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Original Article

Measuring Satisfaction of Some Postgraduate Engineering Students at Shiraz University about Virtual and Remote Laboratories

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Abstract

The purpose of this case study was to measure satisfaction of some postgraduate engineering students at Shiraz University about virtual and remote laboratories. The participants were 18 electrical engineering students selected from Shiraz University through purposeful samples. The studied variables in order to measure the satisfaction of remote laboratories included students' focused attention during the use of the virtual laboratory (FA), perceived usefulness of virtual lab (PU), virtual lab approval by students (Confirm), students' satisfaction with the virtual laboratory(Satisfaction), fun and enjoyable virtual lab (Play), easily perceived by students in using a virtual lab (PEU), Attitude to the virtual laboratory (Attitude), tendency to use the virtual lab continuously (ICU), quality of virtual laboratory design (QD). Results revealed that students' satisfaction with the virtual laboratory was above the middle standard rating. Furthermore, from the students' point of view, the quality of the virtual laboratory had a significant effect on their "Satisfaction" with the virtual laboratory (Sig. 0.000, B = 0.885), and from the perspective of the students, the QD had a significant effect on ICU (Sig. 0.000, B = 0.937). Finally, the regression analysis showed that the QD had a significant effect on students' attitudes toward the virtual laboratory (Sig. 0.000, B = 0.885).

Keywords

Virtual labs, Remote labs, Satisfaction, Postgraduates, COVID-19

Introduction

Some Today due to the development of information technology, the concept of education has changed as a continuous and lifelong process. Therefore, one of the vital aspects is to seek for transforming teaching methods in the global context to meet expectations and to form the lifelong educational process (Zydney, McKimmy, Lindberg, & Schmidt, 2019).

Due to the high-speed manifestation of information communication and technology, many face-to-face educational environments are now reformed by computers and digital technologies (Bawaneh, 2021). Therefore, the context of teaching and learning is faced with a larger demand for virtual and more flexible education than ever before (Lakhal, Bateman, & Bedard, 2017). Such transformations are now pillars of new education systems in most countries toward the best achievement and outcome of education (Raes, Detienne, Windey, & Depaepe, 2019; Lakhal, De Sherbrooke, & Bateman, 2017.)

Though e-learning has been around in some parts of our education system in last few decades, but it has become a vital part of all education systems very recently. The term “learn from home” has become prevalent in higher education during the COVID-19 crisis. Despite

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the challenges faced in all learning domains, our primary focus is toward the virtual transition, which significantly impacted engineering education where the theory and lab work go hand in hand to induce the design and development of virtual learning tools (Khan & Abid, 2021).

Also, it is important to recognize how universities are currently producing lab-based practical experiments for students, how they are introduced through online platforms in the COVID-19 period, and what approaches and actions must be taken to achieve learning outcomes through high-quality educational experience in the COVID-19 and post-COVID-19 period (Gamage, Wijesuriya, Ekanayake, Rennie, Lambert & Gunawardhana, 2020). Engineering Education is a challenging field requiring an adequate and systemic mixture of theory classrooms and synchronized lab instructions (Khan & Abid, 2021). In engineering education, The laboratory's essential role to understand and adjust theoretical concepts, observation capability, analyzing skills, teamwork, and communication are important (Kapilan, Vidhya & Gao, 2021).

Despite such facts, the inadequate and poor facilities in the laboratory and some weaknesses from fellow students and laboratory instructors could cause some problems in well-understanding the content and instructions in conventional laboratory setups (Yalcin-Celik et al., 2017). Besides, their critical and creative thinking in conducting experiments and deep learning is sometimes low in conventional laboratories. Studies have reported that the latest laboratories' availability would motivate students in the learning process as it helps them get hands-on practice with the newest technology (Kapilan, Vidhya & Gao, 2021). Consequently, an innovative approach is needed to integrate knowledge and the learning process that helps solve mentioned problems and increase motivation and enough preparations in designing new and perfect experiments while providing flexibility and rapid expansions (Dunne & Ryan, 2010). This can be achieved with the help of remote and virtual laboratories (RV.L). A computer-assisted activity that helps the students conduct the experiments in a real or virtual laboratory environment.

Employing a distanced and virtual laboratory component in engineering learning has several advantages such as unlimited access and repeating the experiments (Rowe, Koban, Davidoff & Thompson, 2018). Furthermore, according to various research, it can help increase student test scores, improve students' attitudes and prepare them for the hands-on lab, and reinforce basic conceptual knowledge (Radhamani, Kumar, Nizar, Achuthan, Nair & Diwakar, 2021). on the other hand, employing remote Labs with actual equipment provides flexibility in terms of time and location and thus more efficient use of laboratories.

Despite the mentioned benefits, there are some elements and variables that affect students' satisfaction during the use of such laboratories, and they cannot be easily ignored, such as students' focused attention during the use of the virtual laboratory, perceived usefulness of virtual lab and students' satisfaction with the virtual laboratory (Stefanovic & Klochkova, 2021). Therefore, the present study has been prepared to confirm the effect of these variables on the level of student satisfaction in remote and virtual laboratories.

Literature review

Web-based labs

The virtual environment is one of the most exciting achievements of information technology (Reeping & Knight, 2021). Virtual Instrumentation means using software environments instead of conventional physical tools and devices to measure and control various variables. Using virtual environment technology, engineers and professionals can save time and money and increase product quality at a lower cost. Virtual devices analyze and adjust them by providing a new structural model of the process (Safavi, 2013). Web-based education using simultaneous and asynchronous learning network environments has been widely considered in the literature of related studies (Latchman, Ch Salzmann, Thottapilly & Bouzekri, 1998;

Kang & Temkin, 2022). Web-based laboratories are divided into two categories: remote laboratories and virtual laboratories.

Virtual laboratory

Laboratories based on software and training simulations are called virtual laboratories (VL). In addition to images and videos of real devices and tools, simulated models of devices and tools are available to users in this environment. The use of virtual laboratories is one of the forms of in based learning (Yousef and Widyaning C, 2020). Researchers consider the use of virtual laboratories as one of the ways to overcome the limitations of facilities and infrastructure as supporting elements in using practical activities (Wang, 2018). The rapid action of communication technology has made the design and development of virtual testing environments a reality in action. In practice, it has made it possible to build a variety of virtual laboratories (Zhang and Zhang, 2019). In many areas of knowledge, especially in practical and technological fields such as engineering, laboratory work is an essential learning components. Students should devote most of their learning time to solving practical problems and sensory experiences (Estriegana, Medina-Merodio & Barchino, 2019).

Therefore, it is necessary to design learning tools that provide students with practical opportunities to research and to learn how to do things. Several researchers have reached this conclusion, that an significant solution is the virtual laboratories development.

Remote laboratory

Real labs that connect to the user over the network are called remote labs (RL), as the devices are used over a network. These labs are often able to compete with traditional methods, provide better facilities for networking and data monitoring. In other words, advances in Internet services have made it possible to remotely monitor and control a system, which has led to the creation of numerous remote laboratories around the world. The unique advantage of remote laboratories compared to virtual laboratories is that the user can communicate with real domains via the Internet, which is more realistic and attractive then simulated software environments. In a remote laboratory, the operator can perform the test, change its control parameters, see the result, and receive data through the network (Safavi, 2013).

Due to the increasing expansion of virtual and remote laboratories in universities worldwide and the opportunities shown in this regard, the need to use these opportunities for technical and vocational training centers is completely felt. establishing such laboratories allows students, trainees, and other professionals to perform their desired experiment via computer at any time and place, thus a better understanding of the test, and the necessary skills. Virtual and remote laboratories can be used as an effective alternative to common practical activities, especially when, due to limited laboratory equipment, not all students can have long-term and easy access to this equipment (Herlandi, Al Amin, Pahami and Satria, 2019). A more detailed comparison of real, virtual and remote laboratories is provided in table 1.

Table 1. Compare of Real and Web-based Labs

Lab type	Advantages	Disadvantages
Real	• Teamwork • Interaction with the teacher • Real data • Interact with real equipment	• Planning • Cost • Time and space constraints • Requires the presence of a teacher or laboratory manager
virtual	• Description of concepts • Attractive environment • Low cost	• Unreal data • Lack of interaction with real equipment

	• Attractive to the user • No time limit and Place • Better understanding of conducting experiments and teaching theory • Cooperation of educational and research centers	
Remote	• Interact with actual equipment • Calibration • Real data • Average cost • No time limits and place • Less damage to laboratory tools and equipment • Expand the number of students • Cooperation with industries	• "virtual presence" in the laboratory • Requires the presence of an online technician

Factors on the effectiveness of remote labs in learning outcomes

The emergence of remote laboratories was closely related to the spread of technological innovations because without the support of advanced technology, they could not be used. Remote laboratories have gained popularity since the rapid Internet uptake in the mid to late 1990s (Machotka, Nafalski & Nedic, 2011). An example of the first research conducted and remote laboratories in Iran presented by Safavi entitled “the First Iranian Virtual and Remote Laboratory for Control Engineer” (Safavi, Salehi, Motamedi, et al., 2007). This study can be considered the first example of the first use of remote laboratories in Iran, used mainly in electric machines and automatic control. Although technology is the basis for the development of remote laboratories and should not be recognized as the ultimate goal, The optimal learning output is due to the interaction between the learner and the technology, not the technology itself, which imposes a function of the learning outcomes (DiSessa, 2001; Bhute, Inguva, Shah & Brechtelsbauer, 2021).

The belief that remote laboratories are a tool to improve learning or a way to complement traditional laboratories plays a key role in their development and use and in the research conducted. On the one hand, remote laboratories have changed in terms of technological advancement. On the other hand, this progress was made to serve the need to improve learning, especially in students' conceptual understanding and operational knowledge. In remote laboratories, learners have a sense of physical and mental separation from equipment (XieLi, Huang, Sung & Jiang, 2021). Therefore, it is essential to create a satisfactory level with good technology learning and support interfaces (Lindsay, Naidu, & Good, 2007). For example, although most students in this study believed that they had performed a real and practical laboratory and obtained valid and acceptable data, they still preferred a experimental and practical laboratory because of the negative sense of separation from the device (Lowe, Newcombe, & Stumpers, 2013; XieLi et al., 2021).

Olson and Olson (2000) suggested that in addition to the nature of technology to determine the effectiveness of telecommuting, other factors such as the strength of relationships between group members are also crucial (Tang, 2021). Sonnenwald, Whitton, and Maglaughlin (2003) in their longitudinal research, also examined group processes in remote laboratories. The results indicated that the final learning outcomes were comparable between different types of laboratories (c.f. Lindsay, Naidu, & Good, 2007; Mayer, 2001). It shows that in studying the effectiveness of the laboratory, much attention should be paid to student-related learning behaviors and outputs, incredibly individual and group processes (Wei, Treagust, Mocerino, Lucey, Zadnik & Lindsay, 2019).

A few studies have provided learning outcomes for remote laboratories (e.g., Corter, Nickerson, Esche, & Chassapis, 2004, 2007; Lindsay & Good, 2005; Lima, Viegas & Garcia-Peñalvo, 2019; Garcia, Quiroga & Ortin, 2021). The overall conclusion of the above studies is that the learning outcomes in all three traditional practical laboratories, remote laboratories, or simulations are almost equivalent. But in general, despite the preference for conventional laboratories, students find remote laboratories more desirable in the quality of their learning due to their convenience and ease of use, with a group and collaborative approach (Bhute, 2021).

Although many previous studies have explored the key variables that impact the adoption of Web-based labs satisfaction in several contexts such as are Learning effectiveness, cost-effectiveness, student satisfaction, teacher satisfaction, and ease of access (Abumalloh, Asadi, Nilashi et al., 2021), COVID-19 unexpected pandemic has presented an extraordinary context, which would switch influence the global education system especially in the field of remote labs in engineering education.

Considering the novelty of the research context, the present study seeks to identify some important variables for measuring satisfaction of some engineering students at Shiraz University about virtual and remote laboratories while providing a model to enhance the learning outcomes.

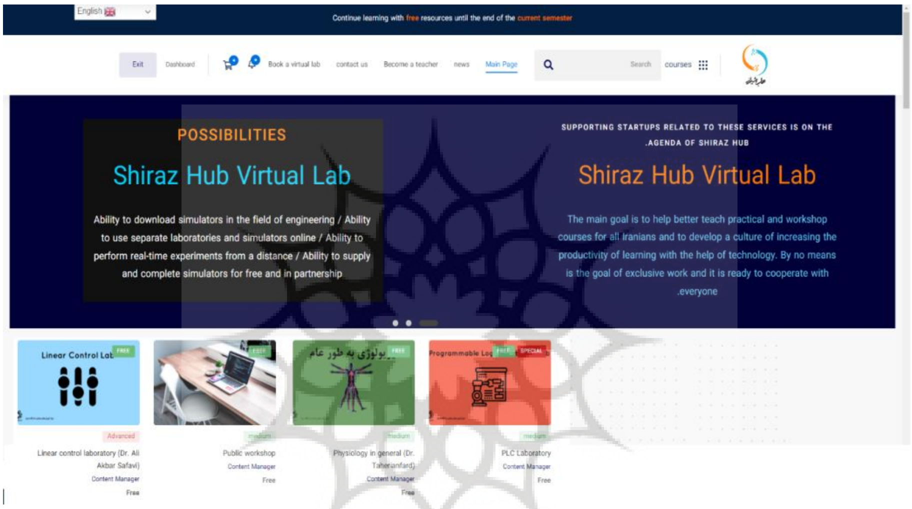

Figure 1. Shiraz University-Virtual and Remote Lab Platform

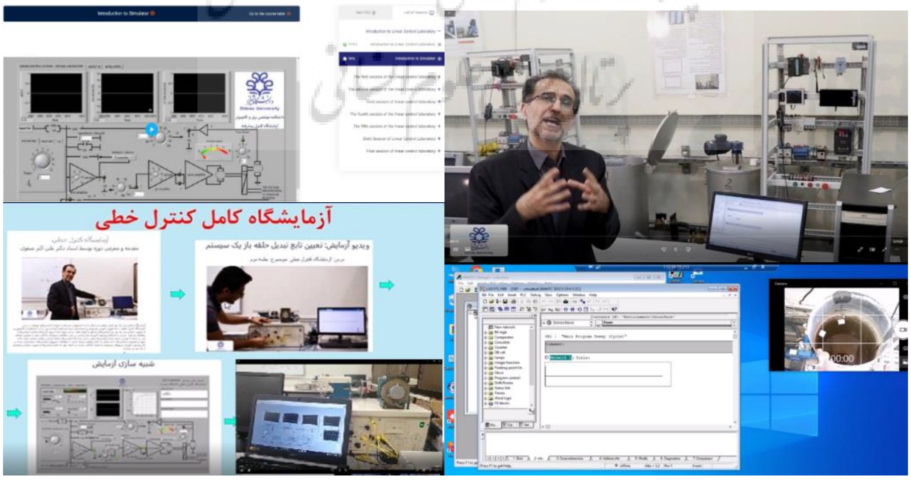

Figure 2. Virtual and Remote Labs for Linear Control and Programmable Logic Controllers

Table 2. Demographic profile: Gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Man	16	88.9	88.9	88.9
	Female	2	11.1	11.1	100.0
	Total	18	100.0	100.0	

Table 3. Demographic profile: Level

Level					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachelor	10	55.6	55.6	55.6
	M. Sc	8	44.4	44.4	100.0
	Total	18	100.0	100.0	

Table 4. Demographic profile: marital status

Marital status					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Single	13	72.2	72.2	72.2
	Married	5	27.8	27.8	100.0
	Total	18	100.0	100.0	

Table 5. Demographic profile: Age

Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 25 years	10	55.6	55.6	55.6
	26 to 30 years	4	22.2	22.2	77.8
	31 to 40 years	3	16.7	16.7	94.4
	41 to 50 years	1	5.6	5.6	100.0
	Total	18	100.0	100.0	

Measures

The questionnaire was divided into two parts(39-items). The first part consisted of key demographic variables, and the second part obtained information about students' focused attention during the use of the virtual laboratory (FA), perceived usefulness of virtual lab (PU), virtual lab approval by students (Confirm), students' satisfaction with the virtual laboratory(Satisfaction), fun and enjoyable virtual lab (Play), easily perceived by students in using a virtual lab (PEU), Attitude to the virtual laboratory (Attitude), tendency to use the virtual lab continuously (ICU), quality of virtual laboratory design (QD) in the form of statements formulated to determine user perceptions. The survey items were adapted from instruments used in past research. The questionnaire was viewed by two experts in the field of education and engeenering for checking face and content validity. The following measures were contained in a 39-items.

In this study time distortion (2 items), focused attention(2 items), perceived usefulness(3 items), confirmation(3 items), satisfaction(3 items) adapted from Zhang et al. (2020). Furthermore, to assess playfulness(2 items), perceived ease of use(4 items), and attitude the 8-item scale developed by Padilla-Meléndez et al. (2013) was used. To assess intention to continue using remot lab (2 items) developed by Zhang et al. (2020) was used. To assess quality of design, an 6-item scale was developed based on the research of Domínguez et al. (2014).

The reliability coefficients for the questionnaire were 0.95, respectively. These items were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The survey began in May 2021 and lasted two weeks, during which a total of 18 questionnaires were distributed and returned.

Result

Study variables (FA, PU, PEU, etc) are provided and defined in column 1 of Table 6. Demographic information on the participants such as age, gender, academic discipline was also presented.

Table 6. Descriptive Statistics

Study variables	*N*	*Min*	*Max*	*Mean*	*Std. Deviation*	*Variance*
FA (Students' focused attention during the use of the virtual laboratory)	18	1.00	5.00	3.6481	1.15171	1.326
PU (Perceived usefulness of virtual lab)	18	1.00	5.00	3.7407	1.05133	1.105
Confirm (Virtual lab approval by students)	18	1.00	5.00	3.6481	1.16861	1.366
Satisfaction (Students' satisfaction with the virtual laboratory)	18	1.00	5.00	3.5139	1.24697	1.555
Play (Fun and enjoyable virtual lab)	18	1.00	5.00	3.3333	1.37199	1.882
PEU (Easily perceived by students in using a virtual lab)	18	1.00	5.00	3.5926	1.12926	1.275
Attitude (Attitude to the virtual laboratory)	18	1.00	5.00	3.4167	1.38532	1.919
ICU (Tendency to use the virtual lab continuously)	18	1.00	5.00	3.4630	1.29422	1.675
QD (Quality of virtual laboratory design)	18	1.00	5.00	3.5083	1.17245	1.375
Valid N (listwise)	18					

Statistical Analyses

First of all, it should be noted that according to the number of samples (18 participants), the Shapiro-Wilk test was used to measure normality.

Table 7. Summary of the use of analytical reasoning

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Confirm	0.229	18	0.013	0.908	18	0.079
Satisfaction	0.186	18	0.099	0.891	18	0.041
Play	0.191	18	0.080	0.897	18	0.050
PEU	0.137	18	0.200*	0.936	18	0.246
Attitude	0.163	18	0.200*	0.894	18	0.046

ICU	0.174	18	0.158	0.910	18	0.088
QD	0.150	18	0.200*	0.910	18	0.086
FA	0.231	18	0.012	0.853	18	0.009
PU	0.209	18	0.037	0.890	18	0.039
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

shown in the Table 8, after performing the analysis of variables: "Confirm", the approval of the virtual laboratory by the students; "Play", "PEU", ICU and "QD" was recognized as normal and the One-Sample T-test was used for analysis. To analyze "FA", "PU", "Satisfaction" and "Attitude" were used from the One-Sample Median Test.

Table 8. Tests of Normality

Study variables	**Normality of data**	**Test used**
FA (Students' focused attention during the use of the virtual laboratory)	not approved	One Sample Median Test
PU (Perceived usefulness of virtual lab)	not approved	One Sample Median Test
Confirm (Virtual lab approval by students)	Approved	One Sample T test
Satisfaction (Students' satisfaction with the virtual laboratory)	not approved	One Sample Median Test
Play (Fun and enjoyable virtual lab)	Approved	One Sample T test
PEU (Easily perceived by students in using a virtual lab)	Approved	One Sample T test
Attitude (Attitude to the virtual laboratory)	not approved	One Sample Median Test
ICU (Tendency to use the virtual lab continuously)	Approved	One Sample T test
QD (Quality of virtual laboratory design)	Approved	One Sample T test

Table 9. One-Sample Statistics results

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Confirm	18	3.6481	1.16861	0.27544
Play	18	3.3333	1.37199	0.32338
PEU	18	3.5926	1.12926	0.26617
ICU	18	3.4630	1.29422	0.30505
QD	18	3.5083	1.17245	0.27635

Table 10. One-Sample Test

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Confirm	2.353	17	0.031	.64815	0.0670	1.2293
Play	1.031	17	0.317	.33333	-0.3489	1.0156
PEU	2.226	17	0.040	.59259	0.0310	1.1542
ICU	1.518	17	0.147	.46296	-0.1806	1.1066
QD	1.839	17	0.083	.50833	-0.0747	1.0914

1. The normality of the data was confirmed in 5 variables "Confirm", "Play", "PEU", "ICU", and "QD" and therefore the analysis should be used from the One-Sample T-test. The results showed that students 'satisfaction with "Confirm" virtual lab approval and "PEU" was easily perceived by students in using the virtual lab above the standard (3), while students' satisfaction with "Play" was fun and enjoyable. Being a virtual laboratory; "ICU" is the tendency to use the virtual laboratory continuously and "QD" is the quality of virtual laboratory design at the standard level (3). Therefore, students 'satisfaction with "Confirm" virtual laboratory approval by students and "PEU" perceived by students' ease of use of virtual laboratory was higher than the standard (3).
2. According to the results of Tables 3 and 4 of the four-variable "Satisfaction" data, students' satisfaction with the virtual laboratory; "Attitude" attitude to the virtual lab; "FA" Students' focused attention during the use of the virtual laboratory and "PU", the perceived usefulness of the virtual laboratory was not normal. One Sample Median Test was used for analysis.

The findings revealed that all "Satisfaction" variables, students' satisfaction with the virtual laboratory; "Attitude", attitude towards the virtual laboratory; "FA", students' focused attention during the use of the virtual laboratory, and "PU", the perceived usefulness of the virtual laboratory is above the middle standard rating (3). This means that there is a significant difference between the middle criterion rank limit (3) and the middle rank. Therefore, it can be inferred that students' satisfaction with the four variables of the virtual laboratory was higher than the average criterion (3).

Test a few supplementary research questions

Did the quality of the design (QD) of the virtual laboratory, affect the "Satisfaction", the students' satisfaction from the virtual laboratory?

Table 11. Variables Entered/Removed

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	QD[b]	.	Enter
a. Dependent Variable: Attitude			
b. All requested variables entered.			

Table 12. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.885[a]	0.784	0.770	0.66372
a. Predictors: (Constant), QD				

Table 13. ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	25.577	1	25.577	58.060	0.000[b]
	Residual	7.048	16	0.441		
	Total	32.625	17			
a. Dependent Variable: Attitude						
b. Predictors: (Constant), QD						

Table 14. Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	-0.254	0.506		-0.501	0.623
	QD	1.046	0.137	0.885	7.620	0.000
a. Dependent Variable: Attitude						

Regression analysis showed that from the students' point of view, the quality of the design (QD) of the virtual laboratory had a significant effect on their "Satisfaction" with the virtual laboratory (Sig. 0.000, B = 0.885).

Did the "QD" quality of the virtual lab design affect the "ICU", the students' willingness to use the virtual lab continuously?

Table 15. Variables Entered/Removed

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	QD[b]	.	Enter
a. Dependent Variable: ICU			
b. All requested variables entered.			

Table 16. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.937[a]	0.878	0.871	0.46566
a. Predictors: (Constant), QD				

Table 17. ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	25.006	1	25.006	115.322	0.000[b]
	Residual	3.469	16	0.217		
	Total	28.475	17			
a. Dependent Variable: ICU						
b. Predictors: (Constant), QD						

Table 18. Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	-0.166	0.355		-0.468	0.646
	QD	1.034	0.096	0.937	10.739	0.000
a. Dependent Variable: ICU						

Regression analysis revealed that from the perspective of the students, the "QD" of the virtual laboratory design had a significant effect on "ICU", students' tendency to use the virtual laboratory continuously (Sig. 0.000, B = 0.937).

3- Did the "QD", the quality of the virtual lab design, affect the "Attitude", students' attitudes towards the virtual lab?

Table 19. Variables Entered/Removed

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	QD[b]	.	Enter
a. Dependent Variable: Attitude			
b. All requested variables entered.			

Table 20. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.885[a]	0.784	0.770	0.66372
a. Predictors: (Constant), QD				

Table 21. ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	25.577	1	25.577	58.060	0.000[b]
	Residual	7.048	16	0.441		
	Total	32.625	17			
a. Dependent Variable: Attitude						
b. Predictors: (Constant), QD						

Table 22. Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-0.254	0.506		-0.501	0.623
	QD	1.046	0.137	0.885	7.620	0.000
a. Dependent Variable: Attitude						

Regression analysis showed that from the perspective of the students, the "QD" of the virtual laboratory design had a significant effect on students' attitudes toward the virtual laboratory (Sig. 0.000, B = 0.885).

Discussion

Due to the increasing changes in technology, engineering education is currently facing several challenges to meet the needs of higher education in the dimensions of curriculum design, implementation, and evaluation for delivering the required practical experience to attain engineering skills, especially in the educational context affected by COVID-19. To bridge this gap, enhancing remote labs is one of the best alternatives for providing suitable teaching methods and linking theory with practice. According to the research findings, Regression analysis showed that from the students' point of view, the quality of the design of the virtual laboratory had a significant effect on their satisfaction with the virtual laboratory, which is in line with research Brooks & Alper (2021), that showed in most cases, developed platforms designs can be (fairly) readily adapted for new capabilities in increasing the quality of students learning.

Other findings reveal that from the perspective of the students, the "QD" of the virtual laboratory design had a significant effect on "ICU", students' desire to use the virtual laboratory continuously, which is in line with research Saeed Al-Maroof et al. (2021). Faculty members in that study also reported that, if they were aware of the positive impact of such technology on student learning, they would be inspired to learn and use remote labs. As a result, this overall phenomenon would help faculty members to obtain practical exposure, acquire better skills and become more proficient in using the remote labs. as a result of this, students' tendency to continue using the remote labs has been enhanced.

At last, from the perspective of the students, the "QD" of the virtual laboratory design had a significant effect on students' attitudes toward the virtual laboratory, which is in line with research Abou Faour & Ayoubi (2017), that showed although the use of remote laboratory does not influence the attitudes more than the real lab does, the use of virtual laboratory promotes the students' perception of remote labs' function and benefits.

This study has the limitation that only one university in Iran (Shiraz University) is considered to measure the satisfaction of engineering students in remote and virtual labs and suggest for future to choose researcher to choose larger scale. But given results, revealed a good perspective to curriculum designers, university and college administrators to do not neglect the high potential use of the remote and virtual laboratories and make fundamental changes in their Instructions and technological infrastructure to meet mentioned demand.

Furthermore, for successful implementation and widespread use of virtual and remote laboratories for the post-COVID period, as another achievement of the research, some vital aspects of study contributions are suggested as the design of quality enhancement indicators, periodic guidelines for faculty improvement, updating of remote laboratory equipment and software efficiency, and establishing an accurate and relevant evaluation system to measure the level of students' learning satisfaction. The present study was limited in terms of defining a case study at shiraz university. It is difficult to generalize the results of this study because the sample is restricted only to engineering students.

Conclusion

Evaluation of the educational benefits of virtual and remote laboratories in higher education through a case study was presented. In this case study, different dimensions of engineering students' satisfaction with virtual and remote laboratories have been measured. While we need further evaluations of such labs in future, according to this study, a comprehensive picture of students' experiences and their satisfaction with virtual and remote laboratories was shown which proved quite satisfactory.

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