A Comparison Study on The Learning Scenarios in Physics Laboratory: Real Learning vs Virtual Learning

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https://doi.org/10.5109/7326924

出版情報：Evergreen. 11 (4), pp.2800-2805, 2024-12. 九州大学グリーンテクノロジー研究教育センター
バージョン：

A Comparison Study on The Learning Scenarios in Physics Laboratory: Real Learning vs Virtual Learning

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(Received July 9, 2024; Revised September 18, 2024; Accepted October 4, 2024).

Abstract: The Laboratory section plays a significant role in the Engineering Physics course. However, due to many challenges in the past few years, professors and laboratory instructors have to conduct these sessions virtually through online sessions. In this research, we evaluate the process of virtual learning and compare it to traditional learning sessions. We have conducted the study on the ohm's law experiment in the physics laboratory at Ajman University, involving 175 first year students. The grades and answers to questionnaires are analyzed in three datasets. The first dataset involved 59 students who conducted the experiment through a face-to-face laboratory under the supervision of the laboratory instructor (Real Learning). In the second dataset, 67 students performed the experiment virtually with the online supervision of a laboratory instructor (Virtual Learning). 49 students are involved in the third dataset where instructions are given virtually to students, and then they conducted the experiment through the traditional face-to-face laboratory method (Virtual-Real Learning). The comparison showed that the third method VRL is the most significant method towards grades and understanding achievements, and the VR method showed the lowest performance. In addition, student feedback has also marked the VRL method as the most favorable scenario.

Keywords: Physics laboratory; Real Learning; Virtual Learning; Face-to-Face laboratory; Virtual Learning; Ohm's Law

1. Introduction

Practical sessions application is considered as a significant part of the understanding process in most physics courses. This knowledge is achieved through the combination of theoretical and experimental (practical laboratories). In scientific studies, the theoretical and experimental parts are very important to develop clear insights and establish valid laws in nature[1-4]. In physics courses, students are involved in face-to-face laboratory sessions to enhance their understanding through experimental applications, which is considered as a complementary component to the knowledge attainment of the course. However, real physics laboratories are not available in many educational institutions due to financial or unexpected restrictions such as Covid19 pandemic[5-8]. Therefore, they rely on virtual reality laboratories to conduct the necessary experiments, where laboratory instructors are expected to supervise the sessions online. Furthermore, virtual reality laboratories are considered as an excellent alternative when physical presence is not allowed in academic institutions. It is worth mentioning that students are still able to change the setting of the used devices in the virtual reality laboratories in the same way they do in traditional face-to-face laboratories. In principle, virtual reality laboratories rely on simulation programs that have the same setting as traditional experiments. In addition, virtual reality learning is considered as a safer method in delivering knowledge and enhancing students' understanding while repeating the experiment as many times as possible[9-12]. Moreover, students are in favor of the virtual reality learning as the chance of making mistakes in the measurements is smaller, which offers them accurate information for their understanding of the measured quantities.

An important lesson was learned from the lockdown during the Covid19 pandemic that the need for virtual reality laboratories and online teaching methods are essential in maintaining the flow of the educational process without interruption for such reasons[5-8]. In addition, many institutions decided to continue with the virtual and online teaching and learning methods partially or in full capacity even after the end of the lockdown restrictions.

In previous studies from the past few years, virtual reality laboratories have been proven to give excellent results, even better than traditional face-to-face teaching methods[9-11)]. These conclusions are supported by the high performance of students, which is reflected in their high grades. In physics courses education, virtual reality laboratories are used to enhance students' understanding of the theoretical topics, which are typically given in the lectures. This is widely applied in different topics such as classical mechanics, electricity, electromagnetic, thermodynamics topics, etc. There are many simulation software's that can accurately model such basic and simple laboratory experiments, and the number of simulation programs has largely increased with the advancement of technology[13-19]. Moreover, combining virtual reality experiments with traditional teaching and learning methods has been proven to be also very efficient in different fields of study such as physics and mathematics[20-24)]. In this study, we perform a comparison between standard learning (face-to-face) and virtual learning methods. In addition, a separate group is considered where both methods are integrated into the learning process. This comparison allows us to assess the performance of the students using different teaching techniques.

The rest of the paper is organized as follows: after the introduction in Section 1, the Ohm's law laboratory experiment is presented in Section 2. In Section 3, the evaluation of the results from the three groups under study is discussed. In addition, the results of the questionnaires are evaluated in this section. Finally, conclusions are presented in the last section, Section 4.

2. Materials and Method

In this study, we focus on the use of virtual reality laboratories without considering the teaching method of the theoretical lectures. The objective of our study is to evaluate the performance of students when the laboratory experiments are delivered virtually and face-to-face. In the first part of this comparison, the grades are analyzed from both samples. In the second part of the paper, a questionnaire is distributed to evaluate students' satisfaction and opinions on these scenarios. The experiment about Ohm's law is selected in the study, which will require students to use a few electrical devices to adjust the settings of the current, resistance, and potential difference. In addition, a stopwatch is made available to students to record their measurements in both virtual reality and face-to-face scenarios. The total number of registered students in this course and included in the comparison is 175 students. For the purpose of comparison, the results from students' performance and satisfaction are analyzed in three main groups:

Group 1: The experiment is conducted in the physics laboratory in the presence of the students and their instructor. A total of 67 students are involved in this group, and it will be called in this manuscript as the "Real Learning" group (RL).

Group 2: The experiment is conducted by 59 students virtually. The group is called in this manuscript as the "Virtual Learning" group (VL).

Group 3: 49 students are involved in this group. The instructor explained the experiment to students in this group virtually VL in the first half of the laboratory session, and then students were asked to do the experiment themselves using the RL method in the second half of the session. This group is called in this manuscript as the "Virtual and Real Learning" group (VRL).

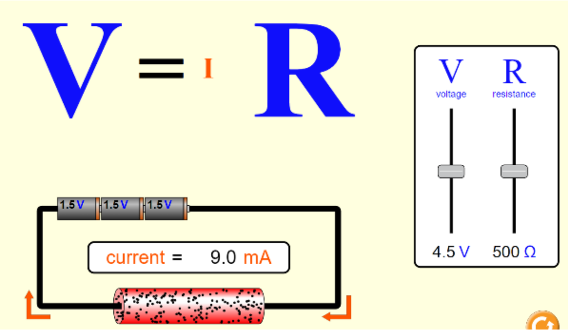

Fig. 1: Diagram of the simulation experiment in the PHET software[13)] (https://phet.colorado.edu/).

3. Results and Discussion

This study was conducted on the Ohm's law laboratory experiment in the physics laboratory at Ajman University, and it involved 175 engineering students in three groups; 59 students used the RL scenario, 67 students used the VR scenario, and 49 students used the VRL scenario. Generally, students are registered in different sections in this course, and we randomly selected two sections for each group. Students are requested to conduct ten practical experiments in the physics laboratory during the semester, and the Ohm's Law experiment is selected for this study. A manual of all laboratory experiments is made available to students at the beginning of the semester.

The experimental work in the physics laboratory accounts for 20% of the total mark of the course. We have considered 20 marks for the Ohm's law experiment, and this mark was added to marks from other experiments and weighted to 20. First of all, we show the distributions of the final grades of the selected experiment for the three groups in Fig. 2, and their corresponding mean values in Table 1. It is noted that marks in the RL and VRL groups are between 15 and 20 while marks of the VR group show the larger spread of the grades, between 13 and 20, with about 20% of the grades at 15. This indicates that students in this group might have found difficulties applying the VR method. On the other hand, the majority of grades in the VRL group are above 18, which indicates that this method helped students to better understand and achieve higher marks than other groups. This can be also seen from the average scores in Table 1, as the VRL group has the highest mean between groups. It can be concluded that different grade distributions are obtained from different learning scenarios, and the performance of students in the VRL group was able to achieve better grades than students in the RL and VR groups.

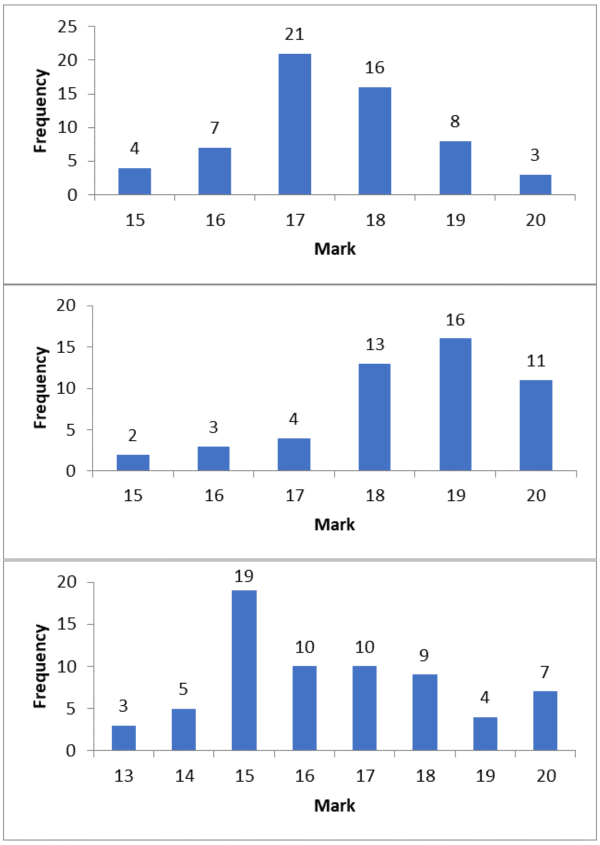

Fig. 2: Frequency distributions of the final grades of the RL group (Top), VL group (Middle), and VRL group (Bottom).

Table 1. Means corresponding statistical errors of the frequency distributions of each group.

	RL	VL	VRL
Mean	17.45 ± 0.50	16.44 ± 0.73	18.45 ± 0.50

In the next step, the difference in the grade distributions between groups is evaluated by distributing a questionnaire to all students. The questions in the questionnaire are designed to check students' understanding of the experiment including the background of the selected topic, the measurement instructions of the requested variables, the processing of the collected data, and the statistical uncertainties. Each question has a weight of one point. The outcome points of the questionnaire are presented in Fig. 2, and the corresponding mean values are given in Table 2. It can be seen from the figure that the points of the VR group have more spread than the points from the RL and VRL groups. In a simple comparison, it can be noted that the data points in the RL and VL groups are clustered at 3, 4, and 5 points with more than 85% of the points in the RL group and more than 90% in the VR group. On the other hand, 80% of the points in the VRL group are at 4 and 5. This is also reflected in the high average of points of the VRL group in Table 2. It is also another indication that the performance of students in the VRL group is better than other groups. Additionally, the normality of the distribution is checked with the Kolmogorov-Smirnov Test[25,26]. The results of the test showed that the three distributions do not match with a normal distribution.

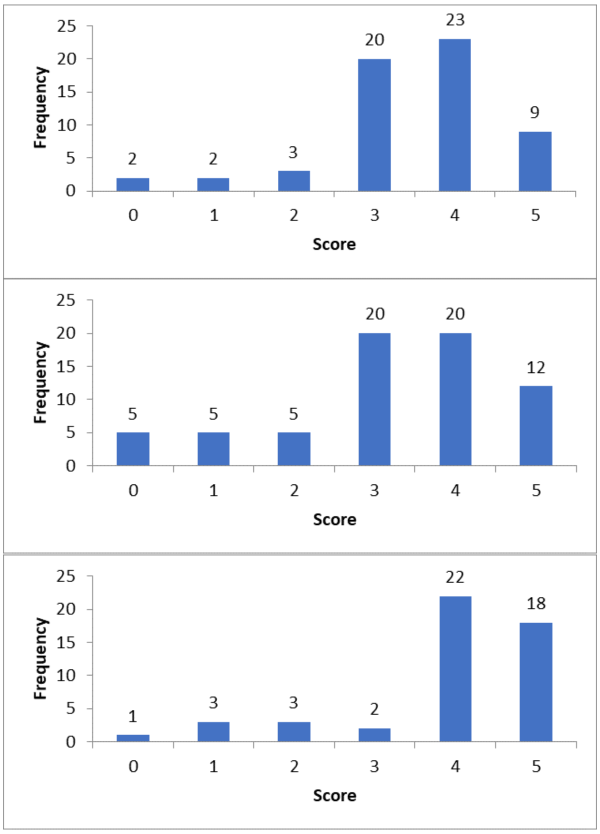

Fig. 3: Frequency distributions of the results of the questionnaire from the RL scores (Top), VL group (Middle), and VRL group (Bottom).

Table 2. Means and their corresponding statistical errors of the frequency distributions of the scores of each group to the first questionnaire.

	RL	VL	VRL
Mean	3.47 ± 0.44	3.21 ± 0.41	3.94 ± 0.5

Furthermore, we conduct the nonparametric Mann-Whitney U Test[27-29] to check the significance difference between the three groups. The test is applied to the groups in pairs. Results of the comparison between the RL and VL groups showed that there is no significant difference between these groups (U = 1812, p-value = 0.4237). On the other hand, the comparison between RL and VRL, and VL and VRL groups showed clear significant differences (U = 1003, p-value = 0.0063) and (U = 1083, p-value =

0.0018), respectively. In conclusion, the points of the VRL group are significantly higher than points from the other two groups, which makes it the most efficient way for students' understanding and comprehension.

In order to evaluate the opinion of students in regard to the learning scenario, we have distributed another questionnaire of five questions, and the satisfaction level is measured according to the Likert scale[30-32] as shown in Table 3:

Question 1: The student had enough prior knowledge to successfully conduct the experiment.

Question 2: The lecture was very informative and useful to successfully conduct the experiment.

Question 3: The laboratory instructor provided enough and clear instructions, which made it easy for students to conduct the experiment.

Question 4: The students had enough time in the lab session.

Question 5: I conducted the experiment multiple times to understand it.

Table 3. Satisfaction degrees in the Likert scale[30-32].

Degree of Satisfaction	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

The average values of the satisfaction level are shown in Table 4. It was observed that the results from the third group possess the highest means for all questions, which indicates a higher satisfaction rate from students in this group. In addition, the satisfaction points are tested with the Mann-Whitney U Test to evaluate the significant statistical difference (SSD) between the three groups and for all questions. The outcomes of the test are presented in Table 4. It can be seen from the table that the only significant statistical difference exists only for the question related to the theoretical background given in the lecture, Question 2. This significance is present between RL and VL groups, and between VL and VRL groups, which means that it was more difficult for students in the VL group to use their understanding from the lecture in conducting the lab experiment, and this is also reflected in the low average value in their second question.

Table 4. Means of the five questions from the three groups.

	RL	VL	VRL
Question 1	3.93 ± 0.12	3.96 ± 0.07	4.27 ± 0.08
Question 2	4.14 ± 0.11	3.64 ± 0.13	4.49 ± 0.06
Question 3	3.86 ± 0.11	4.09 ± 0.08	4.39 ± 0.07
Question 4	3.67 ± 0.13	4.12 ± 0.11	4.12 ± 0.11
Question 5	4.10 ± 0.13	4.06 ± 0.07	4.10 ± 0.09

Table 5. U, p-values, and statistically significant difference between groups.

		RL - VL	RL - VL	VL - VRL
Q. 1	U	1926	1336	1336
	p-value	0.81034	0.05614	0.08914
	SSD	No	No	No
Q. 2	U	1455	1273	958
	p-value	0.01078	0.28914	0.00014
	SSD	Yes	No	Yes
Q. 3	U	1728	1037	1402
	p-value	0.22628	0.01174	0.18024
	SSD	No	Yes	No
Q. 4	U	1615	1175	1605
	p-value	0.07672	0.09492	0.84148
	SSD	No	No	No
Q. 5	U	1895	1375	1636
	p-value	0.68916	0.65994	0.97606
	SSD	No	No	No

4. Conclusions

We conducted a study to evaluate the learning scenario of engineering physics courses for engineering students. The study is conducted on the practical part of the course in the physics laboratory. The Ohm's Law experiment is chosen for the study, and a total of 175 students are included to form three groups. The experiment was conducted by 59 students in the first group using the traditional learning in the physics laboratory "Real Learning, RL", 67 students in the second group conducted the experiment virtually "Virtual Learning, VL", and 49 students in the third group were given the experiment virtually and then asked to conduct the experiment again using the standard learning process, this group is called "Virtual-Real Learning, VRL". The results of the grades of the students from the laboratory were evaluated and found that the performance of the third group was found to better than the first two mentioned groups. It is also noted that the VR group has the lowest performance between groups. In addition, at the end of the semester, an evaluation questionnaire form is given to students to evaluate students' satisfaction with the used learning method. It was determined that the VRL method is their most favorable scenario. This conclusion is consistent with previous studies about the combination between real and virtual learning[33-37].

Acknowledgements

We would like to acknowledge Ajman University for supporting the research.

Nomenclature

RL	Real Learning
VL	Virtual Learning
VRL	Virtual-Real Learning

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