such as Globally Harmonized System (GHS) pictograms, common hazardous chemicals, and basic laboratory safety practices and emergency. They also stated that safety education should be integrated into university courses in order to make safety a priority in the laboratory. Many studies similar to these findings highlight the need for more effective and careful laboratory safety training (Fivizzani, 2016; Hill, 2021; Ménard &Trant, 2020; Meyer, 2017; Sigmann, 2018; Yang et al., 2019). Studies on laboratory safety suggest that various educational methods should be used to bridge theory and practice (Akpullukçu & Çavaş, 2017; Gallego et al., 2013; Hill & Finster, 2016).

Akpullukçu and Çavaş (2017) stated that the use of scientific methods will produce effective solutions so that individuals can work safely in the laboratory and take precautions against problems. The use of various methods and strategies that allow mental reasoning and questioning rather than transferring information is essential for pre-service teachers to grasp the subject "laboratory safety". In this context, it is necessary to use different strategies such as case studies, problem-based learning and context-based learning, in order for the pre-service teachers to know about laboratory safety. From this point of view, we preferred to conduct the research based on real-life incidents in the laboratory by referring to international news. One of the points determining our preferences is that pre-service teachers may encounter similar incidents in the laboratory courses they will take in other semesters and also in their future teaching lives in the laboratory environment. Another is to confront pre-service teachers with real-life scenarios or problems with cases (Svinicki & McKeachie, 2012), to enable them to analyze the incident and to discover their knowledge about the hazard classification of the chemicals; their physical and chemical properties; their physical, health and environmental hazards; their pictograms (hazard symbols); their safety precautions; their storage conditions and first aid practices that could be taken for the accident. Cases reinforce the practical content on laboratory safety (Carr & Carr, 2016). Therefore, with this study, it is crucial to provide pre-service teachers with a preliminary experience and readiness about the laboratory safety. Using international news about accidents to case studies we aimed to obtain rich layers of information and understanding about the knowledge of laboratory safety from the pre-service teachers' perspective. This knowledge, while not claiming generality in a positivistic sense, does offer pre-service teachers a chance to discern what kind of knowledge they should have in terms of safety, how they can follow the laboratory accidents they may face, what kind of solutions they can apply to their own context and what they cannot. Considering that the information about safety made before the experiments in the laboratory environment is deficient and limited, it is extremely crucial to raise awareness on these issues with various learning strategies. When the related studies on pre-service teachers are examined, it is observed that they are mostly aimed at investigating the knowledge levels and attitudes of them about laboratory safety (Anılan, 2010; Artdej, 2012; Can et al., 2015; Kırbaşlar et al., 2010). In this study, we thought that the use of the cases would pave the way for obtaining more detailed data and making deeper interpretations, since we aimed to reveal the change in the knowledge of pre-service teachers about laboratory safety over time, based on the incidents encountered in the laboratories. In recent years, the importance of lab safety education and deficiencies of students about lab safety stand out in the results of the literature on the subject, which constitutes the framework of this study. For this reason, this study is significant in order for pre-service teachers who will train in the laboratory to gain experience in lab safety and to identify their deficiencies. Based on all the above-mentioned issues, in this study, it is aimed for pre-service teachers to learn more permanently about laboratory safety, and cases are used for this. In this regard, within the scope of laboratory safety, cases related to the accidents that occurred in the laboratory environment were presented to the pre-service teachers, and the cases were discussed with various dimensions. We try to answer the following questions in the study:

- To what extent do the knowledge of pre-service teachers in various dimensions within the scope of laboratory safety change through the cases?
- What is the knowledge of pre-service teachers regarding various dimensions within the scope of laboratory safety according to the categories of accuracy?
- What are the views of pre-service teachers on laboratory safety implemented with cases?

Method

Research Design

The research design used for this study was the case study that investigates contemporary phenomenon within its real-life context when the boundaries between the phenomenon and context are not clearly evident or not sufficiently theorized; and in which multiple sources of evidence are used (Merriam, 2013). Gerring (2007) and Hancock and Algozzine (2006) define case studies as deeply grounded studies that describe phenomena or cases in detail that occur in their natural conditions over a period of time using various data collection tools. Since this study sought to determine the role of cases in increasing the freshman pre-service teachers' knowledge related to the laboratory safety subjects, single case-holistic design was used. Single case-holistic design that reveals a situation is based on the systemic approach of a phenomenon (Yin, 2014). In this context, the current research invokes qualitative methods that use various data collecting tools and numerous perspectives to obtain some kind of explanation of the change of the students' knowledge about the laboratory safety subjects over time.

Participants

The sample group of the study was selected according to the typical case sampling method, which is one of the purposive sampling methods. According to this method, a typical situation is determined among the many situations in the study universe related to the research problem and data is collected from this sample (Creswell, 2013; Marshall & Rossman, 2014). In this context, pre-service teachers studying in the Chemistry Teaching Program of a state university in the Aegean region (Turkey), taking the Laboratory Safety course in Fall Semester of 2018-2019 were selected as the study group. In this study, in which knowledge levels of pre-service teachers on laboratory safety during the process was examined, with this method, the knowledge and expertise of them could be benefited from and rich information could be obtained from pre-service teachers. The study group consisted of 21 freshman pre-service teachers, and 19 of the participants were female and 2 were male pre-service teachers. In their experience with the laboratory, pre-service teachers only took part in the experimental environment in secondary education through observing demonstration experiments and did not receive any training on laboratory safety. This situation showed that pre-service teachers did not have knowledge of this subject, and that they were a homogeneous group.

Data Collection Tools

In this study, worksheets containing cases related to laboratory accidents and semi-structured interview form were used as data collection tools.

Worksheets with Cases

Worksheets presented to pre-service teachers during the research process include 4 cases obtained from the international news. Cases enable pre-service teachers to face the real-life experiences. Also, cases assist to fill the gap between theory and practice in the teaching environment and help pre-service teachers develop solutions to a problem in the face of a problem (Ching, 2014). Thus, pre-service teachers actively participate in the learning process by improving their knowledge and skills. In addition, this study, which is handled within the framework of cases, provides an opportunity for pre-service teachers to produce solutions to the problems they may encounter in their laboratory practices in the future. In this context, worksheets presented to pre-service teachers include four different cases. The sources of cases were selected from ready-made cases and included international news on the World Wide Web. The international news was translated into Turkish by the researchers, and then they were finalized by checking the translation and making corrections by two faculty members who are experts in the discipline of English Language Teacher Education. Various criteria were taken into account when selecting the real-life cases by the researchers. The first criterion was about the accident that the pre-service teachers might encounter in the future as well as the structure that interested them. Another criterion was that various chemicals that could cause accidents were included in different classifications of hazardous substances. In this regard, it was considered that pre-service teachers should have knowledge about these classifications, which include the chemical substances they will encounter in the laboratory environment. For example, in 1st case, the lab explosion that occurred at the University of Hawaii on September 23, 2016 was caused by a mixture of oxygen gas (an oxidizing and compressed gas), hydrogen gas (a flammable gas) and carbon dioxide gas. The accident described might be experienced by the pre-service teachers in the future and they might be exposed to the types of hazardous chemicals in the laboratory. Table 1 shows the cases implemented in the laboratory safety course every week and the cause of the accident, the chemicals responsible for the accident, a description of the accident, and hazard classification of the chemicals in these cases.

Worksheets included 11 open-ended questions related to the cases that would enable pre-service teachers to reflect on their thoughts on different aspects of laboratory safety. The questions were asked in alphabetical order as A, B, C... K (see Table 2). Cases and questions were analyzed by researchers, who administered the course of laboratory safety, and necessary revisions were done.

Table 1. Cases implemented in the laboratory safety course every week

Week	Case	Title of the news	Source and date	Description of the accident	Chemicals responsible for the accident	Hazard classification of the chemicals
1	1	University of Hawaii fined $115,500 for lab explosion	https://cen.acs.org/articles/94/web/2016/09/University-Hawaii-fined-115500-lab.html (September 23, 2016)	While preparing a gas mixture of 55% hydrogen, 38% oxygen, and 7% carbon dioxide when an electrostatic discharge likely ignited the mixture, an explosion occurs.	A gas mixture of hydrogen, oxygen, and carbon dioxide	Compressed gas (for all gases) Oxidizing (for Oxygen gas) Flammable (for Hydrogen gas)
2	2	Two high school kids burned in lab accident	https://nypost.com/2014/01/02/students-injured-in-high-school-science-class-blast/(January 2, 2014)	During the flame experiments that a chemistry teacher conducted with four kinds of nitrate salts, a volatile methyl alcohol fumes accumulated in another laboratory and when the buildup of methyl alcohol fumes reached the chemistry laboratory where the flame test was carried out, fumes ignited into a fireball that sped across a countertop and engulfed a sophomore student.	Methyl alcohol	Flammable Toxic Health hazard
3	3	Princeton University laboratory accident sends three people to the hospital	https://www.nj.com/mercer/index.ssf/2012/05/ princeton_university_laborator.html (May 23, 2012)	It is the chemical irritation of both the female student and the people around her as a result of the severe steam created by a post-doctoral female student accidentally adding solvent waste to nitric acid while doing an experiment.	Nitric acid	Corrosive Oxidizing Harmful/irritant
4	4	Severe case of poisoning due to phosgene inhalation during chemical accident	https://mobil.bfr.bund.de/cm/364/ cases_of_ poisoning_reported_by_physicians_2008.pdf (p.28) (March 14, 2008)	A test tube used by a professor working in a university laboratory during the production of phosgene from triphosgene is separated from the apparatus. And during this production, phosgene escapes and causes poisoning.	Phosgene	Toxic Corrosive Compressed gas

Table 2. Questions for cases in worksheets

Questions	
A	What is the cause of the accident in case?
B	Which chemical substance(s) cause the accident?
C	What are the physical and chemical properties of the substances?
D	In which type of hazard classification are the chemical substance(s) included in the CLP (classification, labeling and packaging regulation of substances and mixtures) regulation?
E	What are the health hazards of the chemicals?
F	What are the physical hazards of the chemicals?
G	What are the environmental hazards of the chemicals?
H	Explain by drawing the pictograms specified in the CLP regulation of the chemicals in terms of hazards.
I	What security measures were neglected in the incident? What kind of precautions need to be taken?
J	What are the rules for the storage of the chemicals in this case?
K	What kind of first aid can be rendered to the injured person as a result of the incident?

In each worksheet, the questions directed to the pre-service teachers about cases of various accidents included the cause of the accident, hazard classification of the chemicals causing the accident, their physical and chemical properties; their physical, health and environmental hazards; their pictograms (hazard symbols); their safety precautions; their storage conditions and first aid practices that could be taken for the accident. Table 2 contains the questions asked to pre-service teachers in the worksheets. As an example, a worksheet including case is presented in the Appendix.

Within the framework of cases and questions, the main purpose is to enable pre-service teachers to think about what they need to know when working with chemicals in the laboratory environment and to prepare them for safety and precautions for laboratory courses that they will take in the next terms by allowing them to question in this process.

Semi-structured Interview Form

In order to determine the contribution of the pre-service teachers to the learning process of the course taught with cases and their views on laboratory safety, 10-minute semi-structured interviews were conducted with them. Participation was voluntary, and not all the pre-service teachers wanted to be included in the interviews. Therefore, the interviews were implemented with volunteers among them (n=11). The researchers prepared an interview form consisting of four open-ended questions. The questions are presented in the results section of the research. The interviews were conducted individually and in a comfortable environment free of distractions. Before the interview, pre-service teachers were informed about how the interview would be conducted, the data obtained would only be used within the scope of scientific research, their identities would be kept confidential, and their consent was obtained to participate in the interview. The data from the semi-structured interview were recorded on audio tape, then transcribed and finally analyzed by the researchers.

Procedure

The study was carried out in the Laboratory Safety course, which covers two lesson hours (45 min each) per week in the curriculum. The main purpose of this course is to train pre-service teachers on the safety rules and regulations in the laboratory, the physical and chemical properties hazardous chemicals, effects of the hazardous chemicals on the human and environment and handling the hazardous chemicals. At the beginning of the study process, within the scope of the course contents, presentations containing general information about the accidents that may be encountered in the laboratory and their causes, hazard classifications of chemicals and mixtures, pictograms, safety precautions, storage conditions and first aid issues were made by the researchers for approximately 5 weeks and 10 lesson hours in the Laboratory Safety course to pre-service teachers. The purpose of these presentations is to ensure that pre-service teachers are at a certain level of knowledge, have an idea about the questions asked when they encounter cases, and create a framework about relevant topics. Before the case-based implementation process began, the researchers gave a brief explanation to pre-service teachers about how the 4-week process would progress. Then, worksheets were distributed to pre-service teachers and the implementation process was begun by explaining how they should fill in the worksheets. The participants, who filled out the worksheets, expressed their opinions on the cases and the precautions that could be taken in the class discussion, also by using their written statements. The total duration of the study, including interviews, was 10 weeks.

Analysis of the Data

In the analysis of the data from the worksheets, the categories of Correct (C), Partially Correct (PC), Incorrect (IC) and No Answer (N/A) were taken as basis for each question, and the distribution of the answers of the pre-service teachers according to the categories was calculated. In order to assess the total scores to be obtained from the data, the correct category was evaluated as 2 points, the partially correct category as 1 point, and the incorrect and no answer categories as 0 points. The maximum score obtained from 11 questions in each case was 22, and the total score of 21 pre-service teachers was 462. The scores of all pre-service teachers from each case were calculated as the total score, and their scores were presented descriptively on the graph in terms of percentage. In addition to the data obtained quantitatively, in line with these categories, the level of knowledge of pre-service teachers in which questions in the process and their deficiencies in which subjects were also revealed in detail as qualitative data. The content analysis method was used in the analysis of the interview data, which was conducted to examine the change in the knowledge of pre-service teachers about laboratory safety in more detail after the application and to get their views on the application. After the semi-structured interviews were transferred to the word, categories were created, and these categories were given together with frequency value and sample statements. Content analysis was performed separately by the researchers, and the percentage of agreement was calculated 98% by using Miles and Huberman's formula (Reliability= [Agreement/Agreement + Disagreement] x 100) in terms of the reliability of the data (Miles & Huberman, 1994, p. 64).

Findings

Findings of Worksheets with Cases

The distribution of the responses given by the pre-service teachers to the questions in cases by categories is shown in Table 3.

Table 3. Distribution of responses to the questions in cases by categories

Q	Category	Case 1	Case 2	Case 3	Case 4	Q	Category	Case 1	Case 2	Case 3	Case 4
A	C	20	0	4	15	B	C	7	0	3	21
	PC	0	9	14	6		PC	13	0	15	0
	IC	0	10	0	0		IC	0	19	0	0
	N/A	1	2	3	0		N/A	1	2	3	0
C	C	7	9	9	0	D	C	2	8	0	3
	PC	13	10	9	14		PC	11	11	0	18
	IC	0	0	0	7		IC	7	0	18	0
	N/A	1	2	3	0		N/A	1	2	3	0
E	C	2	3	10	7	F	C	5	9	2	0
	PC	18	16	8	14		PC	15	4	16	15
	IC	0	0	0	0		IC	0	6	0	0
	N/A	1	2	3	0		N/A	1	2	3	6
G	C	8	5	7	10	H	C	2	3	0	0
	PC	12	14	11	8		PC	7	13	8	13
	IC	0	0	0	0		IC	11	3	10	8
	N/A	1	2	3	3		N/A	1	2	3	0
I	C	0	3	11	0	J	C	0	2	8	0
	PC	20	16	7	21		PC	20	14	10	21
	IC	0	0	0	0		IC	0	3	0	0
	N/A	1	2	3	0		N/A	1	2	3	0
K	C	0	2	11	11						
	PC	15	12	7	5	Total Scores of Cases		250	207	235	270
	IC	5	5	0	5						
	N/A	1	2	3	0						

Considering the categorical distribution of the responses, we found that correct answers were mostly obtained in questions A and B, and partially correct responses in questions C, D, E, F, G, H, I, J and K. In addition, although correct and partially correct responses were in the majority, incorrect responses were also found in questions A, B, C, D, F, H, J and K.

In question A, pre-service teachers were asked to determine the cause of the accident in case. When we examined the answers to this question, we observed that although the pre-service teachers mostly provided correct answers, a certain proportion of pre-service teachers had incorrect answers. For example, in the 2^{nd} case, some pre-service teachers thought that the *fire occurred as a result of burning (reacting) methyl alcohol with nitrate salt*. In addition, in the partially correct answers given to the 3^{rd} case, pre-service teachers were able to state that *an accident occurred as a result of adding* *solvent to nitric acid*, and we can infer that they could partially distinguish between the incompatible chemicals when mixed. However, what stands out in the findings is that the pre-service teachers could not make statements about how the added solvent caused sparks and splashes.

As we considered the responses to the B question, which identified the chemicals that caused the accident in case, it was determined that although the pre-service teachers answered mostly correctly, they also gave partially correct and incorrect responses. For example, in the 2nd case, some pre-service teachers did not think that the flames in conducting the flame test could ignite methyl alcohol, instead the pre-service teachers stated that *nitrate salts and methyl alcohol reacted and caused a fire*. In the partially correct answers in the 3rd case, the pre-service teachers could not figure out the specific solvent (water or acetone) that caused the accident upon addition of nitric acid, but they could only express that *it was an incompatible solvent*. Here we infer that pre-service teachers do not have knowledge about which chemicals can react to cause accidents because of their interaction with each other and give an undesired chemical reaction when mixed.

In question C, pre-service teachers were asked to indicate the chemical and physical properties of the chemical substances that caused the accident. The responses of the pre-service teachers to this question were mostly partially correct. For instance, they were generally able to express *the physical properties of chemical substances such as color, odor, taste, solubility, melting point and boiling point,* but they could not specify the chemical properties of the substances in terms of flammability and chemical stability. Similarly, in the 4th case, pre-service teachers were able to name the physical properties of phosgene ($COCl_2$), which is generally *a colorless gas and smells reminiscent of freshly cut grass at low concentrations*; but they could not express their reactions. Additionally, some pre-service teachers had misconception that *phosgene has flammable properties*.

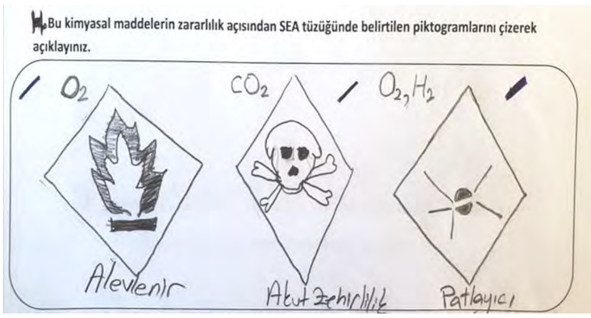
The pre-service teachers were asked about the hazard classifications of the chemicals in the incident according to the CLP (Classification, Labelling & Packaging) regulation. We observed that the responses to the D question were mostly partially correct, and some also incorrect. For example, in the incorrect responses determined in the 1st case, some pre-service teachers stated that o*xygen gas (O_2) is classified as easily flammable and explosive.* Unfortunately, they did not state that oxygen is classified as oxidizing (burning) substances, whereas oxygen (O_2), hydrogen (H_2) and carbon dioxide (CO_2) are classified as gases under pressure. In the 3rd case, some pre-service teachers misclassified *nitric acid as flammable and explosive*. Likewise, they were unable to state that nitric acid is a corrosive substance based on the cause and consequences of the accidents. We also found that some pre-service teachers confused the oxidizing property of nitric acid with the classification of explosive. Since nitric acid is not self-igniting, its classification as an explosive substance is incorrect. However, nitric acid, a strong oxidizing agent, reacts violently with many metal and organic substances. In the partially correct responses in the 4th case, some pre-service teachers classified *phosgene as a toxic and* *mutagenic substance* but did not specify its corrosive property. In short, we can conclude that pre-service teachers do not have sufficient knowledge about the classification of the hazardous chemical.

Another question (E) on the effect of hazardous chemicals on the health was directed to pre-service teachers. The majority responses were both correct and partially correct answers. Incorrect answers were not found. In the partially correct answers, the pre-service teachers stated only the *harmfulness of carbon dioxide* based on the 1st case, but it was not specified what kind of hazard it could cause when there were excess oxygen and hydrogen gases in the environment. They didn't consider that these chemicals could be harmful to health. In the 2nd case, although some pre-service teachers stated that *the toxic property of methyl alcohol is only in case of ingestion,* they did not consider that this property may also occur in case of inhalation or skin contact. In the 4th case, it was observed that a certain proportion of pre-service teachers expressed that *phosgene is toxic in terms of health hazards, in case of skin contact and inhalation.* This indicates that the pre-service teachers were partially aware of the effect of hazardous chemicals on health, and they were unable to explain the consequences of the hazardous chemicals. This was because they were unable to mention the severe skin burns and eye damage, shortness of breath, severe pain in the chest as well as edema by being broken down into hydrochloric acid in the lungs upon inhaling and skin contact with phosgene.

Findings related to another question (F) were the explanations of pre-service teachers about the physical hazards of chemicals involved in cases. In these statements, it was seen that partially correct answers were in the majority. However, on the other hand, we also found that incorrect statements were made regarding the 2nd case. To give an example of incorrect statements, a few pre-service teachers expressed that *methyl alcohol (CH_3OH) was corrosive in terms of physical hazards,* and they confused it with its toxic property, which is one of the health-related hazards. Theoretically, methyl alcohol has toxic properties, not corrosive, when in contact with the skin. Also, its flammable nature was not emphasized. This shows that pre-service teachers do not know the physical hazards of methyl alcohol. In the 3rd case, several pre-service teachers could express that nitric acid corrodes metals. On the other hand, a great majority of pre-service teachers stated in the partially correct answers that *nitric acid (HNO_3) may cause an explosion in a fire due to its strong oxidizing property*. In this sense, the findings indicate that pre-service teachers' knowledge about the physical hazards of chemicals is not sufficient.

Question G was about the effect of hazardous chemicals on the environment. Pre-service teachers' responses to this question mostly contained partially correct statements by mentioning that *the inhaling phosgene may damage plants and animals* based on the 4th case. On the contrary, a few pre-service teachers stated that *phosgene was used only in chemical warfare*, and they did not know its harm to the environment. In the 3rd case, the pre-service teachers were able to state in their correct responses that *nitric acid was toxic in the aquatic environment in terms of environmental hazards*, *and it caused industrial pollution and acid rain*.

In question H, pre-service teachers were asked to draw the chemical hazard pictograms specified in the CLP regulation. The responses to this question turned out to be inaccurate and insufficient. For example, in the 1st case, flammable and explosive pictograms were drawn for oxygen gas. Similarly, they drew an explosive pictogram for hydrogen gas instead of a flammable pictogram. Additionally, we met the same problem for carbon dioxide gas as they drew a toxic pictogram to represent it. This is because the pre-service teachers confused with carbon monoxide gas (see Figure 1). Also, pre-service teachers were unable to draw the compressed gas pictogram for the O_2, CO_2 and H_2 gases. This finding indicated that they could not comprehend the compressed gas pictogram. In the 2nd case, the majority of pre-service teachers were able to draw flammable and toxic pictograms for methyl alcohol. However, they did not draw the health hazard pictogram for methyl alcohol, which included the harmfulness of causing damage to the organs. When the drawings in the 3rd case were examined, although the pre-service teachers could draw the corrosive pictogram for nitric acid, they also drew explosive and flammable pictograms and showed nitric acid in misclassifications. In the 4th case, we determined that a few pre-service teachers drew the flammable and environmental hazard pictograms for phosgene, but they did not draw the toxic and corrosive pictograms. Examples of pictogram drawings of pre-service teachers are given in Figure 1.



(Example of 1st case, PT-9)

(Example of 3rd case, PT-20)

Figure 1. Examples of pre-service teachers' drawings of pictograms

In question I, pre-service teachers were asked on the negligence and the precautions steps taken to ensure laboratory safety. The majority of the pre-service teachers provided correct and partially correct responses. None of them provided an incorrect response. Generally, the pre-service teachers expressed the precautions steps taken without explaining the negligence. For example, in the 1st case, there were statements about *the use of appropriate Personal Protective Equipment (PPE), and the safe storage of cylinders.* For example, there were no statements about keeping oxygen and hydrogen gas away from heat, sparks, flames, and all flammable materials. Pre-service teachers could not evaluate the chemicals separately, which coincides with their statements that all of these gases cause the explosion. Similarly, it was revealed that the pre-service teachers did not express the necessity of using gas masks as a neglected safety measure in the 4th case. Only few pre-service teachers stated that *the gas mask was not used as a neglected safety measure in the incident and the ventilation was not done well.* However, these pre-service teachers did not make statements about the use of PPE, such as gloves and safety goggles; ignoring the fact that phosgene comes into contact with the skin in any way.

Another question (J) directed to pre-service teachers was about the rules for storing the chemicals to ensure laboratory safety. We found that partially correct responses were in the majority. For example, in the 1st case, pre-service teachers generally used expressions such as *ventilation, keeping explosive chemicals away from ignition sources*. The pre-service teachers could not provide information about the storage of chemicals at ambient temperature and the proper methods to dispose and transport tubes containing a mixture of gases. Pre-service teachers stated that in the 2nd case, *chemicals must be stored out of direct sunlight, and their storage areas must be well-ventilated, non-smoking, dry, and cool environment.* However, there were no statements on storing incompatible chemicals separately to avoid a hazardous reaction based on the hazard classifications. This fact reveals that pre-service teachers were unable to classify the materials to be stored according to appropriate hazard warnings and their group of compatible/incompatible chemicals. In the 3rd case, they stated that *the environment should be ventilated for nitric acid, stored in a cool place away from the sun, kept away from flammable, not in contact with water and stored in its original containers.* However, their statements also revealed that pre-service teachers had misunderstood that nitric acid should be stored on the top shelf of a storage unit.

In the last question (K) regarding the cases, the knowledge of pre-service teachers about the types of first aid that should be applied in case of injury during the accident was assessed. It was determined that the partially correct answers constituted the majority, but there were also a few incorrect answers. For example, in the 1st case, they did not know much about the first intervention to be done to the injured person in the event of a limb (arm) amputation. Pre-service teachers stated that *severed limbs should be kept on ice and the emergency services should be reported.* In addition to this, they had incorrect information that *tourniquet intervention should be done in cases where tourniquets should not be applied.* Based on the second case study, it was determined that there was a lack of knowledge on the intervention of 2nd and 3rd degree burns. For instance, a few of the pre-service teachers gave correct answers, stating that *ointment should not be applied,* while most of them incorrectly stated that *ointment should be applied to the burnt area* and *it should be treated with medication*. These findings indicated that pre-service teachers did not consider that the burned area should be cooled and wrapped with a sterile dressing in first aid intervention. In the partially correct answers in the 3rd case, pre-service teachers suggested that *the irritated area should be washed with* *plenty of water during the first aid process for nitric acid irritation, and should be taken the injured person outside in case of inhalation.* Pre-service teachers made incorrect statements in the 4th case, such as that *people exposed to phosgene gas should be made to vomit and drink water and milk.* Although the pre-service teachers knew that phosgene was toxic, they did not have any idea about the first aid to be given for the lethal dose of phosgene.

The percentage of scores per case by the 21 participants is summarized in Figure 2. Considering the total scores obtained from four different cases applied throughout the research process, there was an increasing change in the knowledge levels of pre-service teachers in the 2nd, 3rd and 4th cases after the 1st case. The reason for the high score in the 1st case and the decrease in the next case is due to the fact that the pre-service teachers explained the cause of the accident and chemical that caused the accident inaccurately. In the 2nd case, the fact that the substance causing the fire (methyl alcohol vapors) was not known by the pre-service teachers, and incorrect answers were frequently encountered related to its physical and health hazards and pictogram drawings, which decreased in the total score. In addition to this, in the 1st incident, the chemicals may have been more familiar to the pre-service teachers.

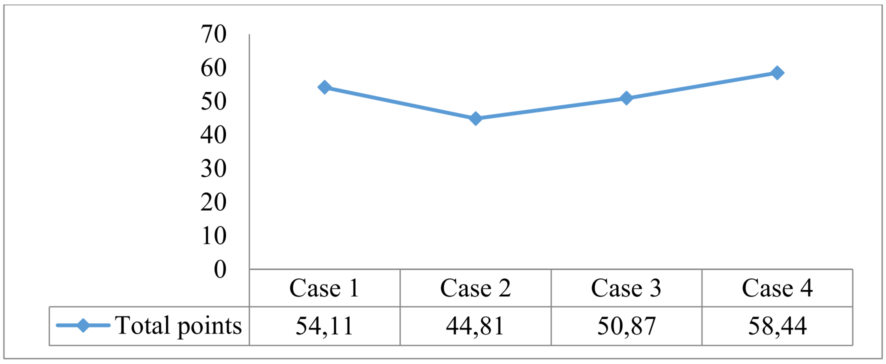


Figure 2. The percentage of scores per case

When evaluating the scores obtained from the case worksheets over 100 points, it was observed that a minimum success rate of 44.81 (Actual total score=207) and a maximum of 58.44 (Actual total score=270) were achieved (see Figure 2). The fact that the total scores are in the range of 45-60 points indicates that the knowledge of the pre-service teachers about laboratory safety is at a moderate level. Considering the results in general, it was revealed that pre-service teachers had a lack of knowledge and also incorrect knowledge, especially on the pictogram drawings of chemicals, hazard statements, rules for the storage of the chemicals, and the first aid intervention.

Findings of the Interview

After the application, the first question asked to pre-service teachers was as follows: *What kind of contributions did the 4-week laboratory safety course based on cases have made for you?* Most of the pre-service teachers (f:9) stated that they acquired more awareness about the classification of chemical substances and they comprehended it better through the cases. Additionally, some pre-service teachers (f:5) realized that they may encounter laboratory accidents in daily life as well, and stated that their contribution in this sense is crucial. A few pre-service teachers (f:4) stated that they were able to analyze hazards of chemical substances in more detail in terms of physical, health and environment via cases. Table 4 contains categories and example statements that emerged from the data of pre-service teachers.

Table 4. Findings regarding the contributions of cases

Categories	f	Sample Statements
Awareness of classifications of chemical substances	9	I learned that many chemicals in the cases are included in various hazard classifications such as flammable and explosive. (PT-3) I realized that the explosion occurred because of the oxidizing property of the oxygen gas, not flammable. I realized that I confused both properties. (PT-9)
Awareness of lab accidents encountered in daily life	5	An accident can happen at any time while performing an experiment in the laboratory. Therefore, it is very crucial to know the properties of chemical substances and how to ensure lab safety. Because the lab is actually where we face reality. (PT-5)
Learning about chemicals' hazards in terms of different types	4	When it comes to the hazards of chemical substances, the first thing that came to my mind was what the most common hazard was. I have not examined the physical, health and environmental hazards of each chemical substance separately. (PT-2)

In order to determine the difficulties that the pre-service teachers had in comprehending the knowledge about the chemicals in the case, the question *Which part of the worksheets related to the cases did you find most difficult to answer?* was asked. A significant part of the pre-service teachers (f:8) stated that they could not write the chemical properties of the substances that caused the accident. This state points out that pre-service teachers do not have sufficient knowledge about the reactions of chemical substances. Another issue that most pre-service teachers (f:10) had difficulty with was that they confused the pictograms of chemical substances and could not draw them. Also, a certain proportion of pre-service teachers (f:5) stated that they could not have an idea about what kind of damage the chemicals stated in the incident had. These findings are presented in Table 5 together with the example sentences of pre-service teachers.

Table 5. Findings regarding the difficulties in cases

Categories	f	Sample statements
Pictograms (hazard symbols) of chemicals	10	It was difficult for me to draw pictograms of the substances. For example, while I was drawing the pictogram of the oxygen gas, it was incorrect that I draw the pictogram of the flammable substance. I realized I had confused it with the oxidizing pictogram. (PT-9)
Chemical properties of substances	8	I could not remember the reactions of most chemicals. I could write down a few physical properties of many chemical substances such as color and solubility, but I could not write how they reacted with which substances. (PT-8)
Hazards of chemical substances	5	I was unaware of the numerous chemical substances' physical and health hazards. For example, although I knew that methyl alcohol was toxic, it had never occurred to me that it was physically flammable. (PT-1)

Considering the accidents in cases, the question *What could be the accidents that you may encounter within the scope of the laboratory application courses you will take in the next semesters?* was asked to the pre-service teachers. Table 6 summarizes the thoughts of pre-service teachers about what accidents they may encounter and which they are more concerned about in the laboratory environment. Accordingly, all of the pre-service teachers (f:11) stated acid and base burns, while a significant part of them (f:7) expressed explosions with physical hazards.

Table 6. Findings regarding the accidents that the pre-service teachers may encounter within the scope of laboratory practices

Categories	f	Sample statements
Acid and base burns	11	I am concerned that acid would irritate my skin. For example, when I draw up acid into pipette, I am terrified spilling it on me. I may not know what to do in a situation like this. (PT-10) If I am doing an experiment using acids and bases, their vapors may get into and burn my eyes. It can even make me blind in the long term. Therefore, I definitely need to use safety goggles. (PT-7)
Explosion	7	Although the instructor is in the laboratory environment, my carelessness or ignorance during the experiment can cause an explosion. (PT-4)

Finally, pre-service teachers were asked the following question: *What should you pay attention to in terms of safety in order not to encounter any accidents in the subsequent laboratory practice courses?*. The findings showed that pre-service teachers mostly focused on the categories of having knowledge of chemicals (f:8), using personal protective equipment (f:11) and using tools and equipment (f:4) (see Table 7).

Table 7. Findings regarding the safety precautions

Categories	f	Sample statements
Personal protective equipment	11	As part of laboratory safety, first, I pay attention to wearing aprons, safety glasses, gloves and having my hair tied. (PT-4) In order to avoid any risk of burns, I take care to have full protective clothing before starting the experiment. (PT-7)
Knowledge of chemicals	8	Before performing an experiment in the laboratory, I research the properties of the chemicals I will use and what effects they have on humans and the environment, and I want to do the experiment only after that. (PT-6)
Use of tools	4	I want to know which laboratory glassware to use in experiments and how. Just like I know that a beaker is different from the erlenmeyer flask because it is heat resistant. I think this is very important to prevent possible accidents. (PT-3)

Discussion and Conclusion

In chemistry laboratories, it is an extremely important precaution that pre-service chemistry teachers have knowledge about laboratory safety, so that they are prepared for occupational injuries they may encounter and risks that may threaten their health. In this regard, real-life examples of laboratory accidents were presented to the pre-service teachers and their knowledge of laboratory safety with its various dimensions was examined in depth by conducting inquiries over these cases.

The results of the study indicate that pre-service teachers generally had insufficient knowledge about the chemical properties of substances, hazard classification and hazard symbols of chemicals, the storage of some chemicals and the incompatible chemicals and first aid. Pre-service teachers associated the damage of chemical substances with the cause of the accident and accordingly misclassified the chemical substances. In addition, they do not know exactly the physical, health and environmental hazards of chemical substances and they may confuse these hazards. One of the prominent results of the study was to raise awareness of pre-service teachers about exemplary real-life accidents that they may encounter while working in a laboratory environment. Based on this result, they also stated that they could notice the deficiencies they experienced in laboratory safety and that the study process conducted with cases contributed to them in this respect. In a similar research, Turner and Shamsid-Deen (2005) developed a lab safety module and implemented Problem-Based Learning (PBL) and Investigative Case-Based Learning (ICBL) to facilitate the retention and synthesis of concepts and terms through real-life scenarios and open-ended situations. Barrier (2005), on the other hand, used activities that allow students time to reflect on lab safety rules and implemented the rules through cooperative learning. As in this study, it was necessary to introduce the subject of laboratory safety from a very broad perspective by presenting real-life cases with active learning methods to pre-service teachers who will be trained in the field of science. In this context, it was concluded that pre-service teachers should be supported with practices to increase their awareness on this subject.

Considering the results of the research, we found that the pre-service teachers had insufficient and inaccurate knowledge on some subjects of laboratory safety in general as well as the correct knowledge. In cases where laboratory use techniques and safety precautions are not considered, laboratory accidents are inevitable, and these accidents can cause irreversible life-threatening hazards (Aydogdu, 2015; Coşkun, 2017; Gong, 2019). Wu et al. (2007) stated that as a result of the safety measures that teachers will take in the laboratory environment, their students will also be affected by this and display cautious behaviors. For this reason, it is essential for pre-service teachers, especially those trained in the field of science, to have sufficient knowledge on safety. In this research, it was determined that the pre-service teachers thought that the chemical substances that caused the accidents during the case were reacting with each other. This also indicated that the pre-service teachers had a lack of knowledge about the properties of the chemicals involved in the accident. Similarly, the same problem was encountered in the question of chemical and physical properties. Pre-service teachers could give answers mostly about the physical properties of substances, but they could not adequately express the chemical properties of substances, such as their reactions, flammability, and chemical stability. The studies emphasized that if students do not know the properties of chemicals, they cannot adequately assess the risks and minimize them with proper preparation, which may cause some minor accidents and even serious injuries, including loss of life (Hill, 2016; Wu et al., 2021).

Another result of the current study was about the knowledge of the pre-service teachers about the hazard classification of chemicals, and it was noteworthy that they had both inaccurate and deficient knowledge on this subject. Pre-service teachers wrote the hazard statements by considering the results of the accidents such as explosion, poisoning. For example, if there was an explosion in case, they responded by thinking that all chemicals involved in the reaction could be explosive. From another perspective, when poisoning occurred in the case, they could only express the toxic property of the chemical, but could not specify its other hazard statements. The lack of knowledge of pre-service teachers about these classifications may cause several problems: they may be unable to evaluate the hazards they encounter while working in the laboratory environment correctly, consequently they may not be able to take the necessary protection measures to avoid possible accidents. For this reason, the most important step that should be acquired by pre-service teachers regarding laboratory safety is the knowledge of the hazardous properties of chemicals (Wu et al., 2021). Laboratory safety training is a course given in the first-year to pre-service chemistry teachers in university education. This training should be supported by other laboratory practices during the laboratory courses. Otherwise, it may be possible for individuals not to recognize chemicals they will encounter in different laboratories or to ignore safety precautions (Hill, 2016).

When we examined the results of the research on what the pre-service teachers comprehended about the physical, health and environmental hazards of chemical substances, it was found that besides the correct answers, they also misclassified many chemical substances. In addition, while the pre-service teachers only stated the hazards of substances such as carbon dioxide, methyl alcohol in terms of health, they could not express other hazards. This is similarly seen in the pictogram drawings of the chemical substances of the pre-service teachers. Although pre-service teachers could show in which hazard classification the relevant chemical was included, they also drew incorrect pictograms that did not belong to the chemical. Additionally, it was determined that the pre-service teachers could not draw the correct pictogram of some chemical substances and they had these shortcomings in their hazard statements. This may be due to pre-service teachers working in the laboratory not paying attention to the symbols of chemical substances and ignoring the warnings and signs on their labels. Parallel to this result, many studies reported that university students were unfamiliar with hazard warning signs for laboratory chemicals and unable to know pictograms of them (Adane & Abeje, 2012; Karapantsios et al., 2008; Lunar et al., 2014; Walters et al., 2017). In addition, as in the results of the current study, pre-service teachers associated the damage of chemical substances with the cause of the accident and therefore added incorrect statements to their correct ones. We encountered this problem, especially in the statements and drawings of the pre-service teachers. Due to the cause of the accident, they showed a corrosive substance such as nitric acid in the flammable and explosive class, and an oxidizing substance such as oxygen gas in the explosive classification. The fact that the pre-service teachers do not have sufficient knowledge in the hazard classification of chemical substances exposes them to possible risks. The studies show that university students, who know these classifications correctly, will both make them aware of the risks and behave more consciously in the protective measures to be taken against these dangers (Vaz et al., 2010; Walters et al., 2017; Ziara et al., 2021). Determining whether the substances to be used while working in the laboratory environment are toxic, explosive, or easily flammable, checking that the pressurized cylinders are always attached to the wall or a solid support, determining the location of the safety information, and reading the safety cards of the chemicals to be used are among the safety precautions to be taken before the study (Walters et al., 2017). In the current study, pre-service teachers mostly focus on using personal protection equipment, using tools and equipment, and having knowledge of chemicals in terms of precautions that can be taken. Walters et al. (2017) and Hill and Finster (2016) emphasized that the security awareness, including security precautions, should be maintained in conjunction with practices and stated that it is important to establish this connection in academic education.

Another result was that pre-service teachers could not give adequate answers about the neglected safety measures that caused the accidents in the cases. Pre-service teachers were able to express more measures to be taken in their responses. In some cases, they ignored a security measure that was very crucial to the case. The reason for this may be the fact that they did not conduct experiments in a laboratory environment before, and therefore they did not receive training on precautions in the laboratory. In addition to this, studies show that responsible instructors work without taking adequate precautions and/or not paying enough attention to security precautions. Al-Zyoud et al. (2019) reported that supervisors had weaknesses regarding how staff deal with specific emergency incidents, such as the proper use of fire extinguishers during an accident so their students do not have adequate knowledge in these situations. The safety precautions that students will learn in the laboratory environment and their ability to protect themselves from the dangers they will encounter affect their whole life (Coşkun, 2017; Gong, 2019). It should not be forgotten that the most important issue to be considered while working in the laboratory in all experimental applications is "safety" (Yılmaz, 2005). Security measures are taken to ensure that all studies are conducted safely, not to limit practical work. Here, the first thing to be considered is that the instructor working in the laboratory has good safety knowledge (Akpullukçu & Çavaş, 2017). Well-trained instructor can guide them in informing the pre-service teachers, ensuring that they follow the rules, eliminating the deficiencies and taking the necessary precautions. In this way, pre-service teachers who acquire these qualifications in their university education can set a good example for their students in laboratory studies in the future.

Another important factor that may cause an accident in laboratory safety is safe storage of the chemicals. Even if pre-service teachers have sufficient knowledge of safety precautions, incorrect storage of chemicals can also cause an accident. In the study, we found that the pre-service teachers had insufficient knowledge about the storage of the incompatible chemicals and incorrect knowledge about the storage of some chemicals. In a similar study, Artdej (2012) stated that the 4^{th} grade pre-service teachers of the Faculty of Education in Thailand have insufficient knowledge about the proper handling, storage and disposal of chemicals and that awareness of this issue should be increased. Similarly, in his research, Gudyanga (2020) determined that the physical science teachers were unaware of the storage and disposal of chemicals and of emergency responses in the chemical laboratory. This same issue has been encountered in various studies (Lacy, 2006; Schenk et al., 2018; Trump & Moore, 2001). This shows that possible accidents can only be avoided if chemicals are handled properly and stored in accordance with strict safety regulations.

In addition to all these safety rules that are expected to be followed in the laboratory, it is also crucial that the first aid to be applied in the event of a possible accident is done quickly and in accordance with the method. The results obtained from the research on this issue indicated that the pre-service teachers did not have sufficient knowledge in terms of first aid in the case of an accident. Pre-service teachers, who think that they may encounter dangers such as acid-base burns and explosion, especially in laboratory applications, have insufficient and incorrect knowledge about the first aid that can be given in cases such as burns and limb amputation that may be seen in these accidents. For example, some pre-service teachers have inaccurate knowledge about how the first aid will be applied to the burned area, such as applying ointment and treating it with medication. This shows that they did not think that the burn area should be cooled and wrapped with a sterile cloth. Therefore, it was observed that there were incorrect interventions in their statements, the result of which could be quite dangerous. If the pre-service teachers have basic concepts of first aid, they can deal with injury in a more confident way in case of any possible accident and it is easy to improve the awareness in this issue in a very limited time (Akıllı, 2018; Altınkaya Kurtulmuş, 2019; Huston et al., 2018).

To sum up, the results of this study indicated that chemistry pre-service teachers could partially increase their knowledge levels on laboratory safety covered with cases; however, this knowledge was not at a sufficient level. Unlike the existing literature, this study dealt with laboratory safety issues in various dimensions and tried to shed light on the current situation of pre-service teachers on these issues.

The results show that pre-service teachers should be educated about laboratory safety, should acquire an understanding of laboratory safety in a broad perspective, and this should be permanent by establishing a relationship with their real lives. Future studies on this subject should be conducted that can lead students to change their behavior by assimilating laboratory safety knowledge. In addition, in order to improve the awareness of pre-service teachers on this subject, some suggestions were made considering the results of the study and the relevant literature.

Recommendations

- Our study is limited by a small sample size; in addition, it has the limit of only including one class in university. Hence, our results cannot be seen as representative of the whole of the population. Therefore, similar studies can be repeated over different samples. In addition, these case studies on laboratory safety can be conducted at different grade levels taking laboratory courses, and the level of knowledge on this subject can be investigated according to the grade level.
- Studies can be carried out within the scope of experimental activities in order for pre-service teachers to have a more concrete and in-depth knowledge about the properties of chemicals, their hazards, precautions to be taken during use, rules for storage, and necessary first aid in case of possible accidents. Within the frame of experimental activities, laboratory safety issues can be handled from a wide perspective with active learning methods such as case studies, problem-based learning and cooperative learning, and thus, the knowledge of pre-service teachers on this subject can be increased.
- A wide variety of sample scenarios can be presented to the pre-service teachers about the accidents that may occur in the use, storage and disposal of chemical substances in the laboratory, and these issues can be studied in depth by questioning over the events that have occurred.

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Appendix . Example of 3rd Case

Princeton Üniversitesi laboratuvar kazası sonucu, üç kişi hastaneye sevk edildi!!!

Princeton Üniversitesi Frick Kimya Laboratuvarı'nın B seviyesindeki nükleer manyetik rezonans laboratuarının bir bölümü

Bu öğleden sonra Princeton Üniversitesi Frick Laboratuvarı'nda ani bir yangına ve havaya kimyasal madde karışmasına neden olan bir kazanın ardından üç kişi hastaneye sevk edildi.

Trenton Yangın Departmanı Kaptanı Michael Oakley, doktora sonrası araştırma yapan bir kız öğrencinin deney yaparken yanlışlıkla nitrik asite çözgen atığı eklemesi sonucunda bu öğrencinin, bir başka Princeton öğrencisinin ve bir güvenlik görevlisinin kimyasal tahrişler nedeniyle tedavi altına alındıklarını söyledi.

Olaydan etkilenen bu kişiler, planlanmamış bir kimyasal reaksiyonun çalıştıkları laboratuar ortamına bir miktar buhar açığa çıkarması sonucunda yaşadıkları kimyasal tahrişler nedeniyle hastaneye sevk edildiler.

Michael Oakley, deney sırasındaki bir anda nitrik aside bir çözücü eklendiğini ve bu kimyasallar birbirleriyle uyumlu olmadığından bir kıvılcım ve duman açığa çıktığını söyledi. Oakley, bu reaksiyonun kimyasal maddeyi barındıran kabın kırılmasına ve kadının yüzüne bir miktar maddenin sıçramasına neden olduğunu ifade etti. Ayrıca kadının gözlerinin altında bir kısım yanma hissettiğini ve tahriş olan bölgeyi laboratuarda musluk suyuyla yıkadıktan sonra hastaneye gönderildiğini belirtti. Güvenlik görevlisi, odaya girdikten sonra kollarında kaşıntı ve kızarıklık oluştuğunu söyledi ve diğer öğrenciyle birlikte hastaneye sevk edildi.

Oakley, yangının laboratuarda çıktığını ve havadaki kimyasalların neredeyse hepsinin, öğrencinin deney yaptığı özel bir çeker ocak aracılığıyla bertaraf edildiğini ekledi.

Tehlikeli maddelerin önlenmesine yönelik çalışan Trenton ekibi, turnusol kağıdı ve izleme sayaçlarını kullanarak olay yerinde uçucu organik bileşikler için bir test, kitle tehlike testi ve diğer değerlendirmeleri gerçekleştirdiler. Testler negatif çıktı ve binadaki hava kalitesi iyiydi. Oakley, olayı takiben oda temizliğinin yapılmasının üniversite yetkililerine devredildiğini söyledi. Oda ve binanın geri kalanı, okul yetkilileri tarafından kontrol edildikten sonra yeniden araştırmaya açılmıştır.

Haber kaynağı: https://www.nj.com/mercer/index.ssf/2012/05/princeton_university_laborator.html

A. Örnek olayda geçen kaza neden kaynaklanmıştır?

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