

The Effects of Laboratory Safety Professional Development Seminars Implemented on Science Teachers: Laboratory Safety Knowledge Levels

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ABSTRACT

When laboratory accidents in schools, especially in recent years, are examined, it is remarkable that many of these events resulted from the incorrect implementation of laboratory safety. The most significant role in the administration of laboratory safety belongs to science teachers. During this process, the necessity of laboratory safety training is for teachers to gain knowledge, skills, and attitude with regard to laboratory safety. This study aimed to investigate science teachers' knowledge level regarding laboratory safety and increase science teachers' knowledge level regarding laboratory safety through professional development seminars. Professional development seminars were carried out for teachers in eight modules which included both visual presentations and active learning-teaching activities. Training activities were planned in consideration of the subjects and experiments included in the current Turkish general science curriculum. The single-group pre-test post-test design, a semi-experimental design application, was used. To investigate the effects of laboratory safety professional development seminars, pre- and post-tests were applied to only one group. The "Laboratory Safety Knowledge Test" developed by the researchers was applied to determine teachers' improvement regarding laboratory safety. According to findings, there was a statistically significant difference between scores of changes in teachers' knowledge level regarding laboratory safety before and after professional seminars. Moreover, there was not a demographically significant difference between scores of changes in teachers' knowledge level. It is considered that the findings of the research will contribute to school laboratories being safer and more effective environments in which the activities of science lessons are carried out.

KEY WORDS: Laboratory safety; professional development seminars; science lesson; dimensions of laboratory safety; laboratory safety modules

INTRODUCTION

Science is not just a collection of natural facts about the world, but a way of inquiry and thinking based on empirical criteria, logical thinking, and constant questioning (MEB, 2018). The present century appears to be a period in which great and important advances have been made in the field of science, and innovative and creative developments have been revealed. As a result of this process, rapid advances in science and technology are also effective in the change of societies. It has been seen that human beings adapt to this change more easily than it is thought, and in addition, the developments that have taken place pave the way for new questions and searches.

Some changes are being worked on to meet the changing needs of society and individuals. In parallel with these developments, educational program developers have discussed new methods and processes that enable students to be much more active and to construct scientific concepts as meaningful structures in the mind. Among these methods, one of the most effective applications on active learning processes is the laboratory method. The laboratory method is a teaching method that

facilitates a more permanent learning in which students are able to work individually or in groups (Sarı, 2011). Students are also known to learn more effectively when theory is supplemented by a large component of laboratories (Llanos et al., 2021).

It has been argued that the natural sciences that describe vital events cannot be learned without examining and questioning. There have been many studies that show that laboratory practices are important and significantly effective in students' science achievement and development of positive attitudes toward science (e.g., Hofstein et al., 2005).

"Laboratory Safety" is the process of approaching problems with scientific methods in the name of taking precautions to determine the malfunctioning situations against the dangers that may occur against the tools and equipment and machinery. In additional, it defines the dangers that may occur in the studies prepared in the experiments carried out in the laboratory (Bayrak and Ağaoğlu, 1999).

Laboratory safety in schools covers the risks that may occur in processes such as the use, labeling, storage, and waste disposal of chemicals in science lessons and the precautions to be taken in learning environments. Safety must be a consideration for

everyone exposed to hazardous substances, as well as to the risks in the standard operation of laboratory equipment. To prevent accidents, considerable efforts have been undertaken to improve safety education (Wu et al., 2020).

In addition, the use of laboratory equipment and glassware, fire and electrical accidents, and biological hazards are among the factors affecting the formation process of laboratory safety. The use of personal protective equipment and being conscious about first aid are among the precautions to be taken before possible accident situations.

The purpose of laboratory safety is to protect all persons in the laboratory, as well as the study material, from any kind of accident. In terms of school science curriculum, safety and health issues are at the forefront of sensitive issues that should be emphasized at least as much as other science subjects and materials (Fuller et al., 2001). In addition, the laboratory environment is often a more dangerous area to work with the materials not often used in the classroom environment. Alaimo et al. (2010) pointed out that increasing understanding of chemical hazards and risk management needed to be accompanied by a new culture of concern for laboratory safety.

In laboratory applications, teachers have a great responsibility in all kinds of precautions and emergency response applications regarding laboratory safety. Science teachers should ensure the safety of their students, provide a healthy working environment, and be able to determine what kind of situations students may encounter as a result of their actions. For students to avoid harming themselves or causing injury to others, they need to be instructed on how to behave safely (Townsend and Goffe, 2022). Science teachers should carefully inform the class and give the necessary instructions for safety before independent studies. It is one of the duties of the teacher to experience the activities to be done beforehand and to present the possible risks. Therefore, the environment where the experiment or application will be made should be organized in accordance with the realization of the activity. Dangerous situations should be reported to the necessary units immediately in the form of a report. It is important to have consistent behavior regarding the rules in practice. Records containing all processes of laboratory practice should be kept properly and dated in any case. The teacher should be present in the laboratory at all times to carry out the necessary safety counseling throughout the process and have information about the legal processes with regulations regarding the security dimension of the activities carried out in the science lessons. Primarily, teachers should prepare written information containing safety rules for their students, distribute these instructions to their students, and update their instructions at regular intervals.

According to National Science Education Standards, science teachers need to improve their skills and knowledge about laboratory safety issues. Today, laboratory applications are more widely used in science lessons. The increase in usage also leads to an increase in the responsibilities of science teachers (NSTA, 2007). An effective science teacher should

have the skills to plan experimental research and work safely in the laboratory.

In a study by Erol et al. (2010), it was concluded that science teachers felt inadequate about having all the necessary knowledge and skills to create a safe working environment in the laboratory. In addition, it was explained that the same situation applied to recognizing and using all the tools and equipment in the laboratory.

Therefore, many studies (Omokhodion, 2002; Simonne and Eakes, 2008; Wu et al., 2020) emphasized that science teachers should attend in-service courses that include first aid training and laboratory safety information for situations they may encounter in the laboratory.

In the face of possible accident risks, it is very important to inform science teachers about possible dangers that may occur during the lesson and classroom safety that should be maintained (DeMary, 2000). Especially with the increasing emphasis on active learning practices, it has been pointed out that teachers should focus more on laboratory practices and, accordingly, on issues such as safety and responsibility (CSSS, 2000).

Purpose of the Study

When the studies on science laboratories are examined, it is understood that teachers need safety training for the use of laboratories in science classes. At the same time, it was understood that many accidents were caused by lack of knowledge about laboratory safety (Erol et al., 2010; Roy et al., 2010; Pekdağ, 2020; Wu et al., 2020; Llanos et al., 2021).

When the national and international studies are examined, it is noteworthy that in general, science teachers cannot perform laboratory practices at the desired level (Fuller et al., 2001; Omokhodion, 2002; Güzel, 2003; Baltürk, 2006; Kaleli et al., 2006; Küçüköner, 2010; Türk, 2010; Kaya and Büyük, 2011).

In the light of explanation above, this study aimed to increase the level of knowledge on laboratory safety for teachers with taking the necessary precautions against possible accidents in the laboratory and acting consciously in case of a possible accident. Laboratory safety professional development seminars included the use of chemicals, labeling, storage, waste disposal, use of laboratory equipment and glassware, precautions against fire and electrical accidents, biological hazards, use of personal protective equipment, and first aid. It is thought that laboratory safety through professional development seminars will contribute to the understanding of the importance of laboratory safety in schools.

Research Question

What are the effects of professional development seminars on science teachers' knowledge of laboratory safety?

Sub-Questions

1. How do science teachers' knowledge levels of laboratory safety differ significantly before and after professional development seminars?

2. How do science teachers' knowledge levels of laboratory safety differ significantly in terms of gender before and after professional development seminars?
3. How do science teachers' knowledge levels of laboratory safety differ significantly in terms of educational status before and after professional development seminars?
4. How do science teachers' knowledge levels of laboratory safety differ significantly in terms of graduation department before and after professional development seminars?

METHODOLOGY

Procedure

Before beginning the research study, the participants were informed about the aim of the work to be conducted. During the professional development seminars, modules were developed to increase teachers' laboratory safety knowledge levels. Eight different modules were implemented during the 6 weeks. Titles of the modules are presented below.

- Module 1 Introduction of Chemicals Part 1
 - Usage of chemicals
 - Labeling of chemicals
- Module 2 Introduction of Chemicals Part 2
 - Storage of Chemicals
 - Waste Disposal
- Module 3 Correct Usage of Glassware Materials
- Module 4 Accidents Caused by Fire
- Module 5 Accidents Caused by Electrical Problems
- Module 6 Safety Protections
- Module 7 Pathogens
- Module 8 First Aid.

The modules were carried out with informative applications, video presentations, invitations of experts, use of activity booklets, and group studies with laboratory materials.

Research Design

The single group pre-post-test design, which is one of the semi-experimental design applications, was used in this study. Within the scope of the study, laboratory safety knowledge test (LSKT) was applied as a pre-test and then, at the end of the module applications, LSKT was applied to the same group again and the significance of the change was tested on variables.

Sample

The study group of the research consists of 33 volunteer science (secondary school) teachers who attended professional development seminars. Teachers who attended to the research have been working at secondary schools in Turkey. All participating teachers provided informed consent.

Data Collection Tools

To obtain the data of the research, LSKT developed by the researchers was used as a measurement tool to examine the change in the science teachers' knowledge level on laboratory safety.

The dimensions examined within the scope of the research (introducing chemicals, using glassware, fire safety, electrical safety, personal protective equipment, biological hazards, and first aid) were taken into account in the creation of the test items. The test was multiple-choice questions and the questions are prepared with five options.

The test, which was first prepared in 38 questions, was submitted to the opinion of three experts with the specification tables to test the content validity. The experts whose opinions and suggestions are sought are those who work as lecturers in the field of science education. After receiving expert opinion, four questions were removed from the test, and the options for two questions were rearranged. In the final form, LSKT test consisting of 34 questions and was applied to a total of 157 teachers in the pilot study. The difficulty of a substance also affects other technical properties such as the discrimination power of that substance.

To distinguish different levels of achievement and to rank the participants according to their learning levels, the average difficulty of an achievement test is expected to be around 0.50. This is due to the fact that a test with this difficulty is more reliable and more distinctive (Tekin, 1996). In this study, the average difficulty of the test was found to be approximately 0.491 and the discrimination power of 0.269. This result indicates that the test is ideally discriminating. The correlation coefficient shows the degree of relationship between two series of measurements. The validity of the item can be interpreted by looking at the point biserial and biserial correlation values. The biserial correlation value of the test was calculated as 0.266. As a result of the analysis made in the final situation, 10 items were removed from the 34-item knowledge test prepared for laboratory safety. The final version of the test consists of 24 items with five options was administered to 33 science teachers participating in the study before and after the professional development seminars on a single group as a pre-test and post-test, and the significance of the data was tested in terms of the variables examined.

Data Analysis

LSKT applied before and after the professional development seminars and the data were analyzed in SPSS 15.0 program. Significance level for LSKT was accepted as 0.05 and the results were evaluated on this basis. Shapiro-Wilk, Wilcoxon, Mann-Whitney U, and Kruskal-Wallis H-tests were used in the analysis according to the variables of the research. The results of the Shapiro-Wilk test were used in cases where the normality assumption of the laboratory safety knowledge test was examined in terms of gender, education status, and department of graduation. The Wilcoxon signed-rank test is designed for use with repeated measures: That is when your subjects are measured on two occasions or under two different conditions (Pallant, 2005). Wilcoxon signed-rank test results, which are suitable for two related samples, in which the significance of the change scores in the knowledge levels before and after the professional development seminars was

tested, and the normality assumption was non-parametric, were used.

The results of the Mann–Whitney U-test analysis were included for pairwise (female-male and undergraduate-master’s) comparisons, in which the significance of mean scores in knowledge levels before and after professional development seminars was tested in groups where the normality assumption was non-parametric in terms of gender and educational status. Kruskal–Wallis tests allow to compare two or more than 2 groups. Scores are converted to ranks and the mean rank for each group is compared (Pallant, 2005). It is recommended as a non-parametric alternative instead of one-way ANOVA where the normality assumptions are parametric (Büyüköztürk, 2007). Kruskal–Wallis H-test was used in the analysis of LSKT scores in terms of graduation department (science-physics-chemistry-biology) of science teachers.

RESEARCH RESULTS

In this context, research findings were given in terms of knowledge level, gender, educational status, and graduation department which were tabulated and interpreted. The significance of the mean scores in laboratory safety knowledge levels obtained as a result of transferring the module applications during the research process.

Research Results of Questions 1

How do science teachers’ knowledge levels of laboratory safety differ significantly before and after professional development seminars?

The effect of professional development seminars on science teachers was examined according to knowledge levels. Table 1 shows, the pre- and post-test results according to the LSKT are presented with the mean (\bar{X}) and standard deviation (SD) values.

As shown in Table 1, the pre-test mean score for LSKT before the professional development seminars was 10.42, while the post-test was 19.12. According to the results, it is seen that post-test mean score was higher than the pre-test score (\bar{X} : 8.70). Wilcoxon signed-ranks test which is the non-parametric alternative to the repeated measures t-test was used to understand whether the difference between pre- and post-test mean scores was statistically significant. Relevant data are given in Table 2.

According to the results of the analysis, Table 2 shows that significance level was <0.05 which means that there was a statistically significant difference between the two scores in the knowledge levels before and after the professional development seminars ($Z = 5.02, \rho < 0.05$).

Research Results of Questions 2

How do science teachers’ knowledge levels of laboratory safety differ significantly in terms of gender before and after professional development seminars?

The effect of professional development seminars on science teachers was examined according to gender. The distribution of science teachers participating in the study in terms of gender is given in Table 3 with frequency and percentage values.

As shown in Table 3, 14 (42.4%) of the 33 science teachers in the sample were female and the remaining 19 (57.6%) were male. When the results were examined, it can be said that the number of teachers participating in the study was similar to each other in terms of gender distribution.

To assess the significance of the change in the knowledge level of the participants in the study in terms of gender, whether the data had a normal distribution or not were examined. According to the results, it was decided which of the parametric or non-parametric statistical techniques would be used. Table 4 shows the results of the normality test applied on the distribution of science teachers participating in the study in terms of gender.

In cases where the number of samples is <50 , the Shapiro–Wilk test can be used to test the conformity of the data to the normal distribution (Büyüköztürk, 2007). Since the number of participants in the groups was <50 (n : 14 for male and n : 19 for female); Shapiro–Wilk test was preferred in comparison of groups.

According to Table 4, the results for the post-test scores for male (0.727), post-test scores for female (0.090), and the difference between pre- and post-test for male (0.503) showed a normal distribution because the ρ values were greater than the significance level of 0.05; however, pre-test scores of male ($\rho = 0.014$), pre-test scores of female ($\rho = 0.046$), and difference between pre- and post-test of female participants ($\rho = 0.019$) was >0.05 which means that the data did not

Table 1: Comparison of knowledge test pretest-posttest scores related descriptive statistics

n	Pre-test		Post-test		Difference between pre- and post-test	
	Mean (\bar{X})	SD	Mean (\bar{X})	SD	Mean (\bar{X})	SD
33	10.42	3.11	19.12	2.76	8.70	3.71

Table 2: Wilcoxon signed- ranks test

Wilcoxon signed-ranks test	Difference between pre- and post-test
Z-value	5.02*
Asymp. Sig.	0.000**
n	33

*Based on negative ranks, ** $\rho < 0.05$

Table 3: Distribution of the sample by gender

Gender	Frequency (f)	Percentage
Female	14	42.4
Male	19	57.6
Total	33	100

Table 4: Test of normality (gender)

Test of normality	Gender	Kolmogorov-Smirnov ^a			Shapiro-Wilkis		
		Statistics	df	Sig.	Statistics	df	Sig.
Pre test scores	Male	0.186	14	0.200	0.835	14	0.014*
	Female	0.220	19	0.016	0.899	19	0.046*
Post test scores	Male	0.118	14	0.200	0.960	14	0.727
	Female	0.164	19	0.191	0.915	19	0.090
Difference between pre and post test	Male	0.175	14	0.200	0.946	14	0.503
	Female	0.207	19	0.031	0.878	19	0.019*

* $p < 0.05$

follow normal distribution. Since the change in knowledge levels did not show a normal distribution in at least one of the groups, it was decided to use the Mann–Whitney U-test, which is a non-parametric test. Since one of the variables considered is categorical (gender) and the other is continuous (change in knowledge level), the Mann–Whitney U-test was preferred. In Table 5, the results of the Mann–Whitney U-test, which was conducted to determine whether the ranks for the gender differ significantly are given.

As shown in Table 5, value is 0.094, which indicates no statistically significant difference. It is understood that the effect of professional development seminars on science teachers according to gender does not show a significant difference

Research Results of Questions 3

How do science teachers' knowledge levels of laboratory safety differ significantly in terms of educational status (undergraduate and graduate) before and after professional development seminars?

The effect of professional development seminars on science teachers was examined according to educational status. The distribution of science teachers participating in the study in terms of educational status (undergraduate and graduate) is given in Table 6.

As shown in Table 6, 29 of the 33 science teachers had undergraduate education while four of them had graduate education. Percentage distribution of the teachers participating in the study according to their education status was determined as 87.9% undergraduate and 12.1% graduate.

To assess the significance of the change in the knowledge level of the participants in terms of educational status, whether the data had a normal distribution or not were examined. According to the results, it was decided which of the parametric or non-parametric statistical techniques would be used. Table 7 shows the results of the normality test applied on the distribution of science teachers participating in the study in terms of educational status.

Since the number of participants in the groups was < 50 ($n = 29$ for undergraduate and $n = 4$ for graduate); Shapiro–Wilk test was preferred in comparison of groups. If the significance value of the Shapiro–Wilk test is > 0.05 , it indicates that the data have normal distribution.

Table 5: Mann–Whitney U-test (gender)

Mann–Whitney U-test	Gender	n	Mean rank	Sum of rank	U	ρ
Score difference	Male	14	13.75	192.50	87.5	0.094*
	Female	19	19.39	368.50		
	Total	33				

* $p < 0.05$

Table 6: Distribution of the sample by educational status

Educational status	Frequency (f)	Percentage
Undergraduate	29	87.9
Graduate	4	12.1
Total	33	100

According to Table 7, the differences between undergraduate pre-test scores ($\rho = 0.029$) and difference between pre- and post-test scores ($\rho = 0.038$) did not have a normal distribution. Since the change in knowledge levels did not have a normal distribution in at least one of the groups, it was decided to use the Mann–Whitney U-test, which is a non-parametric test. Since one of the variables considered is categorical (educational status) and the other is continuous (change in knowledge level), the Mann–Whitney U-test was preferred. In Table 8, the results of the Mann–Whitney U-test, which was conducted to determine whether the ranks for the educational status differ significantly, are given.

As shown in Table 8, $\rho = 0.655$ indicates no statistically difference between having graduate or undergraduate education status on the knowledge levels before and after the professional development seminars ($\rho > 0.05$). It is understood that both the science teachers who have graduate and undergraduate education status have a similar change in their laboratory safety knowledge levels after the professional development seminars.

Research Results of Questions 4

How do science teachers' knowledge levels of laboratory safety differ significantly in terms of graduation department before and after professional development seminars?

The effect of professional development seminars on science teachers was examined according to department they graduated

Table 7: Test of normality (educational status)

Test of normality	Educational Status	Kolmogorov-Smirnov ^a			Shapiro-wilk		
		Statistics	df	Sig.	Statistics	df	Sig.
Pre test scores	Undergraduate	0.132	29	0.200	0.919	29	0.029*
	Graduate	0.151	4		0.993	4	0.972
Post test scores	Undergraduate	0.130	29	0.200	0.939	29	0.092
	Graduate	0.314	4		0.854	4	0.240
Difference between pre and post test	Undergraduate	0.179	29	0.018	0.924	29	0.038*
	Graduate	0.203	4		0.980	4	0.899

* $p < 0.05$

from. The distribution of science teachers participating in the study in terms of the graduation department (biology, science, physics, and chemistry) is given in Table 9.

As shown in Table 9, 5 (15.2%) of the 33 science teachers in the study group graduated from biology and 15 (45.5%) of them from science department while 8 (24.2%) from physics and remaining 5 (15.2%) from chemistry department.

To assess the significance of the change in the knowledge level of the participants in terms of educational status, whether the data had a normal distribution or not were examined. According to the results, it was decided which of the parametric or non-parametric statistical techniques would be used. Table 10 shows the results of the normality test applied on the distribution of science teachers participating in the study in terms of graduation department.

Since the number of participants in the groups was < 50 (biology $n = 5$, science $n = 15$, physics $n = 8$, and chemistry $n = 5$); Shapiro–Wilk test was preferred in comparison of groups. If the significance value of the Shapiro–Wilk test is > 0.05 , it indicates that the data have normal distribution.

According to Table 10, pre- ($p = 0.046$) and post-test scores ($p = 0.032$) of biology departments and post-test scores of science department ($p = 0.032$) did not show normal distribution. In addition, score difference of chemistry department ($p = 0.030$) did not show a normal distribution.

Since the change in knowledge levels did not have a normal distribution in at least one of the groups, it was decided to use a non-parametric test. The Kruskal–Wallis test, which is similar to the Mann–Whitney U-test but allows the comparison of more than 2 groups, was preferred in the analyses. The Kruskal–Wallis test results of the change scores in the laboratory safety knowledge level of science teachers graduated from different departments are given in Table 11.

Kruskal–Wallis test is the non-parametric alternative to a one-way between groups analysis of variance which allows to compare the scores on some continuous variable for three or more groups (Pallant, 2005). According to Table 11, scores from LSKT were converted to ranks and the mean rank for each graduation department (biology, science, physics, and chemistry) was compared. The finding shows that the significance level was 0.421 which is > 0.05 . Therefore, these

Table 8: Mann–Whitney U-test (educational status)

Mann Whitney U test	Educational Status	n	Mean Rank	Sum of Rank	U	ρ
Score difference	Undergraduate	29	16.72	485.00	50.0	0.655*
	Graduate	4	19.00	76.00		
	Total	33				

* $p < 0.05$

Table 9: Distribution of the sample by educational status

Graduation department	Frequency (f)	Percentage
Biology	5	15.2
Science	15	45.5
Physics	8	24.2
Chemistry	5	15.2
Total	33	100

results do not statistically differ in LSKT scores across the different graduation departments [$\chi^2(2) = 2.81$, $p > 0.05$]. It is understood that the effects of professional development seminars on laboratory safety knowledge levels do not show a significant difference in terms of graduation department of science teachers.

DISCUSSION

In this section, the effects of laboratory safety professional development seminars applied to science teachers on laboratory safety knowledge levels are explained.

Discussion on Research Questions 1

In the first sub-problem of the research, the difference in laboratory safety knowledge levels of laboratory safety professional development seminars applied to science teachers was examined in terms of mean scores. When the scores of science teachers from the laboratory safety knowledge test before and after participation in professional development seminars were examined, it was seen that (Table 2) the difference between pre- and post-test mean scores was statistically significant based on positive ranks ($Z = 5.02$, $p < 0.05$). It can be said that the professional development seminars applied based on the data increase the laboratory safety knowledge level of science teachers and have an

Table 10: Test of normality (graduation department)

Test of normality	Graduation department	Kolmogorov–Smirnov			Shapiro–Wilk		
		Statistics	df	Sig.	Statistics	df	Sig.
Pre-test scores	Biology	0.349	5	0.046	0.771	5	0.046*
	Science	0.215	15	0.061	0.893	15	0.074
	Physics	0.144	8	0.200	0.978	8	0.955
	Chemistry	0.254	5	0.200	0.803	5	0.086
Post-test scores	Biology	0.364	5	0.029	0.753	5	0.032*
	Science	0.205	15	0.089	0.869	15	0.032*
	Physics	0.192	8	0.200	0.941	8	0.619
	Chemistry	0.216	5	0.200	0.885	5	0.332
Score difference	Biology	0.214	5	0.200	0.821	5	0.119
	Science	0.196	15	0.127	0.941	15	0.400
	Physics	0.292	8	0.043	0.901	8	0.293
	Chemistry	0.350	5	0.045	0.750	5	0.030*

* $p < 0.05$

Table 11: Kruskal–Wallis test

Kruskal–Wallis test	Graduation department	n	Mean rank	df	Chi-square χ^2	Sig. ρ
The difference between pre- and post-test scores	Biology	5	11.90	3	2.81	0.421*
	Science	15	19.47			
	Physics	8	15.00			
	Chemistry	5	17.90			
	Total	33				

* $p < 0.05$

important effect on improving the laboratory safety knowledge levels.

When the relevant literature is examined, some studies supporting the results of the research were found. In one of these studies, it was emphasized that teachers needed training on the use of laboratories. Güzel (2003) stated that about half of the science teachers needed special training for laboratory use, and about three quarters of them were willing to participate in in-service courses to increase laboratory use.

It was determined that some mistakes were made in the study put forward by Coştu et al. (2005) to determine the deficiencies of the pre-service science teachers' skills in using laboratory materials correctly. These results also support the need for training on laboratory safety.

Gudyanga (2020) states the requirements for develop professional development programs for in-service teachers, especially those who may not have majored in chemistry, aimed at improving their chemical laboratory safety awareness.

Erkan and Göz (2006) stated that 92.2% of the teachers from different departments and 89.6% of them had a lack of knowledge about heart massage and artificial respiration in the study they carried out with the aim of determining the level of knowledge of primary school teachers about first aid. It has been suggested that teachers should be trained on first aid and that a health worker should be present in schools. In the study conducted by Karaca et al. (2006), on determining the

difficulties encountered in the laboratory in science education, it was emphasized that some of the problems encountered were caused by the insufficient explanation of safe working techniques in the laboratory. Similarly, one of the studies on the positive effects of professional development seminars belongs to Ekpo (1998) which focused on the development of some safety modules in terms of the development and design of chemistry laboratories in secondary schools and stated that developed modules play an important and effective role in reducing possible accidents.

In the study conducted by Omokhodion (2002) on laboratory health and safety of science students, it was suggested that appropriate training and inspections should be carried out in which laboratory students studying in science classes can protect themselves by ensuring that students learn safe working practices during their education under the supervision of instructors.

Townsend and Goffe (2022) emphasized that the courses to be given on laboratory safety were comprehensive. One of the biggest challenges for educators is to make their students to understand the importance of course content. They mention that this is necessary not only for the curriculum but also for daily life skills.

Alaimo et al. (2010) mentioned the emergence of a new culture that has concerns about laboratory safety and similarly in another study by CSSS (2000) pointed out that teachers should focus more on laboratory safety practices in recent years.

Discussion on Research Questions 2

In the second sub-problem of the research, the difference in the laboratory safety knowledge levels of science teachers before and after professional development seminars is examined in terms of gender.

When the scores of the science teachers from the laboratory safety knowledge test before and after participating in the professional development seminars are examined (Table 5), it can be said that the change in the laboratory safety knowledge level of the science teachers attending the professional development seminars does not statistically differ in terms of being male or female ($U = 87.5$ $\rho > 0.05$). This finding can be interpreted as that after the seminar training, female teachers had an equal increase in knowledge about laboratory safety with male teachers.

When the relevant literature is examined, some studies supporting the results of the research were found. In a study comparing the views of science and technology teachers on the undesirable student behaviors, they encounter in laboratory environments according to the gender variable; it is stated that the gender variable does not cause a significant difference (Üstün, 2013). In another study, the level of teachers' self-efficacy regarding laboratory practices in science teaching was compared in terms of gender, and there was no significant difference between genders in terms of teachers' levels of self-efficacy in laboratory practices (Akdemir, 2006). In another study examining the effect of gender, Baltürk (2006) stated that the attitudes of science teachers toward the use of laboratories do not differ according to gender. Similarly, in Akçöltekin's (2008) study on laboratory proficiency in primary school science lessons, it was seen that there was no difference according to gender when the views of teachers about the purposes of laboratory practices were examined.

Çakmak (2008) stated that there was no significant difference between the teachers in terms of the level of self-efficacy in laboratory practices, according to gender, and they generally find themselves competent. In the study carried out by Türk (2010) to determine the laboratory competences of primary school science teachers, the laboratory competences of primary school science teachers and the variation of these competences according to gender was investigated. As a result of the study, it was understood that there was no significant difference between the opinions of teachers of different genders about laboratories. Kaya and Boyuk (2011) investigated the self-efficacy views of gender reassignment science teachers about gender and laboratory studies. It is stated that science teachers are competent in terms of laboratory practices, and there is no statistically significant difference between teachers' self-efficacy scores according to gender.

Discussion on Research Questions 3

In the third sub-problem of the research, the difference in the laboratory safety knowledge levels of science teachers before and after professional development seminars is examined in terms of educational status.

When the scores of science teachers from the laboratory safety knowledge test before and after participating in the professional development seminars are examined (Table 8), it can be said that the difference in the laboratory safety knowledge levels of the science teachers who attended the professional development seminars does not statistically differ in terms of educational status ($U = 50.0$ $\rho > 0.05$).

It is understood that professional development seminars cause a higher increase in the knowledge level of teachers who have graduate status, but this increase does not show a significant difference in terms of educational status (undergraduate and graduate).

This finding can be interpreted as that teachers who have undergraduate or graduate degrees after the seminar training had an equal increase in knowledge level about laboratory safety. When the relevant literature is examined, some studies supporting the results of the research were found. In the study conducted by Kaya and Büyük (2011) on the competencies of science teachers for laboratory studies, science teachers' graduation status and views on laboratory studies were investigated. At the end of the research, it was determined that there was a statistically significant difference against the graduates of the education institute. In a similar study conducted by Gudyanga (2022), the teaching experience of teachers was investigated instead of undergraduate or graduate status. The results suggest no significant difference in participants' chemical laboratory safety awareness according to the duration of their teaching experience. In this case, it is considered that science teachers need training and seminars on laboratory safety in any case, regardless of graduation degree.

Discussion on Research Questions 4

In the fourth sub-problem of the research, the difference in the laboratory safety knowledge levels of science teachers before and after professional development seminars is examined in terms of graduation department (science, biology, chemistry, and physics).

When the scores of science teachers from the laboratory safety knowledge test before and after participating in the professional development seminars are examined (Table 11), it can be said that the difference in the laboratory safety knowledge levels of the science teachers who attended the professional development seminars does not statistically differ in terms of graduation department (science, biology, chemistry, and physics) [$x^2(2) = 2.81$, $\rho > 0.05$].

Considering the mean ranks for the groups, although it is seen that the teachers who graduated from science field has the highest (19.47) and biology field has the lowest (11.90) scores from LSKT results does not statistically differ in terms of being graduated from science, biology, chemistry, or physics.

It is understood that the graduation of different departments such as biology, science, physics, or chemistry does not have different effects on the LSKT scores. Results can be interpreted as that the teachers who graduated from science, biology,

physics, and chemistry had an increase about laboratory safety at similar rates after the professional development seminars on laboratory safety issues.

When the relevant literature is examined, some studies supporting the results of the research were found. In a similar study by Akdemir (2006), the difference in the proficiency levels of secondary school science teachers regarding laboratory practices according to their graduation departments was examined. The answers given to the survey results were evaluated one by one on the basis of items, and it was stated that the difference in proficiency levels in 16 of the 36 items did not show a significant difference in terms of having a biology, physics, chemistry, or science graduation.

In another study (Karaca et al., 2006), the opinions of the teachers participating in the survey about the laboratory conditions according to their graduation departments were discussed. When the results explained with qualitative frequency and percentage values are examined, 70% of science teachers and 52.2% of chemistry teachers find the ventilation of the laboratory insufficient. Most of the teachers stated that there were no first aid materials in the laboratory, 60% of the chemistry and science teachers stated that there was no fire extinguisher and 60.2% of the physics teachers stated that there was not enough experimental material. Besides, it was stated that there was no significant difference in terms of graduation departments from the views of the teachers about the difficulties in laboratory practices

In the study carried out by Türk (2010), laboratory competences were investigated according to graduation departments of participants. According to the findings, it is stated that there is no significant difference between the medians of the total scores of teachers from different graduation departments

In the study of Erkan and Göz (2006) to determine the knowledge level of teachers about first aid, results show that most of the teachers (68.4%) have not received training on first aid before. It is stated that there is no significant difference between the knowledge of teachers about first aid according to their graduation departments.

In a study examining similar variables, Kaya and Boyuk (2011) investigated the self-efficacy views of science (science and technology, physics, chemistry, and biology) teachers about laboratory studies. At the end of the research, it is stated that science teachers think that they are sufficient in terms of laboratory applications and there are significant differences between the groups according to the graduation department.

CONCLUSION

It can be said that the professional development seminars applied based on the data increased the laboratory safety knowledge level of these participating science teachers. However, in terms of gender, educational status, and graduation department variables do not cause a significant difference, it is understood that professional development seminars with

modules have an important effect on improving the laboratory safety knowledge levels of science teachers.

As a conclusion, some suggestions are explained in terms of contributing to the field. The content of the disciplines taught in science department in faculties of education should be enriched in terms of laboratory safety content, and it should be transformed into active learning experiences as well as theoretical information. In this way, transferring laboratory safety practices, which are considered as professional development trainings, from teachers to students can be facilitated. All laboratory courses should involve safety, so safety education and safe laboratory practices should be integrated as part of the normal course of study (Wu et al., 2020).

Laboratory safety training should be given to the students who participate in the laboratory practices of the science course in secondary schools, accompanied by their teachers, within the scope of the curriculum. It is thought that informing parents and administrators as stakeholders, sharing responsibilities and duties, will increase the effectiveness and permanence of the laboratory safety trainings.

The chemical material list in the school laboratories should be prepared by the science class teachers, including the name, symbol, hazard class, and warning explanation of the chemical, and should be hung in the laboratory and checked up to date. In this way, it can be ensured that students recognize chemicals and learn what kind of precautions they should take about their use.

Science teachers should be trained within the scope of the old and new labeling system for recognizing and improving the chemicals in the laboratory and should be able to replace old and torn labels using new pictograms.

Science teachers should prepare material safety data sheets covering the definition of the chemical and the supplier company, the composition of the hazardous chemicals, their physical and chemical properties, fire and explosion information, first aid and health hazard information, and precautions to be taken during use and storage. Teachers should use the forms as part of the laboratory inventory.

Based on this study, the following recommendations are made:

1. It should be ensured that science teachers have the necessary laboratory safety training on the cleaning of broken chemical-containing glassware and the use of spirit stove. Thus, it can be ensured that glass shards and alcohol furnace explosions, which are effective in the formation of a large part of the accidents, are minimized
2. It should be ensured that science teachers have the necessary laboratory safety training about fire extinguisher and control. In this way, it is possible to reduce material and moral losses by intervening in fires that occur in a way that can be controlled
3. It should be ensured that science teachers have the necessary laboratory safety training about the precautions

to be taken to be protected from the dangers that electricity may cause in schools, electricity leakage, electrical sockets, grounding, and leakage current relay. It is thought that these trainings will be effective in preventing electrical accidents that may occur, especially in schools with old buildings

4. It should be ensured that science teachers have the necessary laboratory safety training on the types of protective glasses, the use and installation of eyewash taps, and the safety of face, hand, body, and foot protection. In this way, it can be ensured that students also gain similar habits by encouraging them to use personal protective equipment effectively
5. It should be ensured that science teachers have the necessary laboratory safety training on requirements to reduce the danger of infectious diseases in schools. Applications that may cause infectious diseases include the use of syringes, injector spray, blood group determination test, oral sampling, culture examination, animal bites, and allergic reactions
6. In addition, necessary information should be given about the risks that may arise in public areas before taking the students on research trips
7. It should be ensured that all science teachers receive the necessary laboratory safety first aid training on situations that may occur in the laboratory that require first aid
8. Situations requiring first aid that may occur in the school laboratory can be explained as chemical spill-splash, fire, electrical shock, animal bite, and allergic reaction. In addition, chemical ingestion-poisoning, foreign matter in the eye and nose, cuts, bleeding, injury, loss of consciousness, respiratory, and cardiac arrest can be exemplified. The obligation to have an infirmary in public schools should be included in the scope of laws and regulations.

ETHICAL STATEMENT

Personally identifiable data was not collected. All participants voluntarily participated in the study and were informed about the content of the research. Official Permission has been obtained for the application from the Ministry of National Education (MoNE), Innovation and Educational Technologies General Directorate and is presented as supplementary.

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