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Examining Pre-Service Teachers' Views about Online Chemistry Laboratory Learning Experiences Amid the Covid-19 Pandemic

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ABSTRACT

With the continued spread of the COVID-19 crisis, the universities were closed temporarily in Turkey just as in the rest of the world. As a result of this, many educators and students tried to adapt online education quickly. This research study examined 67 pre-service teachers' views on online chemistry laboratory learning experiences amid the COVID-19 pandemic. A data collection tool consisting of seven open-ended questions was used. Data sources included responses given to open-ended questions about the online chemistry laboratory learning experiences, the applications used for the chemistry experiments (e.g., simulations, images, and videos), the methods used for assessing online learning, and the system used for the virtual classroom platform. Content analysis was applied to participants' responses. Participants' views about online chemistry laboratories amid the COVID-19 pandemic were gathered in five themes: (i) advantages and disadvantages of online chemistry laboratories, (ii) effects of online chemistry laboratories on learning outcomes, (iii) views on technological applications used in online chemistry laboratories, (iv) views on measurement and assessment methods used in online chemistry laboratories, and (v) views of pre-service teachers on the virtual classroom platform used in online chemistry laboratories. The findings of the study highlighted that online laboratory learning has both advantages and disadvantages. The findings also included the strengths and weaknesses of the system used for the virtual classroom platform. The findings may provide useful information on how to design a positive online laboratory experience such as integrating hands-on activities as a part of the online laboratories to overcome the lack of "learning by doing" and using videos containing more detailed explanations about the experimental setup.

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Introduction

COVID-19 has emerged as a global threat; it has had sudden and unexpected effects on our individual and social lives. With the COVID-19 pandemic, social relations began to be conducted remotely and many social lives had to be suspended. Some significant measures have been taken by countries such as restrictions on travel, reducing mass mobility, remote working, and distance education. There has been a rapid transition to distance education after the closure of schools, colleges, and universities. Schools, universities, teachers/instructors, and students have taken responsibility for remote learning. Efforts in many countries included the use of various digital platforms with educational content and educational technology solutions (Moreno & Gortazar, 2020), including Turkey.

Although distance education and online learning are concepts that have become very much a part of our lives during the COVID-19 pandemic, have been studied for decades. When the literature is examined, efforts have been made to clear up the confusion surrounding these concepts (Bates & Bates, 2005; Hodges et al., 2020; Moore et al., 2011). Distance education describes learning activities that take place when there is a physical separation between the instructor and the learners (Moore et al., 2011). Communication between the instructor and the learners can be through audio and video teleconferences, audio and video recordings, written correspondence, or multimedia systems. At present, the main communication technology is the World Wide Web. Online learning is a form of distance learning and refers to learning that takes place via computers and the Internet (Carliner, 2004).

There is an assumption that universities can easily adapt to online learning during a pandemic (Bassett & Arnhold, 2020) since they are no strangers to online education. However, this may not be the case because there are several particular class types at the tertiary level, including lectures, tutorials, laboratories, practical workshops, and fieldwork. Online learning during the pandemic may be particularly challenging for students and educators in practical applications and laboratory-dominated departments. One of those departments is science education.

The laboratory has always had a central and distinctive place in science education (Clough, 2002; Hofstein & Lunetta, 1982; Nersessian, 1991). Ausubel (1968) stated the importance of the laboratory with the following words: "The laboratory gives the students appreciation of the spirit and method of science... promotes problem-solving, analytic and generalization ability... provides students with some understanding of the nature of science" (p. 345). With the rapid advancements in information and communication technology, laboratory education environments have changed significantly (Scanlon et al., 2002). Traditional face-to-face laboratories have moved in to online.

There are two common types of the online laboratory: remote and virtual laboratories (Budai & Kuczmann, 2018). While in a virtual laboratory, experiments are simulated by using software, the remote laboratory allows the students to work on real-time experiments via the Internet from a remote location (Balamuralıthara & Woods, 2007). Remote and virtual labs can be integrated into the learning management system (LMS) in universities. Since the LMS controls the access of users to a website and ensures that all teaching resources are offered in the same environment, integration of online labs and the LMS is advantageous (Ruano et al., 2013). The type of online laboratory examined in the present study is not a remote lab. However, it is not a virtual lab either because the experiments were not based entirely on simulations. The online chemistry laboratories subjected in this study were designed owing to the COVID-19 pandemic. In the laboratory courses, pre-service teachers were provided with data previously obtained from face-to-face laboratories or simulation programs and videos of experiments in video-sharing platforms.

In science education literature, many studies are investigating the effectiveness of online laboratories or comparing traditional face-to-face laboratories with online laboratories in terms of their advantages and disadvantages (Başer & Durmuş, 2010; Brinson, 2015; Chini et al., 2010; Frederick, 2013; Nedic et al., 2003). An example is a problem of whether psychomotor skills are developed in online laboratories. According to Brinson's (2015) review of the empirical research about learning outcome achievement in virtual and remote versus traditional laboratories (face-to-face laboratories), there are few studies to compare the learning outcome in terms of psychomotor skills. Parker and Zimmerman (2011) found that students who performed microscopy in a live microscopy setting in the traditional lab significantly better than those who performed it in a virtual lab setting. However, Brinson (2015) reported that in other studies in terms of psychomotor skills such as setting up of an electrochemical cell (Hawkins & Phelps, 2013), robotic manipulation (Tzafestas et al., 2006), and the physical building of circuits (Farrokhnia & Esmailpour, 2010), the students in the online labs were significantly better than those in the traditional labs. Moreover, Seth and Haron (2016) conducted a literature study on the development capability of psychomotor skills according to the types of online labs. They claimed that “a virtual reality laboratory and remote laboratory only uses the "mouse click" and this cannot represent the required psychomotor development” (p.7).

In chemistry education, laboratory courses are traditionally considered an integral part of chemistry (Reid & Shah, 2007). In departments of chemistry and chemistry education, in higher education, for each chemistry course, there is usually a laboratory course; for example, for the organic chemistry, analytical chemistry, and physical chemistry courses along with the organic chemistry laboratory, analytical chemistry laboratory, and physical chemistry laboratory courses. Therefore, chemistry laboratory educators may have had more difficulty in conducting so many laboratory courses by delivering full content in the rapid transition to online learning (Tran et al., 2020). In the present study, there are three kinds of online chemistry laboratories: general chemistry laboratory, analytical chemistry laboratory, and organic chemistry laboratory. In the literature, there are often "online chemistry labs" studies not involving sub-branches of chemistry. Conducting the study in different domains of chemistry enriches its scope. In addition, the variety of experiments in the online chemistry laboratory courses is the strength of the study.

Before the COVID-19 pandemic, the studies on online laboratory courses were mostly quantitative. For example, when the literature on online biology laboratories is examined (Barbeau et al., 2013; Hauser, 2013; Johnson, 2002; Riggins; 2014), mostly quantitative studies comparing student performance in online and face-to-face classes are seen. There are also qualitative studies examining the quality and efficacy of online laboratory courses (e.g. Rowe et al., 2018). However, still there is a need for qualitative studies investigating what can be done to develop students' science concepts and skills through online education (Biel & Brame; 2016; Faulconer & Gruss, 2018; Winborne, 2020). In this regard, the qualitative nature of the present study is important since it exhibits the pre-service teachers’ views about online laboratory learning.

In Turkey, distance education in higher education institutions has been widespread since 2009 (Telli & Altun, 2020). There are 123 distance education centers (DECs) in 207 universities in Turkey. In their descriptive study in 2017, Kirkan and Kalelioğlu examined the overall DEC situation of universities in Turkey, they found that the most frequently selected programs were computer programming as an associate degree program and e-MBA in Business Administration as an undergraduate program Thus, it appears that online learning in science education and chemistry laboratories in Turkey is less common than in other fields. The present study aimed to examine the views of pre-service teachers about online chemistry laboratories designed due to the COVID-19 pandemic and the virtual classroom platform used in these laboratories. Therefore, the study fills an important gap in terms of online learning in science education and chemistry laboratories in Turkey.

Research Question of the Study

The research question of this study is: What are the views of pre-service teachers about online chemistry laboratories designed due to the COVID-19 pandemic?

Methods

Design of the Study

This was a survey study with a qualitative approach. In surveys, data are collected from individuals who represent a group whose are asked questions to determine the characteristics, views, perspectives, and beliefs of the relevant group (Fraenkel et al., 2012). It should be noted that this study was a qualitative survey study, not a statistical survey study. While in qualitative survey studies "the diversity of a subject within a given population is examined", in statistical survey studies the purpose is to show "the numerical distribution of the properties of a subject in a population" (Jansen, 2010). In qualitative studies, “the number of participants in a sample is usually somewhere between 1 and 20” (Fraenkel et al., 2012 p.103). The purpose of this qualitative survey study was not to make a statistical generalization but to reveal the diversity of the opinions of the participants in a particular group with open-ended questions. Considering both the purpose of the study and the sample size, it can be said that this study has met the requirements of the qualitative survey study.

Participants

The participants were 67 pre-service teachers in the Faculty of Education at a state university in Ankara, Turkey. They were selected using convenience sampling. In convenience sampling, the sample group consists of individuals who are easily accessible, available at a given time, and willing to participate (Cresswell, 2013). In the present study, the participants were selected by convenience sampling, because of their accessibility. Although convenience sampling appears to be a limitation, the participants in this study exemplify the profile of pre-service teachers studying at a state university. A total of 67 pre-service teachers from the Chemistry and Biology Education Departments participated. Although the pre-service teachers had face-to-face laboratory experiences for one semester, they did not have any experience of online laboratory courses. Characteristics of the participants are shown in Table 1.

Table 1

Participants' Characteristics

Department	N	%
Biology Education	18	27
Chemistry Education	49	73
Total	67	100
Gender		
Female	63	94
Male	4	6
Total	67	100
Grade Level		
1st grade	34	51
2nd grade	15	22
3rd grade	18	27
Total	67	100
Attended Place		
Province	46	69
County	20	30
Town	1	1
Total	67	100
Device Used		
Computer	40	60
Smart Phone	8	12
Computer and Smartphone	15	22
Computer, Smart Phone, and Tablet PC	1	1
Face-to-face Laboratory Experience	67	100
Online Chemistry Laboratory Experience	-	0

Ethical Considerations

At the beginning of the study, the participants were informed about the research procedure. They were told a study would be conducted within the scope of online laboratory courses and the findings of the study would be reported. The participants were informed that participation in the study was voluntary. In scientific studies, it is important to keep the identities of the participants confidential following ethical rules (Crow et al., 2006). In the present study, all participants were numbered to keep their identities confidential. These numbers were used in direct quotations.

Research Procedure

During the first four weeks of the spring semester of 2020, all laboratories in the university were conducted face-to-face. In the remaining weeks due to the sudden decision to make a transition to online education, the face-to-face laboratories had to switch quickly to become online laboratories. Online laboratories and, of course, other courses, started to be conducted with the university's Learning and Content Management System (LCMS) and the virtual learning technology license purchased by the university. The features of the virtual learning technology are sound, image, documentation, and screen sharing, using the whiteboard, raising hands, chatting with others, and replaying.

The research was conducted in the General Chemistry Laboratory, Analytical Chemistry Laboratory-II, and Organic Chemistry Laboratory-II courses. General chemistry laboratory courses for 1st-grade pre-service chemistry and biology teachers were conducted with the same content. Analytical chemistry laboratory course was conducted with 2nd-grade pre-service chemistry teachers and organic chemistry laboratory course was conducted with 3rd-grade pre-service chemistry teachers. The curriculums of those laboratory courses were not changed when they switched to being conducted online. The General Chemistry and Analytical Chemistry Laboratory-II courses, which take up two hours a week, were conducted in online education for a total of 60 minutes in two 30-minute sessions per week. The Organic Chemistry Laboratory-II course took up four hours a week, while the online education was held for a total of 120 minutes in two sessions of 60 minutes per week. All sessions in the online laboratory courses were online and took place with the simultaneous participation of students and laboratory instructors. During these sessions, while the instructors' cameras and microphones were on, the students generally participated by writing messages in the chat section of the system. In the first sessions of the online laboratory courses, theoretical lectures were delivered using PowerPoint presentations and web applications such as the whiteboard in the online system. In the second session, videos about experiments were posted on the video-sharing platform. The lecturers introduced the materials used in the experiments to the participants, who after had watched all the videos or by stopping videos occasionally. The participants' predictions and observations were asked when the videos were stopped. At the end of the videos, the results of the experiments were discussed. In the second session, instructors and participants used the simulations as well. The list of the experiments is given in Table 2.

Table 2

Experiments in Online Chemistry Laboratory Courses

General Chemistry Laboratory Experiments (For Pre-service Chemistry and Biology Teachers)	Organic Chemistry Laboratory-II Experiments (For Pre-service Chemistry Teachers)	Analytical Chemistry Laboratory-II Experiments (For Pre-service Chemistry Teachers)
• Solutions • Chemical Equilibrium • Acids-Bases • Distillation	• Enolate Reactions-I: Haloform Reaction • Enolate Reactions-II: Aldol Condensation • Cannizzaro Reaction • Detection of Carbon and Hydrogen Elements in Organic Compounds	• Fundamentals of Volumetric Analysis- Introduction to Titration and Types of Titration • Determination of OH^- ion by Neutralimetric titration • Determination of Cl^- ion by Argentometric titration

	• Saponification Ester Hydrolysis • Synthesis of Aspirin • Preparation of Bakelite Polymer • Detection of Elements (N, S, Cl) in Organic Compounds	• Redox Titration Fe^{2+} with Potassium Permanganate • Determination of Cu^{2+} ion by Iodometric Titration • Determination of Ca^{2+} ion by Complexometric Titration

The measurement and assessment processes in these online laboratory courses were as follows: for the General Chemistry and Analytical Chemistry laboratories, assignments were given at the end of every online class. The assignments for the General Chemistry Laboratory consisted of algorithmic and cause-and-effect reasoning questions. For Analytical Chemistry Laboratory-II, the assignments consisted of case-based questions. In the Organic Chemistry Laboratory-II course, pre-experiment questions and reports of experiments were given as assignments. All these assignments were defined as homework activities in the system, which used a virtual classroom platform every week. The laboratory instructors assessed the assignments and scored mid-term examinations. In all laboratory courses, the final exams were carried out as paper-and-pencil assessments. Paper-and-pencil exams which were defined as a homework activity by instructor, were answered by participants and after uploaded to the system.

Data Collection and Analysis

The data collection tool used to obtain the views of the participants about the online chemistry laboratory courses consisted of seven open-ended questions. For the content validity, two experts reviewed these questions on chemistry education. The participants were asked to respond to the questions after the completion of the online laboratory courses. Their written responses to the questions were received which are given below:

- What are the advantages of an online chemistry laboratory?
- What are the disadvantages of the online chemistry laboratory?
- What does the effect of the online chemistry laboratory on learning outcomes?
- Does the effect of the online chemistry laboratory on learning depend on the subject matter taught?
- What are your views about the technological applications used in the online chemistry laboratory?
- What are your views about the measurement and assessment methods used in the online chemistry laboratory?
- What are your views about the virtual classroom platform used in the online chemistry laboratory?

The written statements given by the participants to open-ended questions were analyzed using content analysis. Content analysis can generally be defined as "systematic coding of qualitative or quantitative data based on specific themes or categories" (Fraenkel et al. 2012). First, all written data were read and analyzed by two researchers. They then assigned raw codes and categories by considering the research questions. The code list was renewed as new codes emerged in line with the data collected from the participants during the coding process. During the analysis of the collected qualitative data, the inductive method (Strauss & Corbin, 1990) was used in which firstly, a general conceptual structure was created by two researchers by taking into account the research questions and extracting existing codes and themes in the literature. During the coding process, some of the previously extracted codes which were not stated by the participants were removed from the code list. In addition, the code list was renewed as new codes emerged in line with the data collected from the participants. In this way, while the predetermined code list directs the content analysis, the data obtained as a result of analysis an inductive approach were added to the previously created code list, or the old codes were changed according to the new codes. Participant statements containing 10% of the raw codes and code samples were subjected to consistency analysis by the other two researchers. Consistency (Miles & Huberman, 1994) was calculated as 95% by one of the researchers and 90% by the other. A consensus was reached as a result of discussions with the participation of all four researchers on all coding with incompatibility. After the codes were finalized, they were gathered under a higher-level concept, and categories were created. While creating the categories and placing the codes into the appropriate categories and the research questions were taken into consideration for the internal consistency of the codes under the emerging category. As the participants gave multiple responses to the questions, they were included in more than one category. The findings are presented along with the participants' percentages supported by direct quotations. An example of the code-category list used in the analysis of the data regarding the opinions of the participants is given in Table 3.

Table 3

Part of the Code-Category List Used in Data Analysis

Participant's expression	Code	Category
"We cannot do the experiments practically ourselves. Since we do not do them ourselves, we only learn in theory. We do not gain laboratory experience. We do not directly gain the ability to do experiments, we learned indirectly how to do that experiment through videos".	An obstacle to the development of psychomotor skills	Disadvantages
"I think the lesson conducted with distance education is better. Because the course contents and videos are always in a location that I can access, we can watch the course again whenever we want".	Replay capability	Advantages
"The laboratory lessons with face-to-face training also improved our psychomotor skills. Just like setting up an experiment, completing the experiment. But now it does not happen. We only learned theoretically".	Negative impact on learning outcome Positive impact on learning outcome	Psychomotor learning outcomes Cognitive learning outcomes
"Applications such as simulations, experiment videos, and whiteboards used in online lessons helped me a lot in understanding the lesson".	The usefulness of web applications	Sufficient technological applications

Results

The participants' views about online chemistry laboratory learning experiences amid the COVID-19 pandemic were examined in line with the research question; the views of pre-service teachers about online chemistry laboratories. Participants' views about online chemistry laboratories amid the COVID-19 pandemic were gathered in five themes: (i) Advantages and disadvantages of online chemistry laboratories, (ii) effects of online chemistry laboratories on learning outcomes, (iii) views on technological applications used in online chemistry laboratories, (iv) views on measurement and assessment methods used in online chemistry laboratories, and (v) views of pre-service teachers on the virtual classroom platform used in online chemistry laboratories.

(i) Advantages and Disadvantages of Online Chemistry Laboratories

The theme of advantages and disadvantages of online chemistry laboratories is divided into two categories, namely advantages and disadvantages. As a result of the analyses, a total of 19 codes were identified, seven in the advantages category and 12 in the disadvantages category. Analysis of the participants' views shows that diversity is higher in the category of disadvantages. The percentages of participants' views according to each code are given in Table 4.

Table 4

Distribution of Participants' Views on The Advantages and Disadvantages of Online Chemistry Laboratories

Categories	Codes	%
Advantages	Replay capability	34
	Theoretical parts of the lecture	28
	Use of technology	15
	Time and laboratory material savings	9
	Laboratory safety	7
	Diversity of experiments	1
	Clarity of experiments' results	1
Disadvantages	An obstacle to learning by doing	96
	Not understandable / Not instructive	57
	An obstacle to permanent learning	43
	An obstacle to the development of psychomotor skills	34
	An obstacle to the creation of episodes	33
	An obstacle to the development of scientific process skills	28
	An obstacle to the identification of chemicals and laboratory materials	18
	Lack of communication with the instructor	15
	Limited time /Time constraint	10
	An obstacle to group work	7
	Not entertaining /Not interesting	6
	Not student-centred	6

Examination of Table 4 shows that the advantages that participants often mention about online chemistry laboratories are being able to replay the records of laboratory courses (34%), the theoretical parts of the lecture (28%), and the use of technology (15%). Based on these results, the participants can be regarded as satisfied with the online chemistry laboratories because of the replay capability provided by the virtual classroom platform and the ability to watch the theoretical parts of the lecture over and over again. In addition, it is seen that the participants mentioned the use of technology as an advantage due to the use of web applications in the online chemistry laboratory such as simulation, whiteboard, and video-sharing platform, which are not often employed in face-to-face laboratories. In other words, the participants consider the capabilities (e.g., re-watching the theoretical parts of the lecture) they did not have in the face-to-face laboratory as advantages of the online chemistry laboratory. One participant's views from among the several responses that considered the opportunity to replay to be an advantage are given below:

Participant 1: When we miss the experiment in online sessions, it is possible to watch the experiment again and review it. We would not have such an opportunity in face-to-face education. We can also watch again other parts of the session we missed when we were online… The positive side is that we have the opportunity to watch and review the experiment over and over again. (3rd grade, Organic Chemistry Laboratory-II)

Examination of Table 4 reveals that the participants generally think that the online-chemistry laboratories are disadvantageous. The disadvantages that the participants often mention are that they prevent learning by doing (96%), they are not understandable/not instructive (57%), they prevent permanent learning (43%), they prevent the development of psychomotor skills (34%) and prevents the creation of episodes (33%). According to the participants, the most disadvantageous aspect of online chemistry laboratories is that they prevent learning by practice. Since the participants did not have the opportunity to do the experiments themselves in online laboratories, they regarded this as a major disadvantage and an obstacle to the development of psychomotor skills. One participant's views from among several responses about the disadvantages of online laboratories in terms of being an obstacle to learning by doing are given below:

Participant 2: I find the face-to-face laboratory course more satisfactory because we practice by ourselves and our observation opportunities are more convenient in face-to-face laboratory courses... I do not think that online learning is a better way of learning because we do not carry out the experiments one-on-one. Since we cannot observe the experimental results authentically, we cannot get sufficient visual information. (1st grade, General Chemistry Laboratory)

(ii) The Effects of Online Chemistry Laboratories on Learning

Participants' views about the effect of online chemistry laboratories on learning were examined under the following subthemes: learning outcomes and (ii) dependency on the subject matter. The subtheme of learning outcomes is divided into three categories, namely cognitive, affective, and psychomotor. The percentages of participants' views relating to the effect of online chemistry laboratories on learning outcomes are given in Table 5 below.

Table 5

Distribution of participants' views on the effects of online chemistry laboratories on learning outcomes

Categories	Codes	
	Positive impact on learning outcome	Negative impact on learning outcome
Cognitive learning outcomes	55	9
Affective learning outcomes	7	10
Psychomotor learning outcomes	0	46

The participants think that the online chemistry laboratories have a mostly positive impact on learning outcomes in terms of the cognitive domain (55%), but a mostly negative effect in terms of the psychomotor learning outcomes (46%). Although the participants were asked about the effect of the online laboratory on cognitive, affective, and psychomotor learning outcomes, most of the participants did not respond by making such a comparison. For example, the majority of the participants did not declare their views about the affective learning outcomes. When Table 4 and Table 5 are examined together, it is seen that none of the participants think that the online chemistry laboratory has a positive impact on acquiring psychomotor learning outcomes as it prevents learning by doing. On the other hand, it can be said that most of the participants who have difficulty understanding the theoretical parts of the lecture in face-to-face laboratories think that the online chemistry laboratory has a positive impact on cognitive learning outcomes because they can watch the theoretical parts of the lecture again. One participant's view about the positive effect of online chemistry laboratories on cognitive learning is given below.

Participant 3*:* The lecturing in the online laboratory made a great contribution to improving my learning of chemistry since I was unable to understand some of the instructor's statements in the lecturing part of the face-to-face laboratory (1st grade, General Chemistry Laboratory).

Another subtheme of the participants' views about the effect of online chemistry laboratories on learning is the dependency on the subject matter. This subtheme is divided into two categories, namely depending on the subject matter and not depending on the subject matter. The percentages of participants' views related to the effect of online chemistry laboratories on learning in terms of the subject matter are given in Table 6 below.

Table 6

Distribution of participants' views on the effect of online chemistry laboratories on learning in terms of the subject matter

Categories	Codes	%
Depends on the subject matter	No explanation	35
	Difficulty/Easiness of the subject matter	19
	Familiarity with the subject matter	9
	The attractiveness of the subject matter	7
	Total	70
Does not depend on the subject matter	No explanation	21
	Total	21

It is seen that participants think that learning mostly depends on the subject (70%) in online chemistry laboratories. However, it was determined that 35% of these participants stated that learning depends on the subject matter without any explanation. The participants associated this dependency most with the difficulty or easiness of the subject matter (19%). Some 21% of the participants stated that learning was not dependent on the subject matter in online chemistry laboratories without any explanation. One participant's view about dependency on the subject matter is given below.

Participant 4: Yes, it depends on the subject. While an acid-base experiment is easily understood, the crystallization experiment is difficult to understand and questions about it are challenging for us. (2nd grade, Analytical Chemistry Laboratory-II)

(iii) Views on Technological Applications Used in Online Chemistry Laboratories

The theme of views on technological applications, such as simulation and video sharing platforms, used during online chemistry laboratories is divided into two categories as sufficient and insufficient. A limited number of codes were found under these categories because most of the participants did not provide any explanation as to why they found technological applications sufficient and insufficient. The findings regarding the technological applications used are given in Table 7.

Table 7

Distribution of participants' views on technological applications used in online chemistry laboratories

Categories	Codes	%
Sufficient technological applications	No explanation	55
	The usefulness of web applications	24
	Total	79
Insufficient technological applications	No explanation	17
	Incomprehensible videos of the experiments	4
	Total	21

It is seen that the participants mostly think that the technological applications used are sufficient (79%). Some 24% of these participants find web applications such as simulation, PowerPoint, and whiteboard particularly useful. One participant's view about it is given below.

Participant 5: In the online laboratory, our instructors did their best to help us to understand the subject matter. They let us watch many videos about the experiments for every course, gave us homework allowing us to use simulations, and shared their lecture notes with us. Attempts were made to use technological applications as efficiently as possible. (2nd grade, Analytical Chemistry Laboratory-II).

It is seen that 21% of the participants think that the technological applications are insufficient and that 4% state that the technological applications are insufficient due to the videos of experiments are not being understood. One participant's view about it is as follows:

Participant 6: I cannot say that I fully understood the videos of experiments. I could not fully understand the videos we watched (3rd grade, Organic Chemistry Laboratory-II).

(iv) Views on Measurement and Assessment Methods Used in Online Chemistry Laboratories

The theme of views on measurement and assessment methods used during online chemistry laboratories is divided into two categories, namely suitable and unsuitable. The findings regarding the measurement and assessment methods used are given in Table 8.

Table 8

Distribution of participants' views on measurement and assessment methods in online chemistry laboratories

Categories	Codes	%
Suitable measurement and assessment methods	-	70
	Total	70
Unsuitable measurement and assessment methods	Inability to avoid cheating in the exams	7
	Limited time to complete the exams	7
	Not practice-based exams	7
	Total	21

Table 8 shows that most of the participants (70%) think that the measurement and assessment methods are suitable. However, these participants did not provide any explanation as to why they found the methods suitable. Some 21% of the participants explain why the measurement and assessment methods are unsuitable such as the inability to avoid cheating in the exams (7%), limited time to complete the exams (7%), and no practice-based exams (7%). The views of one participant who finds the measurement and assessment methods suitable and one who finds them unsuitable are given below.

Participant 7: Homework and exams were suitable for the online laboratory course. Pre-experiment questions helped us to understand the experiment more easily. The reports of experiments we wrote after the experiment made the experiment more permanent for us. (3rd grade, Organic Chemistry Laboratory-II)

Participant 8: I think the homework and exams given in this online laboratory course were not suitable to assess what we learned because the exams were paper-and-pencil tests and not practice-based. (1st grade, General Chemistry Laboratory)

(v) Views of Pre-Service Teachers on The Virtual Classroom Platform Used in Online Chemistry Laboratories

The participants' views about online chemistry laboratories amid the COVID-19 pandemic were gathered in two categories: (i) positive aspects of the virtual classroom platform and (ii) negative aspects of the virtual classroom platform. As a result of the analyses, a total of five codes were identified, three in the positive aspects category and two in the negative aspects category. The findings regarding the virtual classroom platform used in online chemistry laboratory education are given in Table 9.

Table 9

Distribution of participants' views on the virtual classroom platform used in online education

Categories	Codes	%
Positive aspects	Usefulness	42
	Replay capability	34
	Providing communication	14
	Total	90
Negative aspects	System problems	64
	Lack of communication	21
	Total	85

Table 9 reveals that the participants have both positive (90%) and negative (85%) views about the virtual classroom platform. The codes regarding the positive views and the percentage of participants are as follows: usefulness (42%), replay capability (34%), and providing communication (14%). An example of one participant's positive view is as follows:

Participant 9: The virtual classroom platform used in this online laboratory helped us a lot. It provided us with the opportunity to communicate with our instructors and allowed us to watch the sessions we could not attend. The virtual classroom platform helped us a lot in understanding the lesson by providing the opportunity to watch the sessions repeatedly whenever we wanted. (1^{st} grade, General Chemistry Laboratory)

On the other hand, the participants pointed out some negative aspects such as system problems (64%) and lack of communication (21%). Examples of one participant's negative views are as follows:

Participant 10: The sound in the virtual classroom platform cut out most of the time. There were many problems such as system freeze... It was an educational period that took place without student-instructor interaction (2^{nd} grade, Analytical Chemistry Laboratory-II).

According to the results about the virtual classroom platform, although the participants generally find the virtual classroom platform useful, it is seen that they also have systemic problems. In addition, there are points about the virtual classroom platform they find both positive and negative in terms of ensuring communication.

Conclusions and Implications

The current situation has imposed many constraints on teaching chemistry laboratories but technology and the Internet allowed instructors to continue teaching and maintain learning by employing various online platforms, but what was the situation like for learners? What were their views about their experience in this new way of teaching and learning? This study analyzed the opinions of pre-service teachers. Although the pre-service teachers talked about the advantages of online laboratories, they mostly focused on the disadvantages. The pre-service teachers' views about the advantages and disadvantages of online laboratories also revealed the points they care about in face-to-face laboratory training. For example, they mostly emphasized the lack of "learning by doing" in online laboratories. "Learning by doing is the process whereby people make sense of their experiences, especially those experiences in which they actively engage in making things and exploring the world. It is both a conceptual designation applied to a wide variety of learning situations and a pedagogical approach in which teachers seek to engage learners in more hands-on, creative modes of learning." (Bruce & Bloch, 2012). Likewise, their opinions about the lack of development of "psychomotor skills" and the absence of "episodes" supported their views about the lack of "learning by doing". Millar (1998) mentioned that there is a "memorable episode supply" function to laboratory tasks. That is, there is some evidence that our memories do not store only ideas and rules but also whole episodes.

On the other hand, pre-service teachers thought that "theoretical lecturing" was given enough and evaluated it as an advantage.

Another advantage of online laboratories, according to the pre-service teachers, was the prevention of accidents that may occur and the prevention of waste of chemicals and some materials in the face-to-face laboratories. It is a well-known fact that teachers often avoid laboratory courses due to material supply and safety problems (Demir et al., 2011). Online laboratories can be a solution to these kinds of problems. Many pre-service teachers also emphasized that the effectiveness of an online laboratory depends on the subject matter in terms of difficulty, familiarity, and interest attraction. The online laboratory instructors can plan their courses by taking these aspects into account.

The pre-service teachers' self-reporting about the effect of online laboratories on learning was examined in three domains: cognitive, affective, and psychomotor. They thought that online laboratories affected cognitive learning the most. This view is also consistent with their thoughts that theoretical lecturing is an advantage during online laboratories. Few pre-service teachers thought that online laboratories had an impact on affective learning. In a recent literature review on remote laboratories in higher education that examined empirical research on the learning benefits of such laboratories, it was found that cognitive and affective learning is equal or better in remote laboratories than in hands-on laboratories (Post et al., 2019). The small number of pre-service teachers who think that online laboratories had an impact on affective learning may be due to the sudden and forced transition to the online laboratory during the COVID-19 pandemic. Affective learning is very much related to attitude and requires adequate and appropriate time for the attitude to develop positively. Many pre-service teachers thought that online chemistry laboratories have negative impacts on psychomotor learning outcomes.

Whether psychomotor skills improve in face-to-face laboratories or online laboratories (Seth & Haron, 2016) is a controversial issue. One of the reasons may be related to what is meant by psychomotor skills. Does psychomotor skill mean a basic movement such as gripping material in the laboratory, or a more complex movement that requires more than one process step, such as setting up an experiment? According to Kasilingam and Chinnavan (2014), psychomotor skills include sequences of motor activities to a certain degree of accuracy, smoothness, rapidity, or force. In the present study, some of the pre-service teachers gave the example for the psychomotor skill of "set up and complete an experiment". However other pre-service teachers' understanding of psychomotor skills could have been examined more thoroughly.

Another issue related to the development of psychomotor skills is its interactive nature with the cognitive domain. There is a cognitive understanding underlying motor activity. Kasilingam, Ramalingam, and Chinnavan (2014) claim that psychomotor activities can be observed through videos, demonstrations, online text descriptions, or with pictures of each step in the sequence since each psychomotor activity contains a cognitive aspect, for example, simulations can be used to observe the steps of a motor sequence. However, as for the assessment of psychomotor activities, they suggested that the student should perform the skill with an instructor if the skill was performed to a set standard. Additional research can be necessary to examine more carefully the effects of online laboratories on the psychomotor domain.

Most of the pre-service teachers approved of the measurement and assessment methods used in online laboratories. The summative and formative assessment processes that were used in their face-to-face laboratories were also used in their online laboratories. Therefore, they may be thinking that the measurement and assessment issue in online laboratories is not unqualified. However, some of them felt that it was easier to cheat in an online class. The studies about "cheating in online education" (Beck, 2014; Watson & Sottile, 2010) reported that online students were no more likely to cheat on exams than those in face-to-face environments. The students need to acknowledge the mechanisms that can detect different types of cheating in the online setting, such as a variety of virtual test-taking strategies, plagiarism detection software, authentication technologies to electronically affirm an online student's identity, and webcams.

Almost all of the pre-service teachers emphasized that they had positive views about the virtual classroom platform used in the present study. They thought that the synchronized system was useful because it provided messaging, document upload, and screen sharing. In addition, they stated that the ability to watch the course records again was a positive aspect of the system. Although they thought that disconnection problems may be caused by the LMS (not working due to many online courses at the same time), it may also be related to Internet connectivity in their locations such as rural areas, or the devices used to connect, such as smartphones or computers. According to Mohalik and Sahoo (2020), Internet connection problems were among the major problems experienced by pre-service teachers in distance education.

The findings provided useful information on how to design and deliver a positive online laboratory experience. For example, to overcome the lack of "learning by doing" in the online laboratories, hands-on laboratory activities can be integrated as a part of the online laboratories using the chemicals and equipment in custom-built, use-at-home laboratory kits or easily accessible and safe materials at home.

Many studies have examined learners' views about online laboratories that are designed in detail (e.g., Brodeur et al, 2015 Brown & Lahoud, 2005; May, 2020; Orduña et al, 2016). The difference with the online chemistry laboratories mentioned in the present study is that they were designed and conducted hurriedly due to the COVID-19 pandemic. According to the findings of the present study, the participants are not completely satisfied with these online laboratories. The laboratory instructors used the videos in online video-sharing platforms for the experiments because they don't have videos of themselves conducting the experiments. Some of the participants stated that the experiments in these videos are not understandable. It appears that they may not understand how to set up the experiments due to the ready-made experiment setups in the videos. Therefore, it is recommended that videos containing more detailed explanations about the experimental setup, the equipment, and materials used, the procedure, and the results of the experiment should be filmed by the laboratory instructors. Thus, videos of experiments filmed in this way for online laboratories will be more useful for learners.

Laboratories play a crucial role in chemistry teaching. Therefore, it is crucial to provide pre-service teachers with laboratory experience in online education amid the COVID-19 pandemic. The present study enabled us to look at the positive and negative points of this process through the eyes of pre-service teachers with online laboratory experience. For this reason, the findings herein will help teacher educators to obtain an in-depth understanding of the many impacts the online laboratory experience has on pre-service teachers.

After the COVID-19 experience, it appears that online laboratories will become more common and that the technologies used will be more diverse in the future. Moreover, learning and content management systems will become more common and specific for chemistry laboratories. Therefore, feedback or views of learners who will use them are important to improve the quality of online teaching in the future (Qiang et al., 2020). In addition, it is important to share online learning experiences in crisis that develop suddenly such as the COVID-19 pandemic in terms of the measures that should be taken now for future criseis. Considering these reasons and the status of distance education and online learning in Turkey, it is thought that the study will contribute to the literature.

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