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Evaluating the Views of Lecturers upon Virtual and Real Laboratory Implementations

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Abstract

The views of lecturers carrying out real laboratory (RL) and virtual laboratory (VL) implementations were analyzed in this study. The descriptive phenomenology design as one of the qualitative research designs was used in the study. The study group was determined using the criterion sampling method. The study was carried out with six lecturers who voluntarily participated into the laboratory and virtual laboratory implementations of a university in the Eastern Anatolia Region. Participating faculty members carried out YÖK Virtual Laboratory implementations besides physics or chemistry laboratory implementations. Semi-structured interview form was used as the data collection tool. During the planning of the study, preliminary interviews were held with the faculty members in order to collect preliminary information and have information about the feasibility of the study. After completing the ethics committee process, a new interview was held with the faculty members making appointments. The interview records were written down after listening to several times, and the information out of the scope of the research was excluded. The answers were grouped categorically, and sub-themes related to each category were determined. The views related to the planning dimension of instruction and preparation for learning were possible to be discussed in three different groups as the views stating that VL was more advantageous, the views stating that RL was more advantageous, and the views that VL and GL provided sufficient opportunities to the lecturer. All the other participants except from one emphasized that RL was more advantageous in terms of correcting incomplete and incorrect learning.

Key Words: *Real Laboratory, Virtual Laboratory, Science.*

Öz

Bu çalışmada, gerçek laboratuvar (GL) ve sanal laboratuvar(SL) uygulamalarını yürüten öğretim elemanlarının görüşleri analiz edilmiştir. Çalışmada nitel araştırma desenlerinden birisi olan betimleyici olgubilim (fenomenoloji) deseni kullanılmıştır. Ölçüt örnekleme yöntemi kullanılarak çalışma grubu belirlenmiştir. Çalışma kapsamında Doğu Anadolu Bölgesinde bulunan bir üniversitenin, laboratuvar ve sanal laboratuvar uygulamalarını yürüten, gönüllü katılım gösteren altı öğretim üyesi ile yürütülmüştür. Katılan öğretim üyeleri fizik veya kimya laboratuvar uygulamalarının yanı sıra, YÖK Sanal Laboratuvar uygulamalarını da yürütmüş olan öğretim üyeleridir. Veri toplama aracı olarak, yarı yapılandırılmış görüşme formu kullanılmıştır. Çalışmanın planlanması aşamasında ön bilgi toplamak, çalışmanın yapılabilirliği konusunda bilgi sahibi olmak için öğretim üyeleri ile ön görüşmeler yapılmıştır. Etik kurul süreci tamamlandıktan sonra öğretim üyeleri ile randevu alınarak yeniden görüşme yapılmıştır. Görüşme kayıtları birkaç kez dinlendikten sora yazılı hale getirilmiş, araştırma kapsamında olmayan bilgiler ayıklanmıştır. Cevaplar kategorik olarak gruplandırılmış ve her kategori ile ilgili alt temalar belirlenmiştir. Öğretimin planlanması boyutu ve öğrenmeye hazırlama ile ilgili olarak görüşleri SL'nin daha avantajlı olduğunu belirten görüşler, GL'nin daha avantajlı olduğunu belirten görüşler ve SL ve GL'nin öğretim elemanına yeterli fırsatları verdiğine ilişkin görüşler olmak üzere üç farklı grupta ifade edilebilir. Bir katılımcı haricinde diğer tüm katılımcılar eksik ve hatalı öğrenmeleri düzeltme konusunda GL'nin daha avantajlı olduğunu vurgulamışlardır.

Anahtar Kelimeler: *Sosyal Sorumluluk, First Things First Manifestosu, Grafik Tasarım, Kurumsal Sosyal Sorumluluk.*

Introduction

Laboratories are essential in science teaching (Çepni and Ayvacı, 2006). Using laboratories in science, physics, chemistry and biology teacher education is undoubtedly one of the most efficient tools for meaningful learning (Batı, 2018). Laboratory activities have remarkable contributions upon students' acquiring scientific process skills such as observation, data collection, classification, making explanation and experimentation (Aydoğdu and Kesercioğlu, 2005). The use of laboratories is considered to be important in terms of enabling students to learn concepts related to the field of science more efficiently (Doğru, Gençosman and Ataalkın, 2011). In laboratories, there are tools and equipment for the activities with which experiment and application studies are carried out. The students study natural sciences by trial and errors under the supervision of the teacher (Çepni and Ayvacı, 2006).

Online laboratories have recently been developed with the improvements in technology (Uğuz, Oral and Aksoy, 2018). Virtual laboratory as an online laboratory implementation refers to an environment where computer-assisted applications are used. Virtual laboratory implementations are considered as simulations that motivate students to the lesson, direct them to research, develop creativity and satisfy curiosity about learning (Akgül, Geçikli, Konan and Konan, 2018). Another online laboratory implementation is distance laboratory. A virtual laboratory is different from distance laboratory. Distance laboratories refer to digital platforms requiring students to interact with a distance laboratory using an interface software (Esquembre, 2004). Due to the global pandemic, a virtual laboratory was created in cooperation with YÖK and TÜBİTAK to carry out general chemistry and general physics laboratory courses, and it has been used since 2020. The virtual laboratory includes lectures, experimental applications and evaluation studies (YÖK, Council of Higher Education, 2020).

In addition to some positive contributions of virtual laboratories (Çivril, 2018; Özdener, 2005; Bozkurt & Sarıkoç, 2008), it has been expressed to affect the development of students' manual skills negatively and remain insufficient in terms of improving ability of using and recognizing the tools of experiment (Çinici, Özden, Akgün, Ekici and Yalçın, 2013). The students' lack of interaction with the laboratory equipment, the absence of some unpredicted errors in the virtual laboratory environment, lack of feedback, lack of discussion and interaction and some problems possible to be experienced due to the use of computers are expressed as some other negative features of virtual laboratories (Çivril, 2018; Kaba, 2012).

In a study carried out upon the efficiency of virtual laboratories (Kaba, 2012), installed form of the experimental setup has been considered as one of the perceived advantages of the virtual chemistry laboratory. Furthermore, the perceived advantages of the virtual laboratory have been identified as not needing to stroll in the classroom for control, students' being able to focus better, completing the experiments in a shorter time, chances of repeating, making mistakes and learning from mistakes as well as being able to be used out of class hours (Çivril, 2018; Kaba, 2012).

It was determined in a study carried out on science teachers and virtual laboratory (Ekici, 2015) that virtual laboratory activities could be used efficiently in science teaching, and it would be appropriate to consider laboratories used for experiments as a complementary method rather than an alternative.

In a study on virtual laboratory applications of secondary school students, it was determined that virtual laboratory implementations were efficient in terms of ensuring both student success and permanence of learning when compared to teacher-centered method (Duman and Avcı, 2016).

Importance of the Study

It was considered that this study contributed upon determining the advantages and inadequacies of the lecturers in terms of necessary planning, implementation and evaluation activities in virtual and real laboratory environments. Determining the deficiencies, inadequacies and advantages in terms of lecturers was possible to contribute upon

making virtual laboratory conditions more suitable for practitioners.

Purpose of the Study

Within the context of the planning, implementing and evaluating the teaching process, it was aimed to evaluate the views of the lecturers on VL and RL implementations. For this purpose, answers to the following questions were sought:

The purpose of the study was to determine the advantages and inadequacy of virtual laboratory implementation and real laboratory implementation according to the views of the lecturer in terms of

1. Planning the instruction,
2. Preparation for learning,
3. Implementing the curriculum,
4. Ensuring student participation,
5. Giving feedback to the student,
6. Correcting incomplete or incorrect learning,
7. Reinforcing what has been learned,
8. Evaluating the student,
9. Supply of laboratory tools and equipment,
10. Ensuring safety in the laboratory

Method

Study Model

In this study, the descriptive phenomenology design as one of the qualitative research designs was planned to be used. Phenomenology studies have focused on people's experiences. It aims to reveal people's perceptions and experiences on a certain subject with their own perspectives (Ersoy, 2017). Phenomenological studies focus on identifying the way people make sense of their experiences (Merriam, 2013). Descriptive phenomenology, on the other hand, aims to describe people's experiences and perceptions (Ersoy, 2017). Some universities have started to use YÖK Virtual Laboratory with the transition to distance education due to the global pandemic. In this planned study, the views of the lecturers who carried out real and virtual laboratory implementations were analyzed.

Study Group

In this study, the study group was determined using the criterion sampling method. In criterion sampling as a purposive sampling method, volunteers who met some criteria participated in the research process (Creswell & Port, 2015). The criteria determined were being carried out laboratory and virtual laboratory implementations at the university where the study was conducted and volunteering to participate into the study. In this context, the study was carried out with six faculty members who voluntarily participated into the laboratory and virtual laboratory implementations of a university in the Eastern Anatolia Region. Participating faculty members carried out YÖK Virtual Laboratory implementations as well as physics or chemistry laboratory implementations.

Data Collection Tools

Semi-structured interview form was used as the data collection tool. During the planning of the study, pre-interviews were held with the faculty members in order to collect preliminary information and have information about the feasibility of the study. After completed the ethics committee process, a new interview was held with the faculty members making appointments. During this process, the interview was started with the questions prepared by the researchers after the approval of the interviewed lecturer about the audio recording, and the flow of the interview was maintained with additional side and sub-questions depending on the answers given. As stated by Türnüklü (Türnüklü, 2000), the lecturers were accordingly enabled to answer in more details. The audibly recorded answers were subsequently listened to and written down by the researchers.

Data Analysis

During the data collection process, face-to-face interviews were held with the faculty members included into the study group with voluntary participation. The interviews made in a semi-

structured form were audio-recorded. In the first step of the analysis, the interview recordings were written down after listening to a few times, and the information regarded to be irrelevant was excluded. In the process of transcribing the verbal expressions, emotional expressions (pause, laughing, stuttering, saddening, etc.) considered to be relevant with the research topic were also regarded. The answers were grouped categorically in line with the research questions and sub-themes related to each category were determined in order to make the information in the interview ready for analysis.

Findings

Findings related to the planning of instruction

There were opinions referring that VL and RL had different advantages in terms of planning the instructional process. While three lecturers regarded VL more advantageous in terms of planning instruction (AA, CC, FF), two lecturers considered RL more advantageous (BB, EE), and one lecturer mentioned that VL and RL provided similarly sufficient advantage (DD). The faculty members who stated VL to be more advantageous offered different reasons for this. It was considered that experimental apparatus' not creating a limitation in planning due to malfunctions and inadequacies in RL simplified the studies of lecturers in planning process. For example, AA stated this as "*Since the breakdown, loss, etc. of experimental apparatus do not occur in VL as in RL, certainty in the instructional plan is ensured." The CC supported this view saying that "VL program is well designed and designed for students. Plan the instruction in terms of the number and variety of experiments is very substantial."* FF, on the other hand, stated that the time given for the laboratory activity in RL was specific and limited, the experiment was carried out within specified hours, whereas VL was stated to facilitate the study of the lecturers in planning process giving a time interval of two weeks for the same subject, and therefore VL was indicated to be more efficient in the process of planning the instruction.

On the other hand, there were lecturers who considered differently on this subject since the subjects in VL were standard and face-to-face feedback could be received. For example, BB said that *"…YÖK virtual laboratory application is insufficient in this respect when compared to the real laboratory. The number of experiments in the YÖK virtual laboratory should be increased considering the subjects lectured in Physics 1 and Physics 2 courses in general." EE stated that "Virtual laboratory is literally virtual laboratory as its name implied. Something with the remote control… I consider it as more disadvantageous rather than RL since VL is not one-to-one, and the students carry out with their own initiative."*

A lecturer (DD) also considered that RL and VL offered similar opportunities in terms of planning the instructional process. In this regard, DD said that *"They are the same in planning the instruction and both are sufficient."*

Table 1. Views of lecturers on planning the instruction in VL and RL

Views	Lecturer	Reason
VL is more advantageous.	AA CC FF	1. Experimental devices are full in VL. 2. No problems are experienced in terms of breakdown, etc. in VL. 3. VL is advantageous in terms of the number and variety of experiments. 4. The experiments are prepared more professionally in VL. 5. The students are flexible in use of time in VL.
RL is more advantageous.	BB EE	1. VL is insufficient in Physics 1 and Physics 2 courses. 2. The standard subjects in VL limit the lecturer in the planning process. RL is more flexible in this regard. 3. Courses in VL are lectured at the initiative of the student, and the lecturer do not have enough control over the process.
VL and RL offer similar opportunities.	DD	1. Both VL and RL provide sufficient opportunities for the lecturer in the instructional planning process.

Findings related to readiness to learning

In addition to the opinions expressing that VL was more advantageous (AA, BB) in terms of preparing students for learning, there were also views expressing that RL was more advantageous (DD, EE, FF) and VL and RL had different advantages in this process (CC) has elements. There was no opinion stating that there was no difference between VL and RL.

The reasons for the advantageousness of VL were carrying out VL experiments with the help of devices such as computers or tablets, possibility to receive support from different digital sources related to the subject during the experiment, including the test sheets on the electronic environment, and benefiting from videos, animations, etc. related to the experiments. In this regard, AA expressed the superiority of VL saying that *"Since virtual laboratory experiments are carried out with devices such as a computer and tablet, students can receive support from different digital resources related to the subject at that moment during the experiment."*

On the other hand, the lecturers who stated RL to be advantageous stated that the students' readiness for the experiment was possible to be measured with quizzes and questions, and whether the student was ready enough for the experiment observing the gestures and mimics of the students was also determined in RL. Regarding this issue, DD stated the superiority of RL related to readiness for learning expressing that *"We can measure students' readiness for learning in real laboratory implementations either verbally or writing with a quiz. In other words, whereas we can measure whether our students are ready for an experiment in real laboratory implementations, there is no tool to measure whether a student is ready for an experiment or not in YÖK virtual laboratory."* FF expressed the superiority of RL in readiness for learning stating that "*So yes, one of the superior aspects of the virtual laboratory is to see the experimental setups and systems there, to use them, and to know that these opportunities will not be available in every laboratory; however, in face-to-face laboratories, we can also predict what they have learned and what they have not learned from their gestures and acts. In this respect, a face-to-face laboratory is better than a virtual laboratory."* Furthermore, it was mentioned that some students did not fully follow the instructions after the feedback from the student, and this was noticed when the experiment was completed. In this regard, EE drew attention to the negative side of VL saying *"The student said s/he did it because it is managed with a remote control and acted on his/her own initiative, s/he can skip some things without doing it, but of course, we see that the reports of the things done as result of this, because we do not want reports immediately, so we see that they come with corrections in their subsequent reports."* There was also a view emphasizing that RL and VL had different advantages in this regard. For example, CC drew attention to the different aspects of RL and VL saying that *"Having no opportunity to hold quizzes/quizzes in the YÖK VL to measure the knowledge and deficiencies of the students before the experiment in real laboratory applications is a disadvantage. It is an advantage that the test sheets are in the YÖK VL system and the students can use them whenever and wherever they want."*

Table 2. Views of lecturers on the dimension of readiness to learning in VL and RL

Views	Lecturer	Reason
VL is more advantageous.	AA, BB	1. Access to digital resources for information required during the experiment in VL. 2. Availability of test sheets in electronic form in VL. 3. Possibility to benefit from opportunities such as videos and animations related to experiments in VL.
RL is more advantageous.	DD, EE, FF	1. In RL, the student's readiness for the experiment can be measured with quizzes and questions. In VL, on the other hand, it is not known whether the student is ready enough or not. 2. In VL, whether the students follow the given instructions adequately is not known, and students who are not ready can participate in the experiment. 3. Some students do not follow the instructions exactly, participate in the experiment without being prepared enough, the lecturer become aware of this situation after the experiment is completed or not become aware ever.
VL and RL offer similar opportunities.	CC	1. In RL, it is possible to check the readiness of the students taking an exam/quiz before the experiment. In VL this is a disadvantage. 2. The presence of the test sheets in VL and student access to these sheets at different times are considered as advantages.

Findings related to the implementation of the instructional plan

In VL, the students were possible to participate into the system at any time within a wide period of time defined for them. AA emphasized the advantage of VL expressing that *"In VL implementations, the students can log in to the system and complete experiments at any time since the*

experimental setups included digital content apart from the individual problems caused by the student and the lecturer." This could be considered as a solution to problems such as course conflicts and lack of time for the student. FF, on the other hand, expressed this issue indicating some of the difficulties in RL: *"It is a little more difficult to plan if different students will use the laboratory and there is a conflict for the student to take the course from the failed or higher grades."*

It was considered that the possibility of conducting more experiments in VL was an advantage. In this regard, CC drew attention to the positive side of VL mentioning that *"It is an advantage to include more experiments in virtual laboratory. Sometimes, the program plan is disrupted in terms of both time and material in real laboratory."*

Being deprived of teacher support during the experiment was considered as a negativity in terms of VL. BB expressed this as: *"The implementation of YÖK virtual laboratory is insufficient in terms of administering the instructional plan when compared to the real laboratory due to the absence of a responsible lecturer during the experiment."* Experiencing some unpredicted disruptions in VL was regarded as a negativity. Students' not touching the experimental devices deprived them of real experiences. This could also be considered as a deficiency of VL. Regarding these issues, EE said *"There is no disruption in the instructional plan, but various problems have been experienced in virtual laboratories in terms of implementing the instructional plan. The reason for these problems is, for example, that the student does not touch the straw, does not touch the support trench, and cannot measure."*

Table 3. Views of the lecturers related to the implementation of the instructional plan in VL and RL

Views	Lecturer	Reason
VL is more advantageous.	AA, CC, DD, FF	1. SL offers flexibility to the student in terms of time regarding the instructional plan. 2. Providing the opportunity of repetition in VL is considered as an advantage for students who need repetition. 3. It is an advantage for VL to include more experiments. Problems in terms of time and material in RL can prevent further experimentation.
RL is more advantageous.	BB, EE	1. Lack of lecturer support during the experiment is a disadvantage for VL. 2. Experiencing some unpredicted disruptions in VL is considered as a negativity. 3. The impossibility of touching the test apparatus and having real experiences can be considered as the negativity of VL.

Findings related to ensuring student participation

VL provided students the opportunity of using a wider range of time for laboratory use. It was considered that this opportunity indicated more advantageousness for students to participate into the course making use of the laboratory when compared to RL. Regarding this issue, AA mentioned *"Students can do their experiments at the time intervals determined by the lecturer. This provides a great advantage in terms of student participation."* BB, on the other hand, emphasized that VL was more advantageous in terms of ensuring student participation saying that *"VL implementation is more advantageous in terms of ensuring student participation as it allows a wider time interval (such as weekends, out of working hours) for conducting experiments."*

Four faculty members stated that RL was more advantageous in terms of ensuring student participation. CC expressed that *"Student participation in YÖK virtual laboratory implementation has been less than expected"* and stated that VL did not reveal what was expected in terms of student participation. While the other three lecturers had actual and physical control over participation in RL, it was stated that this opportunity was not available in RL. Regarding this issue, the view of DD was as: *"We have control of our students in real laboratory implementations in terms of ensuring student participation…We can clearly determine whether students have attended the course or not through attendance forms and observations."* EE stated that VL did not meet the expectations about student participation saying that *"the student regarded a little more loosely and with less participation."* FF, on the other hand, emphasized that student participation in VL could not adequately be controlled saying *"We cannot follow up, we can only see whether the reporting system is right or wrong."* DD, EE and FF, expressed that participation in VL could be increased rewarding class participation and introducing additional control mechanisms.

Table 4. Views of lecturers related to the dimension of ensuring student participation in VL and RL

Views	Lecturer	Reason
SL is more advantageous.	AA, BB,	1. In VL, more time is allocated for students to use the laboratory. The opportunity to benefit from the laboratory in a wide range of time is more advantageous when compared to RL in terms of course participation.
GL is more advantageous.	CC, DD, EE, FF	1. While actual and physical control over participation were possible in RL, VL did not provide this opportunity. 2. Whether participation is actually achieved or not is not possible to be fully controlled in VL.

Findings related to giving feedback to the students

It was stated that feedback was not possible to be given to the student since there was no face-to-face interaction in VL, therefore RL was more advantageous in terms of providing feedback to the students. In RL, on the other hand, all participants agreed about providing instant feedback. For example, AA stated this as *"It is not possible to give feedback while the student is doing the experiment due to the lack of instant interaction on the VL system."* On the other hand, BB mentioned *that "...it is sufficient in terms of giving feedback to the student since the lecturer who evaluated the experiment and students did not have face-to-face communication after the experiment."* CC emphasized the problems experienced in this sense saying that *"Problems were experienced at the point of feedback since the students could not explain their problems by writing. No answer could be offered to the problem since the problem was not fully understood."* Whereas DD said *"YÖK VL is not very helpful in terms of feedback,"* and EE said *"…face-to-face laboratories are more advantageous rather than VL,"* FF emphasized VL's lack of feedback saying that *"We can see reporting in the virtual environment in VL."*

Table 5. Views of lecturers related to the dimension of giving feedback to students in VL and RL

Views	Lecturer	Reason
GL is more advantageous.	AA, BB, CC, DD, EE, FF	1. No feedback can be given to the student since there is no face-to-face interaction in VL. 2. Instant feedback can be provided in RL.

Findings related to correcting incomplete or incorrect learning

Since no instant feedback could be given to the students in VL, whether there was a learning deficiency or this deficiency was not known and could not be corrected. AA stated this saying *"Not giving instant notifications to the class or students in VL and not observing during the experiment cause incomplete and incorrect learning not to be corrected."* BB, on the other hand, mentioned that *"VL is insufficient in terms of correcting incomplete and incorrect learning when compared to the real laboratory due to the absence of the responsible lecturer especially during the experiment."* CC stated that *"We can give direction saying to repeat if there is an error in the real laboratory environment, but this is not possible in virtual laboratory environment"*. DD expressed that *"There is no opportunity to see the mistakes of students and intervene immediately. This opportunity is not available in YÖK virtual laboratory."*

DD stated that VL and RL were complementary implementations for correcting incomplete and incorrect learning. DD expressed that *"Sometimes, I have seen the aspects that are closer to the truth in VL, that is, the teachings here are more beneficial for the students in terms of practice. However, the thing is, in RL we apply face-to-face, I have noticed that the test sheets given to the students are carefully followed, and as result, I notice the two complement each other."*

Table 6. Views of lecturers related to correcting incomplete or incorrect learning in VL and RL

Views	Lecturer	Reason
RL is more advantageous.	AA, BB, CC, DD, EE	1. Since instant feedback cannot be given to the students in VL, it is not known whether there is a learning deficiency or what it is, and it cannot be corrected. 2. In RL, there is an opportunity to see errors and deficiencies in a timely manner and repeat and correct them.
VL and RL were complementary for each other.	EE	1. VL and RL are complementary implementations for correcting incomplete and incorrect learning.

Findings related to reinforcing what was learned

Whereas three of the lecturers considered SL as more advantageous in terms of reinforcing what was learned, the other three considered RL as more advantageous. It was reported that the student had the opportunity of logging into the system again

and again in VL, repeating the experiment and reinforcing what they learned, but they had no such chance in RL. In this regard, AA emphasized the positive side of VL in terms of reinforcing what was learned saying that *"It is a great advantage that virtual laboratory offers the opportunity of reinforcing logging in at different times for the students."* CC, on the other hand, said that *"students can try an experiment as many times as they want, but in real laboratory applications, there is no opportunity to repeat it due to time and material limitations."* EE mentioned that *"Now, we see that an environment where students can turn back and watch over and over again when they are willing is provided in VL in terms of reinforcing the knowledge learned here."*

The views related to advantageousness of RL in reinforcing what was learned focused on face-to-face instruction and noticing and correcting the mistakes and deficiencies immediately. For example, depending on this, BB said that *"YÖK virtual laboratory is insufficient when compared to the real laboratory in terms of reinforcing what has been learned due to the absence of face-to-face communication between the lecturer and the student."* DD stated RL to be more advantageous saying *"In RL, the test notebooks are collected from the students on a weekly basis, their deficiencies are followed, evaluated, and delivered to the student. However, this is not possible in YÖK VL. And the evaluation is made regarding the file uploaded by the student to the system… We do not have the chance to make an explanation about the incorrect files uploaded in VL."* FF, on the other hand, expressed that *" In terms of reinforcing what was learned, students can personally ask the teacher about the points where they need support in face-to-face experiment."*

Table 7. Views of lecturers related to reinforcing what was learned in VL and RL

Views	Lecturer	Reason
SL is more advantageous.	AA, CC, EE	1. In VL, it is possible to log in the system again and again, repeat the experiment and reinforce what has been learned. RL does not offer this opportunity.
GL is more advantageous.	BB, DD, EE	1. Deficiencies in RL are controlled during the course, and immediate feedback and corrections can be provided if necessary. 2. In VL, deficiencies are noticed later, but there is doubt as to whether these deficiencies are also real deficiencies. Deficiencies that are considered to be available are not eliminated, as well.

Findings related to student assessment

Whereas five lecturers considered that RL was more advantageous in terms of assessing the students, one lecturer stated that there was no difference between VL and RL. AA, CC, DD, EE and FF stated that RL was more advantageous in terms of assessing students. Upon this, AA stated that SL was insufficient saying that *"In VL, the students can only be assessed with the report they prepare at the end of the experiment. It is not possible to include the students' progress in the course in the assessment process."* CC and DD, on the other hand, stated inadequacy of VL for the student assessment emphasizing the ethical dimension of VL. CC expressed that *"I think YÖK virtual laboratory is not objective because the student can upload someone else's test sheet."* DD stated that *"I have also witnessed that the students have not prepared the files uploaded in YÖK VL themselves. And I cannot interfere and prevent this too much"*. Stating that RL was superior in student assessment, FF said that *"...we also have an idea about discovering what the students do, how they do, what they know and what they do not know, and their handcraft in a one-to-one relationship."* FF also emphasized that RL was more advantageous in terms of assessing students saying that *"We can only learn how much a student has learned from the virtual reporting system they have prepared in VL…I believe that face-to-face assessment gives easier and more precise results in face-to-face education."* Unlike the other lecturers, BB, on the other hand, stated in terms of student assessment that both laboratories had no superiority or inadequacy in this regard. Upon this, BB expressed both implementations to offer similar opportunities saying that *"There is no difference between the two since the reports prepared after the experiment are assessed by the responsible lecturer in both YÖK virtual laboratory and the real laboratory."*

Table 8. Views of lecturers related to student assessment in VL and RL

Views	Lecturer	Reason
GL is more advantageous.	AA, CC, DD, EE, FF	1. In VL, assessment can only be made depending upon the report prepared at the end of the experiment, not an assessment of the process is possible to be made. This is not possible in RL. 2. In VL, someone else can write a report and upload it to the system instead of the student. This is not possible in RL. 3. In RL, both the process and output are assessed; result-based assessments are noticed in VL.
VL and RL offer similar opportunities.	BB	1. In both implementations, the responsible faculty member makes the assessment. Therefore, the two implementations offer similar opportunities for student assessment.

Findings related to the supply of laboratory tools and equipment

The participants agreed that VL was more advantageous in terms of supplying laboratory tools and equipment. For example, BB stated that *"YÖK VL implementation is more advantageous when compared to the real laboratory in terms of supplying laboratory equipment."* CC, on the other hand, expressed that *"There appears no danger in YÖK VL environment, since there is no deterioration or breakage in the materials."* However, BB, CC and DD immediately emphasized another inadequacy of VL adding that virtual was not possible to replace reality.

Table 9. Views of lecturers related to the supply of laboratory tools and equipment in VL and RL

Views	Lecturer	Reason
SL is more advantageous.	AA, BB, CC, DD, EE, FF	1. There is no need to have tools and equipment physically. 2. There are no problems such as breakage, deterioration, loss, wear and depletion of tools and equipment.

Findings related to ensuring safety in the laboratory

All participants stated that VL was more advantageous rather than RL in terms of ensuring laboratory safety as in the supply of laboratory tools and equipment. For example, BB expressed that *"Because there is no risk of accident in the virtual environment in terms of laboratory safety, YÖK virtual laboratory implementation is more advantageous when compared to the real laboratory."* EE mentioned that *"I don't think there is any danger here, as there is no dangerous chemical to be used in VL. But at RL, students can create an environment they can harm themselves or sometimes harm the laboratory touching any unfamiliar chemical substance or creating a different environment at a different time."*

Table 10. Views of lecturers related to ensuring laboratory safety in VL and RL

Views	Lecturer	Reason
SL is more advantageous.	AA, BB, CC, DD, EE, FF	1. VL does not pose any risk in terms of laboratory safety since the tools, equipment and hardware are not real and the environment where the experiments are carried out is virtual, as well.

Conclusion and Discussion

Planning the Instruction

The views about the dimension of planning the instruction could be expressed in three different groups. The views mentioning that VL was more advantageous were indicated to have reasons such as the fullness of experimental devices, absence of malfunctions or problems with the devices, advantages in terms of the number and variety of experiments, professional preparation of the experiments and flexibility offered to the students about laboratory. Faour and Ayoubi (2018) used virtual laboratory implementation in physics lesson for the 10th grade students. They noted that students of the experimental group using VL revealed significantly better performance rather than the students of the control group who were lectured with interactive demonstrations using real laboratory equipment. Unlike RL which only revealed macroscopic features, VL was based on ability to introduce concepts referring to the microscopic level (Wieman & Perkins, 2006). Findings of this study did not confirm the findings of previous studies carried out by Finkelstein et al. (2006), Shegog et al. (2012), Tüysüz (2010), Tsihouridis, Vavougios and Ioannidis (2013) and Zoubeir (2000).

The views stating that RL was more advantageous in terms of planning the instruction indicated the inadequacy of SL with the reasons that VL did not cover all physics subjects, the standardization of subjects in VL limited the lecturer in planning, and the lecturer had no

sufficient domination related to the process. This result was similar to some previous studies carried out by American Chemical Society-(ACS) (2011), National Science Teachers Association-NSTA (2007), Quinn et al. (2009), Tsihouridis et al. (2014), and Zacharia (2007). Another view was that VL and RL provided sufficient opportunities for the lecturers in the planning process of the instruction.

Readiness to learning

The views related to adequacy of VL for readiness to learning could be classified into three different groups. The lecturers who stated that VL was more advantageous rather than RL considered that it was an advantage to reach the necessary information from electronic sources during the experiment, have test sheets on electronic environment and benefit from the visuals such as videos and animations related to the experiment. In the study conducted by Chodijah, Fauzi & Ratnawulan (2012), it was mentioned that there was a need for practicality and perfection for VL-based learning tools.

Those who considered that RL was more advantageous rather than VL created the second group. The ones in this group considered that the readiness of the student for the experiment was not checked in VL with quizzes, so that students who were not ready for the experiment could participate in the experiment, and some students could participate in the experiment without fully checking the instructions in VL (Zgheib, 2013). The third view was that VL and RL offered different opportunities for readiness to learning, and they did not have any superiority between each other.

Implementing the instructional plan

Whereas there were those who stated that VL was more advantageous in terms of implementing the instructional plan, there were also the ones who stated that RL was more advantageous. Those who argued that VL was more advantageous mentioned that VL provided flexibility for the students in a wide period of time and the opportunity of repeating the experiment when necessary, did not pose a problem in terms of time and material, and included more experiments. Similarly, while listing the advantages of VL, Domingues et al. (2010) reported the shortness of the instructional period, more interaction during the learning process, providing more interesting learning process, and fulfilling the learning process at anywhere and anytime. Furthermore, in their study, Cağıltay et al. (2011) created two different courses for electrical and electronic engineering students including a virtual and distance laboratory, and this virtual and distant access laboratory was assessed by the students. In the study, the students stated that both laboratories were useful because they enabled them to do their experiments without time and place limits.

The ones who stated RL to be more advantageous stated that the lack of support from the lecturer during the experiment, the possibility of experiencing some unforeseen disruptions, and not carrying out the experiment with real devices indicated negative aspects for VL and positive aspects for RL. When Auer (2001) compared RL and VL, he argued that RLs were superior to VLs in terms of having real experimental setup and providing real laboratory experience for the users. Moreover, Deniz et al. (2003) compared RL and VL in terms of hands-on experience, sense of reality, feeling and fact control, freedom of experimentation and form, teacher support, technical support, access time, access limit, supervision, progress control, and educational promotion and obtained similar results.

Ensuring student participation

There were also the ones who argued that VL was more advantageous in terms of ensuring student participation as well as the ones who argued that RL was more advantageous. Students' having the opportunity of using VL in a wide period of time was considered as an advantage in this sense. According to Tatlı and Ayas (2012), VLs played a role in improving students' participation in course and improving their experimental skill activities because they enriched experiences and provided the opportunity of conducting an interactive experiment for students. Actual and physical

control in RL was considered as an advantage. On the other hand, it was stated that impossibility to fully control whether the person participating in the VL and the person who should attend were the same people was a limitation. Experimental activities were possible to improve creative thinking skills of the students, increase mastery on concepts in physics and provide opportunities for students to practice scientific methods (Hermansyah, Gunawan and Herayanti, 2015).

Giving feedback to the student

All participants stated that RL was more advantageous rather than VL in terms of giving feedback to the students. They cited the lack of face-to-face interaction in VL as the most important reason for this. They mentioned that providing instant feedback was an advantage in RL implementations. Arndt (1993) reported that verbal feedback was perceived as a very important way to give direct feedback to written texts; however, students preferred receiving written feedback in addition to verbal feedback. According to the research carried out by Bare (2005), students preferred the collaborative feedback method in small groups.

Correcting missing or incorrect learnings

All the participants except from one emphasized that RL was more advantageous in correcting incomplete and incorrect learning. It was stated that the inability of providing instant feedback and failure to see mistakes and deficiencies in VL in a timely manner were important reasons. A lecturer stated that there was no difference between VL and RL in terms of eliminating missing and incorrect learning. He indicated that VL and RL implementations were complementary to each other in terms of correcting incomplete and incorrect learning.

The feedback process should be completed in a private environment and allocating sufficient time, giving the necessary importance to the teacher's feelings to provide opportunity for explanation and discussion (Hewson and Little, 1998; Clynes, 2008; Kelly, 2007). In another definition, feedback was the process of informing students about whether the desired behaviors were acquired or not, and at what level these behaviors were acquired in teaching-learning process. Regarding the result of this statement, deficiencies and mistakes of the students were determined: the process of completing these deficiencies and correcting the mistakes was also called correction. During the teaching-learning process, feedback and correction were generally used together and remarkable in terms of motivating further learning (Reece, Walker, Clues & Charlton, 2007).

Reinforcing what was learned

There were two different views related to the superiority of VL or RL in terms of reinforcing what was learned. Whereas half of the participants stated that VL was more advantageous in this sense, the other half supported that RL was more advantageous. Those who argued that VL was advantageous justified that logging into the system again and again and repeating the experiment created an opportunity to reinforce what was learned. And the ones who discussed that RL was advantageous stated that students could be controlled throughout the process, mistakes and deficiencies were immediately noticed and corrected in RL implementations. Furthermore, they argued that deficiencies in VL could not be noticed immediately, whether there were deficiencies in real terms after the written reports was not known, and even if there were deficiencies in real terms, they were not eliminated. It was noticed in some previous studies that computer-aided learning environments including virtual laboratories increased the interest in lessons, provided safe repetition especially for laboratory environments in terms of enabling students to see the mistakes and provided success and permanence as result (Martinez-Jimenez, Pontes-Pedrajas, Polo and Climent-Bellido, 2003; Jensen, Voigt, Olbrich & Nejdl, 2004; Yu, Brown & Billet, 2005; Bozkurt, 2008; Duman and Avcı, 2016).

Student assessment

As in correcting missing and incorrect learnings, all participants except one stated that RL was more advantageous in terms of student assessment. Assessing the output along with the process in RL, and assessment just about the product in VL were revealed to be reasons for the positive aspect of RL in student assessment. Similarly, in their study, Koç Ünal (2019) concluded that virtual laboratory implementations were efficient upon increasing success, permanent knowledge, and real laboratory implementations increased success and ensured permanence. On the contrary, when the literature was reviewed, it was revealed that virtual laboratory implementations had a significant effect upon the success of students studying at various grades from primary education to higher education (Gabbard, Hix and Swan II, 1999; Özdener and Erdoğan, 2001; Akçay et al., 2005; Köse et al., 2007; Karalar and Sarı, 2007; Özdener, 2005; Bozkurt and Sarıkoç, 2008; Karamustafaoğlu et al., 2005; Kulik, 2002; Ong and Manan, 2004; Sherwood and Hasselbring, 1986; Nirmalakhandan et al., 2007; Kim, 2006; Wieman and Perkins, 2006; Güvercin, 2010; Bülbül, 2009; Salgut, 2007; Pektaş et al., 2009; Akkağıt and Tekin 2012). Another view on student assessment indicated that the lecturer was the evaluator in both applications, so VL and RL offered similar opportunities for student assessment.

Supply of laboratory tools and equipment

The participants agreed that VL was more advantageous rather than RL in terms of supplying laboratory tools and equipment. There was no need to physically have tools and equipment, and there was no equipment breakage, deterioration, breakdown, and loss in VL. Due to the lack of equipment in the school laboratories and high number of students in the classrooms, most of the possible experiments were performed as demonstration experiments. In this case, simulation software was a good alternative to the demonstration method. Preferring simulation instead of experimenting using costly laboratory equipment provided economic benefits (Akkağıt and Tekin, 2012; Rutten, Joolingen and Van der Veen, 2012).

Ensuring safety in the laboratory

As in supplying the laboratory tools and equipment, the participants agreed that VL was more advantageous rather than RL in terms of ensuring safety in laboratory. The remarkable reason for this superiority was expressed as the fact that the experiments to be carried out included no risk because the tools and equipment were not real but virtual. Duman and Avcı (2016) concluded in their study that virtual laboratories were possible to be an alternative and support to traditional laboratories because the dangers possible to occur in the laboratory environment and the waste of materials could be prevented.

Recommendations

Due to their advantages and disadvantages, VL and RL could be used together. Especially the experiments posing danger and risk could be carried out in virtual environments such as computer laboratories under the supervision of the lecturer. Thus, the risks possible to appear in real experimental environments could be minimized. Moreover, the occasional use of computer laboratories instead of RL could pave the way for the use of existing RL potential by other experimental groups.

In VL implementations, transformations and add-ons such as monitoring and controlling of the processes carried out by the students by the instructor or their assistants, receiving feedback and corrections when necessary, and the lecturers' assessing the process were possible to be created. So that, the issues regarded as a restraint and inadequacy for VL were eliminated relatively.

The number of experiments possible to be performed in VL environment could be increased. So, an environment to gain experience in different subjects was created for students. In addition, opportunity was created for students who lacked laboratory environments or missed the experiments in RL environment.

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